



Leveraging Large Language Models for Global Assessment of National Flood Adaptation Plans



Riverine flood risk

What is the **status of adaptation efforts** to reduce future flood risk?



An example of flood at the Mulde in Grimma, Saxony 2013 (Photo: Astrid Krahn, GFZ Potsdam)



GFZ



EINSTEIN CENTER Digital Future



HEIBRIDS HELMHOLTZ International Berlin Research School in Data Science

Zixin Hu^{1,2}, Andrea Cominola², Heidi Kreibich¹

1 GFZ Hydrology Section, 2 Chair of Digital Water Systems - TU Berlin
✉ zixin.hu@gfz.de

National Flood Management Plans

National and subnational flood management plans are key instruments

- Flood Adaptation measures

 Prevention

 Protection

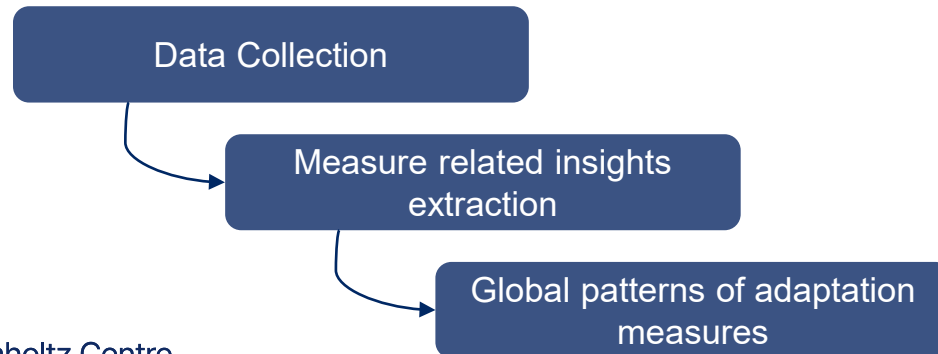
 Preparedness

 Recovery & Review

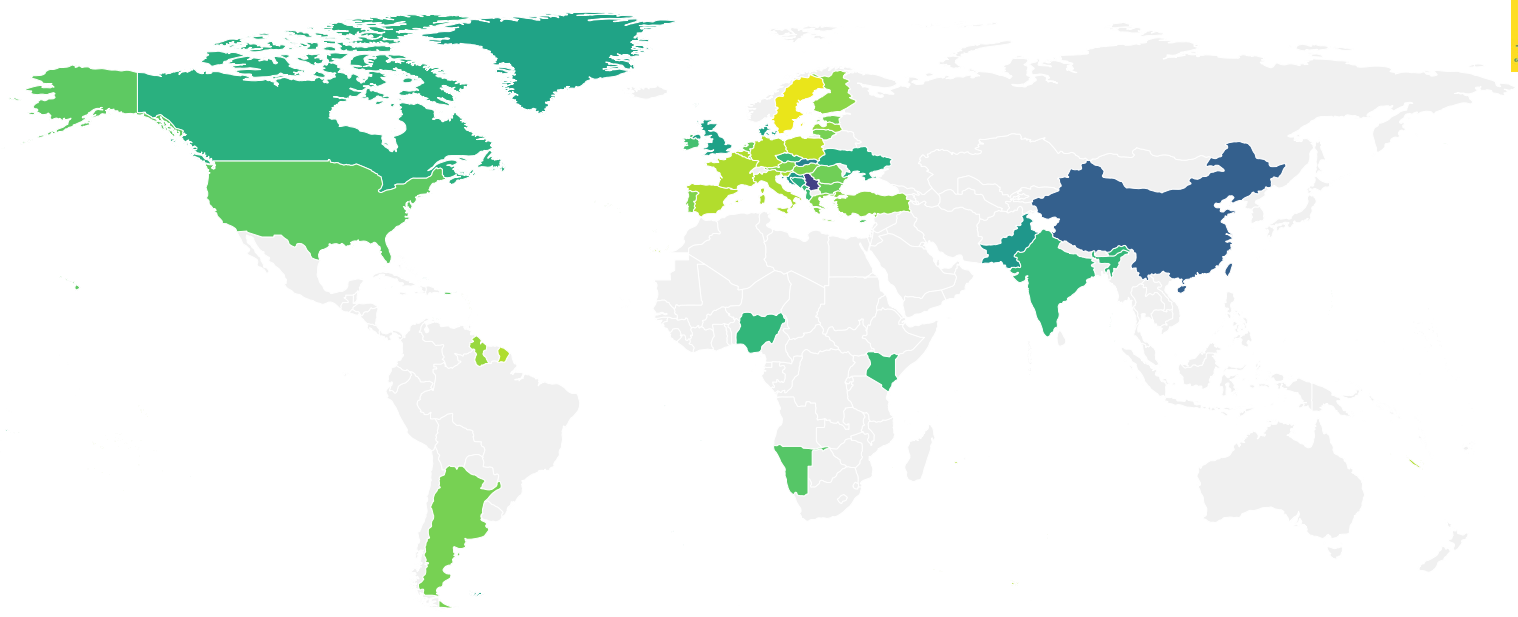
Challenges for a systematic and automated comparison

