1. Introduction

1.1. Context and motivations

This project centers on the integration of Geographic Information Systems (GIS) and Earth Observation (EO) data for effective flood risk management, with a particular focus on Emilia-Romagna, Italy, a region highly vulnerable to floods. In 2021, the environmental protection agency ISPRA warned that 93.9 per cent of Italian cities were at risk of flooding, landslides, and coastal erosion. Emilia-Romagna – before seventeen lost their lives and fifty thousand were displaced due to two devastating floods last May – was flagged by ISPRA as the Italian region most at risk [1]. The project is motivated by the significant economic and social impacts of floods in Italy, which is require precise flood risk assessments to support not only insurance companies but also urban planners and governmental bodies in their risk management and urban development planning.

1.2. Definitions, acronym, abbreviations

- **GIS (Geographic Information System)**: A system designed to capture, store, manipulate, analyze, manage, and present spatial or geographic data.
- **EO (Earth Observation)**: The process of collecting information about the Earth's physical, chemical, and biological systems via remote sensing technologies, typically involving satellites.
- **DEM (Digital Elevation Model)**: A digital representation of ground surface topography or terrain.

1.3. Solution overview

The proposed solution utilizes GIS and EO data to develop an advanced methodology for flood risk assessment. This methodology involves using high-resolution digital elevation models (DEMs), analysis of historical flood data, and other critical geographic and environmental factors to produce detailed flood risk maps. These maps will aid insurance companies in assessing flood risks accurately and aid urban planners and governmental agencies in formulating strategies for land use planning, disaster preparedness, and infrastructure development to mitigate the impact of floods.

1.4. Scope and limitations

Scope:

- The project is designed to develop a flood risk assessment tool tailored for the insurance market in Italy, particularly focusing on Emilia-Romagna.

- It aims to support urban planners in making informed decisions regarding land use and infrastructure projects to enhance flood resilience.
- Governmental bodies can use the insights provided by the project for disaster preparedness and emergency response planning.

Limitations:

- The predictive accuracy of the flood risk maps depends heavily on the quality and resolution of the input data, such as DEMs and historical flood records.
- The model is most effective in areas covered by comprehensive EO and GIS data and might not fully represent regions with insufficient data coverage.
- Unpredictable external factors, such as abrupt climatic shifts or unforeseen environmental events, may influence the accuracy and reliability of risk assessments.

2. Requirements

2.1. Stakeholders

Insurance Companies: They have a vested interest in accurate flood risk assessments to determine insurance premiums and coverage.

- **Urban Planners:** Their decisions impact land use, infrastructure, and community resilience. Flood risk maps will guide their planning efforts.
- **Governmental Bodies (Local and Regional):** Responsible for disaster preparedness, emergency response, and policy implementation.
- **Environmental Agencies:** Their expertise in GIS and EO data contributes to the project's effectiveness.
- **Local Communities:** Residents and businesses in flood-prone areas are directly affected by flood risks.

2.2. Actors

- **User:**
  The primary user of the Flood Risk Assessment Tool, responsible for assessing and managing flood risks. This actor incorporates flood risk data into planning and development processes, utilizes data for emergency preparedness, and contributes to policy-making decisions regarding flood risk management. Users may include professionals such as urban planners, disaster management specialists, insurance analysts, and governmental officials involved in risk assessment and mitigation strategies.

- **System Administrators:**
  The System Administrators are responsible for the maintenance and overall management of the Flood Risk Assessment Tool. Their roles include updating GIS data, ensuring data integrity, managing user accounts, performing system backups, and adjusting risk parameters within the software. System Administrators ensure the smooth operation of the system, troubleshoot technical issues, and implement necessary updates or modifications based on user feedback and system requirements.

2.3. Domain assumptions

In the context of software engineering for flood risk management in geoinformatics, domain assumptions would encompass the specific characteristics, challenges, and requirements of dealing with flood-related data and processes, some of which are in the following:

- **Spatial Data Types:**

Assumptions about the types of spatial data relevant to flood risk management, including digital elevation models (DEMs), hydrological networks, land use/land cover data, and flood extent maps.