- Length, heterogeneity in language, contents and structure

Large language models, natural language processing, and machine learning



Example of national and subnational flood plans



Diversity of flood adaptation measures



This presentation participates in OSPP



Outstanding Student & PhD candidate Presentation contest

PICO 4.12

Thank you!

Zixin Hu, Andrea Cominola, Heidi Kreibich

✉ zixin.hu@gfz.de

Vienna, 7 May 2026





Leveraging Large Language Models for Global Assessment of National Flood Adaptation Plans

Zixin Hu^{1,2}, Andrea Cominola², Heidi Kreibich¹

1 GFZ Hydrology Section, 2 Chair of Digital Water Systems - TU Berlin

✉ zixin.hu@gfz.de

Vienna, 7 May 2026



Content

- Background - Riverine flood risk
 - (Sub)national flood management plans
- Workflow
 - Data Collection – 3 strategies
 - LLM-assisted
 - Dataset & Global map
 - Guided Topic Modelling
 - Seed: flood adaptation measure categories
 - Topic Analysis example
 - Evaluation & Validation
- Results
- Conclusion
- Appendix

Flood Risk

- Riverine flood risk - major natural hazard worldwide



An example of flood at the Mulde in Grimma, Saxony 2013 (Photo: Astrid Krahn, GFZ Potsdam)

\$ 104 billion


Direct global average annual loss¹

7 million

Fatalities in the 20th century²

- What is the status of **adaptation efforts** to reduce future flood risk?

National Flood Plans

- National and subnational flood management plans are key instruments
 - Flood Adaptation measures 
- Challenges for a systematic and automated comparison
 - Length, heterogeneity in language, contents and structure

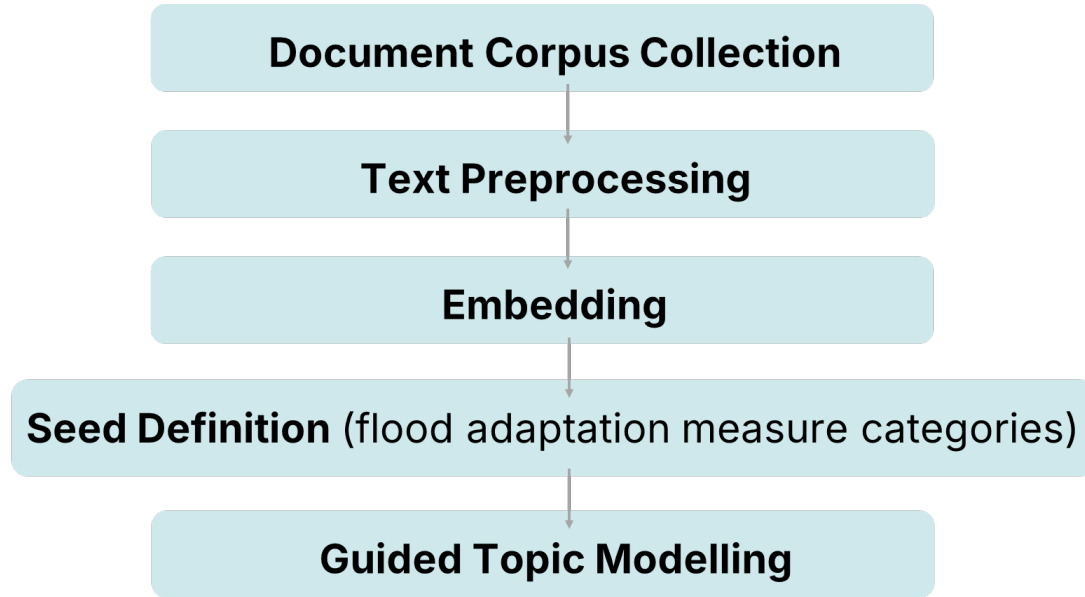


Examples of national and subnational flood plans



National Flood Plans

- Extracting structured insights with natural language processing (NLP) and machine learning



Document Corpus Collection: Flood Plans

- Inclusion Criteria

- 🕒 **Long term:** ≥ 5 years

- 🏛️ Issued by an **official** institution in any language.

- 🌊 **Flood-focused** or includes a specific flood-focused chapter

- 🌍 **National or subnational** level

- Search Approaches

- 👤 **Manual search:** keyword

- 🗉 **LLM** (Large Language Model)-**based search:** GPT-5.1 API + prompt, batch

- 👥 **Community input:** survey-based collection & outreach

Document Corpus Collection: LLM–assisted

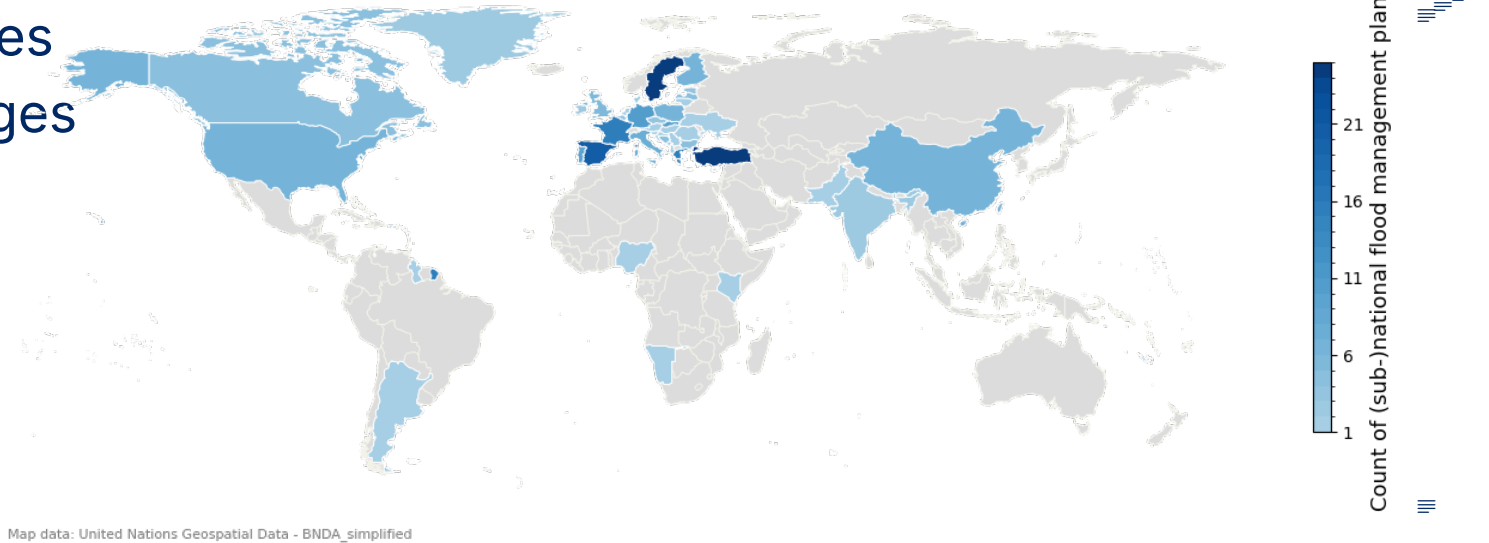
Prompting Pipeline

- Identify official **languages**
- Identify official **websites**
- Conduct document search (**inclusion/exclusion criteria**)
- Check **flood relevance** (e.g., dedicated flood chapter)
- Generate one **JSON file** per country