- **Data Sources:**

Assumptions about the sources of data used in flood risk management, such as satellite imagery, ground-based sensors, historical flood records, and crowd-sourced data.

- **Flood Hazard Assessment:**

Assumptions about the methods and techniques used to assess flood hazards, including statistical analysis, flood frequency analysis, and scenario-based modeling.

- **Vulnerability Assessment:**

Assumptions about the factors that contribute to the vulnerability of assets and communities to flooding, including building types, infrastructure networks, population density, and socioeconomic indicators.

- **Risk Assessment:**

Assumptions about the methods used to quantify and prioritize flood risks, including risk matrices, loss estimation models, and multi-criteria decision analysis.

2.4. Requirements

Developing software for flood risk management in geoinformatics involves addressing a wide range of functional and non-functional requirements to effectively analyze, model, and mitigate flood risks. Here's a list of requirements:

- **Data Acquisition and Integration:**

Ability to import and integrate diverse geospatial data sources, including DEMs, satellite imagery, river networks, land use maps, and weather data.

- **Vulnerability Assessment:**

Features to assess the vulnerability of infrastructure, buildings, and communities to flooding based on factors such as elevation, building type, and population density.

Capability to incorporate socio-economic data for vulnerability assessment.

- **Risk Analysis and Management:**

Tools for quantifying and prioritizing flood risks, considering both the probability and potential impact of flood events.

Support for risk mitigation strategies, such as structural measures (e.g., levees, floodwalls) and non-structural measures (e.g., land use planning, early warning systems).

Integration with decision support systems for evaluating different risk management options.

- **Emergency Response and Preparedness:**

Features for developing flood response plans, including evacuation routes, emergency shelters, and communication protocols.

Integration with real-time monitoring systems for early warning and flood forecasting.

Capability to simulate emergency scenarios and assess the effectiveness of response plans.