 **Manually verify** the reports suggested by GPT

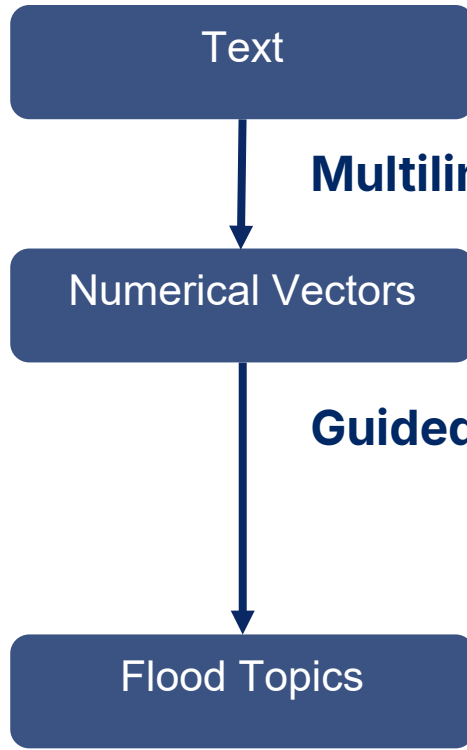
Dataset – (sub)national flood plans

- 222 PDFs identified
- 669966 sentences
- 45 countries
- 29 languages



Guided Topic Modelling

More details

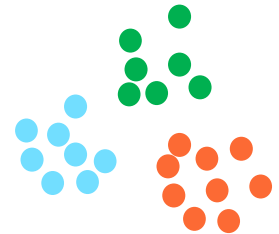
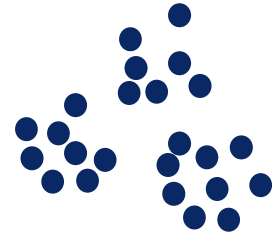


Multilingual Embedding Model

- Preserve semantic similarity

Guided Topic Modelling¹

- Nudge the topic creation to the seeded topics (domain knowledge)



Guided Topic Modelling - seeds

Prevention

- Land use planning policies or regulations to prevent the location of new or additional receptors in flood prone areas;
-

Protection

- Levees, retention basins;
- Reforestation of banks;
- ...

Preparedness

- Flood forecasting & warning;
- Emergency response planning;
- Public awareness & preparedness;
- ...

Recovery & Review

- Reconstruction of buildings and infrastructure;
- Lessons learnt from flood events
- ...

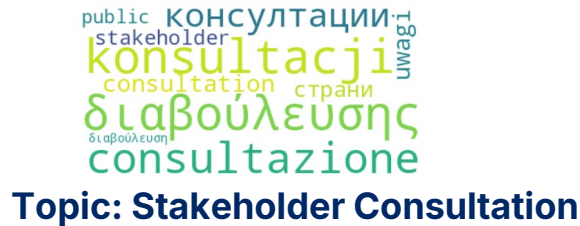
Topic Analysis

 Prevention

 Protection

 Preparedness

 Recovery & Review

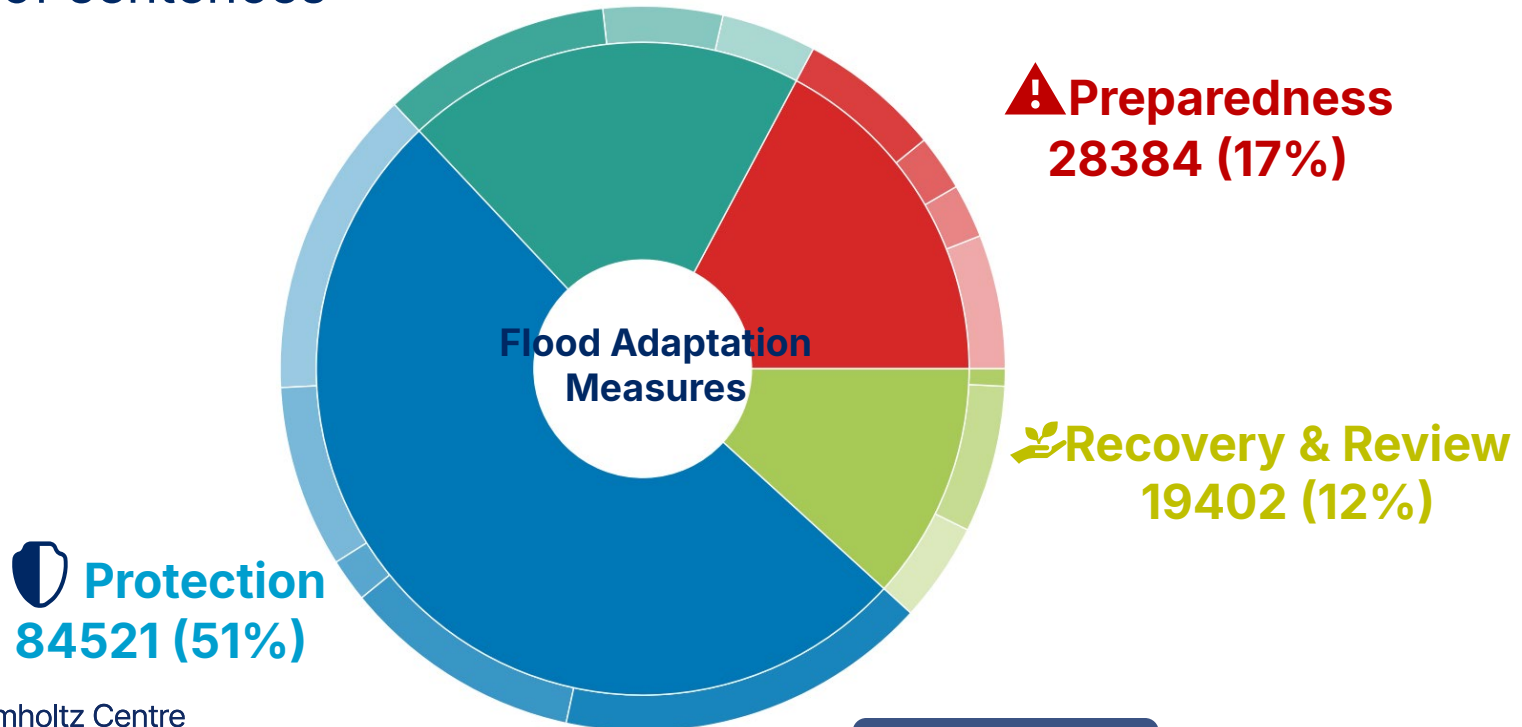


"strict preservation of floodplains in non-urbanized areas, wetlands, including mangrove areas, on the coastline; generally, a ban on construction in high-risk areas"



Global Patterns of Adaptation Measures

- Number of sentences  **Prevention**
32676 (20%)



 **Protection**
84521 (51%)

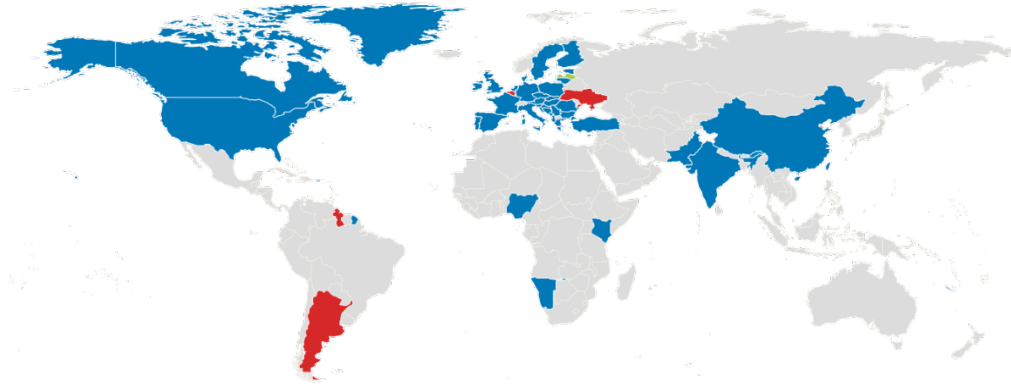
 **Prevention**
32676 (20%)