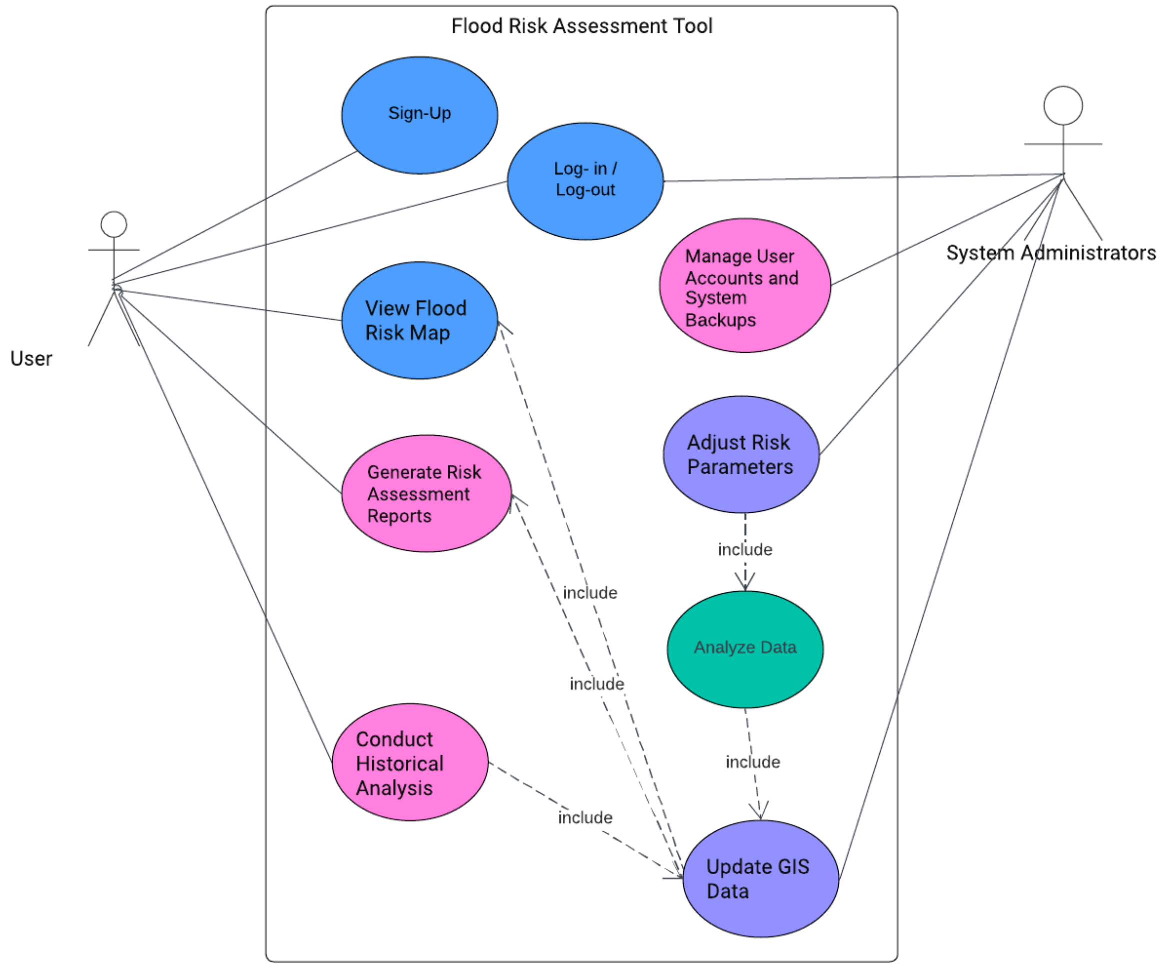
- **Data Visualization and Reporting:**

Interactive visualization tools for exploring flood risk data, including maps, charts, and graphs.

Generation of reports and presentations summarizing flood risk assessments, vulnerabilities, and recommended actions.

By addressing these requirements, software engineers can develop robust and effective solutions for flood risk management in geoinformatics that meet the needs of stakeholders and contribute to more resilient communities.

2.5. Use case diagram and description



System: Flood Risk Assessment Tool

Actors

1. **user**: Assess and manage flood risks. Incorporate flood risk data in planning and development. Use data for emergency preparedness and policy making.
2. **System Administrators**: Maintain and update the system.

Use Case Diagram Structure

- **User**
  - Sign-up

    - Log-in/ Log-out
    - Generate Risk Assessment Reports
    - View Flood Risk Map
    - Conduct Historical Analysis
- **System Administrators**:
    - Log-in/ Log-out
    - Update GIS Data
    - Manage User Accounts
    - Perform System Backups
    - Adjust Risk Parameters

2.6. Use cases

Actors: The user.

Conditions: Always true.

1. User Registration:

- **Flow of Events:**
    1. The user visits the registration page;
    2. They provide the necessary information (such as username, email, and password);
    3. The system validates the input data (e.g., checks if the email is unique);
    4. If validation passes, the system creates a new user account;
- **Exceptional Cases and Special Requirements:**
    - The user's name already exists in the database;

2. User Login:

- **Flow of Events:**
1. The user visits the login page;
2. They enter their credentials (username/email and password);
3. The system verifies the credentials against stored data;
4. If valid, the user gains access to their account;
5. A session token or cookie is generated for subsequent requests;
- **Exceptional Cases and Special Requirements:**

- The user is not registered yet or has put the wrong name or password.

3. User Logout:

- **Flow of Events:**
  1. The user clicks the “Logout” button or link;
  2. The system invalidates the session token or cookie;
  3. The user is redirected to the login page or a logged-out state;
  4. Any temporary data (e.g., shopping cart items) is cleared;
- **Exceptional Cases and Special Requirements:**
  - Log Out was unsuccessful due to browser error.