 **Preparedness**
28384 (17%)

 **Recovery & Review**
19402 (12%)

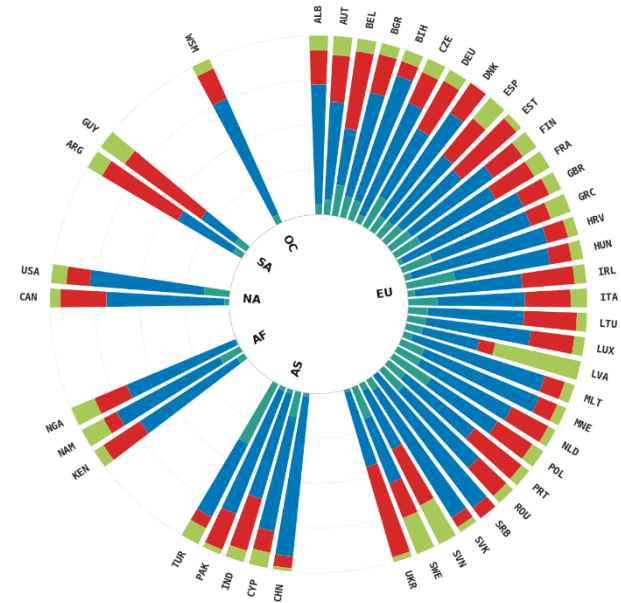
Global Patterns of Adaptation Measures

Dominant Flood Adaptation Measure Category by Country

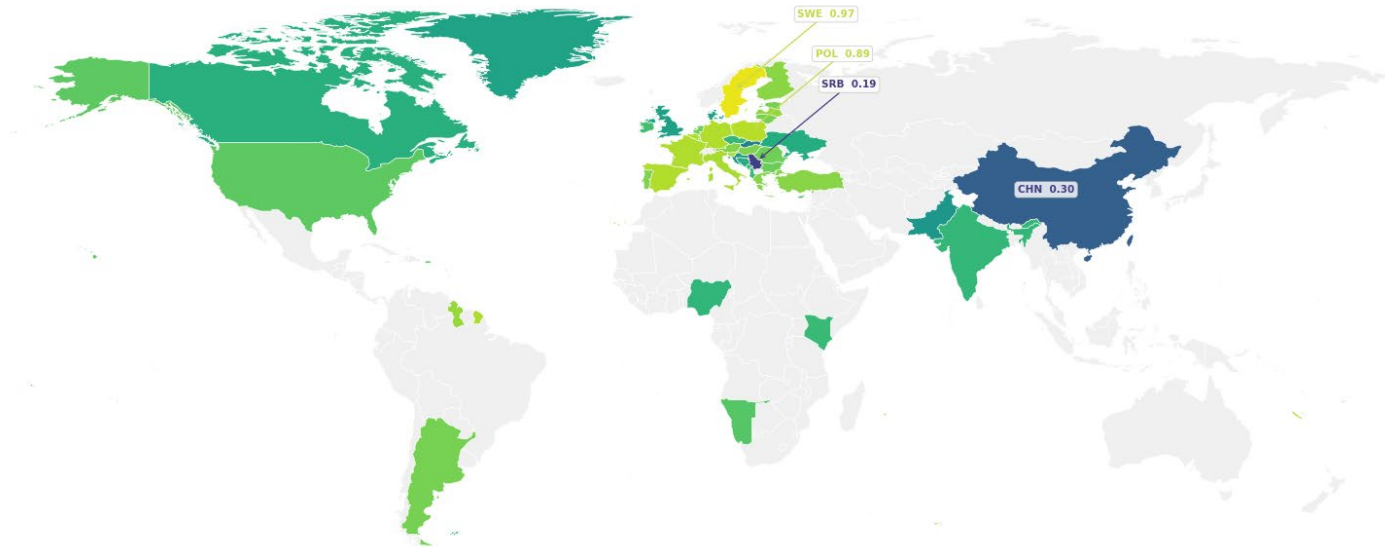


Map data: United Nations Geospatial Data - BNDA_simplified

Flood Adaptation Measure Categories by Country (share of sentences)



Diversity of Adaptation Measures



Entropy across four categories: Prevention · Protection · Preparedness · Recovery & Review



Map: UN Geospatial Data - BNDA_simplified

Conclusion

- **Global dataset of (sub)national flood management plans** compiled
- Effective **Language Model-based workflow established** from document collection to guided topic modelling
- National and sub-national planning is particularly **common in Europe and North America**
- Dominance of **protection measures**. Strong cross-country heterogeneity



Thank you!

Zixin Hu, Andrea Cominola, Heidi Kreibich

✉ zixin.hu@gfz.de

Vienna, 7 May 2026



Models

- Embedding model
 - "paraphrase-multilingual-mpnet-base-v2"
- Dimension Reduction:
 - UMAP
 - Parameters: n_components, n_neighbors, min_dist, metric
- Clustering:
 - HDBSCAN
 - Parameters: min_cluster_size, min_samples, metric, cluster_selection_method

Guided Topic Modelling – seeds

Back

| | Category | Description |
|-----|---|--|
| M11 | No Action | No Action, No measure is proposed to reduce the flood risk in the APSFR or other defined area. |
| M21 | Prevention – Avoidance | Measure to prevent the location of new or additional receptors in flood prone areas, such as land use planning policies or regulations. |
| M22 | Prevention – Removal/Relocation | Measure to remove receptors from flood prone areas, or to relocate receptors to areas of lower probability of flooding and/or lower hazard. |
| M23 | Prevention – Reduction | Measure to adapt receptors to reduce the adverse consequences in the event of a flood actions on buildings, public networks, etc. |
| M24 | Prevention – Other | Other measure to enhance flood risk prevention (may include, flood risk modelling and assessment, flood vulnerability assessment, maintenance programmes or policies etc.). |
| M31 | Protection – Natural flood management / runoff & catchment management | Measures to reduce the flow into natural or artificial drainage systems, such as overflow flood interceptors and/or storage, enhancement of infiltration, etc and including in-channel, floodplain works works and the reforestation of banks, that restore natural systems to help slow flow and store water. |
| M32 | Protection – Water flow regulation | Measures involving physical interventions to regulate flows, such as the construction, modification or removal of water retaining structures (e.g., dams or other on-line storage areas or development of existing flow regulation rules), and which have a significantly impact on the hydrological regime. |
| M33 | Protection – Channel, Coastal & Floodplain Works | Measures involving physical interventions in freshwater channels, mountain streams, estuaries, coastal waters and flood-prone areas of land, such as the construction, modification or removal of structures or the alteration of channels, sediment dynamics management, dykes, etc. |
| M34 | Protection – Surface Water Management | Measures involving physical interventions to reduce surface water flooding, typically, but not exclusively, in an urban environment, such as enhancing artificial drainage capacities or through sustainable drainage systems (SuDS). |
| M35 | Protection – Other | Other measures to enhance protection against flooding, which may include flood defence asset maintenance programmes or policies. |
| M41 | Preparedness – Flood Forecasting & Warning | Measure to establish or enhance a flood forecasting or warning system. |
| M42 | Preparedness – Emergency Response Planning | Measure to establish or enhance flood event institutional emergency response planning. |
| M43 | Preparedness – Public Awareness & Preparedness | Measure to establish or enhance the public awareness or preparedness for flood events. |
| M44 | Preparedness – Other | Other measure to establish or enhance preparedness for flood events to reduce adverse consequences. |
| M51 | Recovery & Review – (General) | (Planning for the recovery and review phase is in principle part of preparedness), Individual and societal recovery, Clean-up and restoration activities (buildings, infrastructure, etc), Health and mental health supporting actions, incl. managing stress. Disaster financial assistance (grants, tax), incl. disaster legal assistance, disaster unemployment assistance, Temporary or permanent relocation, Other. |
| M52 | Recovery & Review – Environmental Recovery | Clean-up and restoration activities (with several sub-topics as mould protection, well-water safety and securing hazardous materials containers). |
| M53 | Recovery & Review – Other | Other recovery and review. Lessons learnt from flood events. Insurance policies. |
| M61 | Other | Other. |