4. View Flood Risk Map: View current flood risks, Access historical flood data

- **Flow of Events:**
  1. The User logs into the GIS System;
  2. The User selects the option to View Flood Risk Map;
  3. The GIS System retrieves the current flood risk data and displays it;
  4. The User can interact with the map (zoom in/out, pan, etc.);
  5. Exit condition: The User closes the Flood Risk Map;
- **Exceptional Cases and Special Requirements:**
  - If the GIS System fails to retrieve current flood risk data, it displays an error message;
  - If historical flood data is not available for the selected period and area, it informs the User.

5. Generate Risk Assessment Reports: Generate location-specific reports, Customize reports for different stakeholders

- **Flow of Events:**
  1. The User selects the option to Generate Risk Assessment Reports;
  2. The User specifies the criteria for the report (e.g., location, risk parameters, time frame);
  3. The Risk Assessment System processes the data and generates a detailed risk assessment report;
  4. The User can download or view the report;

- **Exceptional Cases and Special Requirements**:
  - If the Risk Assessment System encounters errors during data processing, display an error message;
  - The User may need to provide additional information (e.g., risk tolerance levels) for customized reports.

6. Update GIS Data: Import new data sets, Validate data accuracy

- **Flow of Events**:
  1. The User selects the option to Update GIS Data;
  2. The User imports new data sets (e.g., shapefiles, satellite imagery);
  3. The GIS System validates the data accuracy, if it is accurate, it updates the existing data, if the validation fails, the User receives an error message;
- **Exceptional Cases and Special Requirements**:
  - If the imported data format is incompatible, inform the User.
  - If data validation fails, provide details on the issues found;
  - Ensure data integrity during the update process.

7. Adjust Risk Parameters: Modify flood prediction models, Update risk thresholds based on new data

- **Flow of Events**:
  1. Selects Adjust Risk Parameters;
  2. Modifies flood prediction models;
  3. Updates risk thresholds based on new data;
  4. Changes are validated and applied.
- **Exceptional Cases and Special Requirements**:
  - Warns if model changes yield unexpected results;
  - Alerts if risk thresholds are extreme.

8. Conduct Historical Analysis: Analyze trends over time, Compare past and present data for planning

- **Flow of Events**:
  1. Selects Conduct Historical Analysis;
  2. Analyzes trends over time;
  3. Compares past and present data;

4. Extracts insights for planning.

- **Exceptional Cases and Special Requirements**:
  - Alerts if data quality issues affect analysis;
  - Provides warnings for significant deviations.

9. Manage User Accounts and System Backups: Add/remove users, Assign roles and permissions, Schedule automatic backups

- **Flow of Events**:
  1. Selects Manage User Accounts:
     - Adds/removes users (assigns roles);
     - Assigns permissions (admin, read-only);
  - Selects System Backups:
     - Schedules automatic backups;
     - Configures backup destinations;
     - Monitors backup status.
- **Exceptional Cases and Special Requirements**:
- Warns on user account creation errors;
- Alerts on backup failures.

2.7. User stories

1. As a User I can **view the current flood risks** in my area, so that I can analyze trends and make informed decisions.
2. As a User, I can **generate a risk assessment report**, I can specify the location and risk parameters to make informed decisions.
3. As a User responsible for **maintaining GIS data**, I can import new data sets and validate their accuracy using the GIS System, so that our geographic information remains up-to-date and reliable.
4. As a User I can **adjust risk parameters** and update risk thresholds, so that I can modify the flood prediction models.
5. As a User I can **analyze historical data** so that I can compare past and present information and understand trends.
6. As a User I can **manage accounts and backups** in order to maintain the system integrity and data security.

3. Bibliography

1 Trigila A., Iadanza C., Lastoria B., Bussettini M., Barbano A. (2021) Dissesto idrogeologico in Italia: pericolosit`a e indicatori di rischio - Edizione 2021. ISPRA, Rapporti 356/2021