Countries

Back

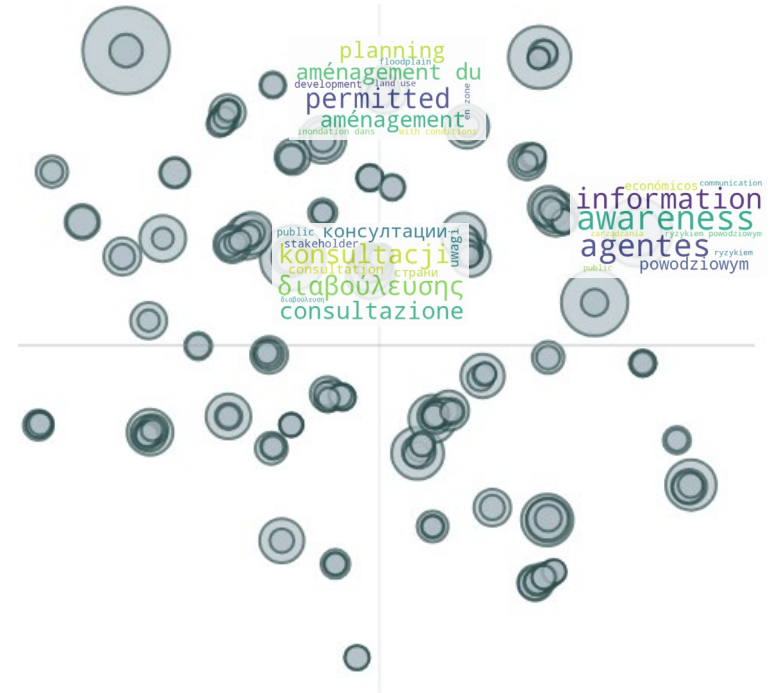
| id | Country | Continent |
|-----|---|-----------|
| ALB | Albania | EUR |
| ARG | Argentina | AME |
| AUT | Austria | EUR |
| BEL | Belgium | EUR |
| BGR | Bulgaria | EUR |
| BIH | Bosnia and Herzegovina | EUR |
| CAN | Canada | AME |
| CHN | China | ASI |
| CYP | Cyprus | ASI |
| CZE | Czechia | EUR |
| DEU | Germany | EUR |
| DNK | Denmark | EUR |
| ESP | Spain | EUR |
| EST | Estonia | EUR |
| FIN | Finland | EUR |
| FRA | France | EUR |
| GBR | United Kingdom of Great Britain and Northern I... | EUR |
| GRC | Greece | EUR |
| GUY | Guyana | AME |
| HRV | Croatia | EUR |
| HUN | Hungary | EUR |
| IND | India | ASI |

| id | Country | Continent |
|-----|--------------------------|-----------|
| IRL | Ireland | EUR |
| ITA | Italy | EUR |
| KEN | Kenya | AFR |
| LTU | Lithuania | EUR |
| LUX | Luxembourg | EUR |
| LVA | Latvia | EUR |
| MLT | Malta | EUR |
| MNE | Montenegro | EUR |
| NAM | Namibia | AFR |
| NGA | Nigeria | AFR |
| NLD | Netherlands | EUR |
| PAK | Pakistan | ASI |
| POL | Poland | EUR |
| PRT | Portugal | EUR |
| ROU | Romania | EUR |
| SRB | Serbia | EUR |
| SVK | Slovakia | EUR |
| SVN | Slovenia | EUR |
| SWE | Sweden | EUR |
| TUR | Türkiye | ASI |
| UKR | Ukraine | EUR |
| USA | United States of America | AME |
| WSM | Samoa | OCE |

Evaluation & Validation

- Density based clustering validation: 0.21
- Topic coherence: 0.66
- Topic diversity: 0.14

- Manual Validation on subset



Global Patterns of Adaptation Measures

- Number of sentences

