**Explanation for Resilience Score Calculations**

**Option 1: Flood Exposure-Based Resilience**

This approach calculates resilience based on the ratio of the total ecosystem area to the total flood exposure. The logic behind this is that higher resilience is associated with a larger ecosystem area compared to flood exposure.

**Implementation Details:**

1. **Inputs:**
   * Total\_Ecosystem\_Area\_km2: Total area covered by all ecosystem classes in square kilometers.
   * Flood\_HP\_Area\_km2, Flood\_LP\_Area\_km2, Flood\_MP\_Area\_km2: Flood areas under high, low, and medium probabilities respectively.
2. **Calculation Steps:**
   * Calculate the total flood exposure as the sum of the three flood areas.
   * Divide the Total\_Ecosystem\_Area\_km2 by the total flood exposure.
   * Multiply the result by 100 to express resilience as a percentage.
3. **Result:**
   * If the total flood exposure is zero, the resilience score defaults to zero.
   * Otherwise, the resilience score reflects how well the ecosystem can resist or recover relative to the extent of flood exposure.

**Option 2: Weighted Ecosystem Resilience**

This approach incorporates weights for different ecosystem classes, acknowledging that not all ecosystem types contribute equally to resilience.

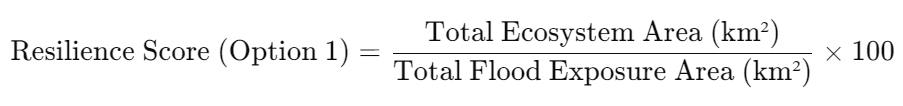
**Implementation Details:**

1. **Inputs:**
   * Ecosystem\_Class\_Areas: A dictionary of ecosystem class IDs with their respective areas in square kilometers.
   * Weights: A predefined dictionary assigning weights to each ecosystem class based on its resilience contribution.
   * Total\_Ecosystem\_Area\_km2: Total ecosystem area for normalization.
2. **Calculation Steps:**
   * For each ecosystem class:
     + Normalize the class area by dividing it by the total ecosystem area.
     + Multiply the normalized area by the corresponding weight to get the weighted contribution.
   * Sum all weighted contributions and multiply by 100 to express resilience as a percentage.
3. **Result:**
   * If no ecosystem areas or weights are defined, the resilience score defaults to zero.
   * A higher resilience score reflects a stronger contribution from ecosystems with higher weights and larger areas.

**Explanation and Calculation**

**Option 1: Flood Exposure vs. Total Ecosystem Area**

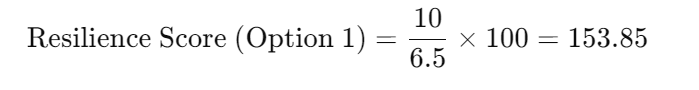
**Mathematical Formula:**

 **Total Ecosystem Area (km²):** Sum of all areas contributing ecosystem services.

* **Total Flood Exposure Area (km²):** Combined areas affected by high, medium, and low-probability floods.

**Example Calculation (Feature 1):**

* **Total Ecosystem Area:** 10 km²
* **Flood HP Area:** 1.5 km², **Flood MP Area:** 2.0 km², **Flood LP Area:** 3.0 km²
* **Total Flood Exposure:** 1.5+2.0+3.0=6.5 km²1.5 + 2.0 + 3.0 = 6.5km²



* Total Ecosystem Area: The sum of all ecosystem types in the analysis region (e.g., forests, grasslands).
* Total Flood Exposure Area: The combined area affected by High, Medium, and Low Probability floods.

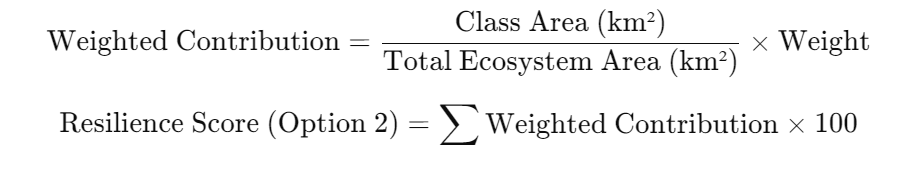
Thresholds for Resilience Scores

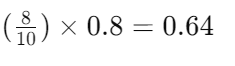
The Resilience Score can be used to classify areas into categories that reflect their ability to withstand floods:

1. High Resilience:
   * Definition: Resilience Score ≥ 150.
   * Interpretation: The ecosystem area significantly outweighs the flood exposure, indicating strong natural capacity to buffer flood impacts.
   * Example: A Resilience Score of 153.85 means ecosystems cover 153.85% of the flood-exposed area.
2. Medium Resilience:
   * Definition: 100 ≤ Resilience Score < 150.
   * Interpretation: The ecosystem area roughly balances with the flood exposure, showing moderate buffering capacity.
3. Low Resilience:
   * Definition: Resilience Score < 100.
   * Interpretation: The flood exposure outweighs the ecosystem area, suggesting limited natural capacity to handle floods.

**Option 2: Weighted Ecosystem Contributions**

**Mathematical Formula:**



* **Weights:** Importance factor assigned to each ecosystem class based on its resilience to floods.
* **Example Ecosystem Class (Feature 1):**
  + **Broadleaved Forest (31100):** Area = 8 km², Weight = 0.8
  + Contribution = 

**Example Calculation (Feature 1):**

* Broadleaved Forest: 0.64, Annual crops: 0.090, Vineyeards: 0.010

Resilience Score (Option 2)=(0.64+0.09+0.01)×100=74

**Classification Ranges**

The resilience scores are classified into three categories based on the ranges of values:

1. **High Resilience:** Resilience Score ≥200
   * Indicates the area has sufficient ecosystem services relative to flood exposure.
2. **Medium Resilience:** 100≤Resilience Score<200
   * Ecosystem services are moderately able to mitigate flood risks.
3. **Low Resilience:** Resilience Score<100
   * Indicates the area is highly vulnerable due to insufficient ecosystem services.

**What the Scores Mean**

* **Option 1:** Highlights the balance between ecosystem services and flood exposure. Higher scores mean more ecosystem areas are available to counteract flood impacts.
* **Option 2:** Emphasizes the importance of specific ecosystems and their weighted contributions to resilience. Areas with a diverse and high-weighted ecosystem profile will score better.

**Why is Option 2 Producing Low Scores?**

* If the **weights** for an ecosystem class are missing or zero, or if the area of these classes is small, the overall score may drop significantly.
* For example, if **Coniferous Forest (32100)** dominates but has a low weight (e.g., 0.7), the score reflects limited resilience contributions.

**Reasoning Behind the Weights of Ecosystem Services**

The weights assigned to ecosystem services represent their **relative contribution to resilience**, especially in mitigating flood risks and enhancing ecosystem functionality. Here's the reasoning for each ecosystem type:

**21100: Arable Land (Weight: Low, e.g., 0.2)**

* **Reasoning:**
  + Arable land primarily serves agricultural purposes and provides limited flood absorption capacity.
  + It is often managed intensively, which can compact soil and reduce water infiltration, increasing runoff and flood risks.
  + Practical Role: Minimal role in flood mitigation; primarily contributes to food production.

**22100: Vineyards & Orchards (Weight: Moderate, e.g., 0.3)**

* **Reasoning:**
  + Vineyards and orchards have permanent vegetation cover, which can provide some erosion control and water infiltration benefits.
  + Their contribution depends on slope management practices and vegetation density.
  + Practical Role: Offers moderate resilience due to root systems stabilizing soil.

**23100: Annual Crops (Weight: Low, e.g., 0.2)**

* **Reasoning:**
  + These are seasonal and often leave the soil bare for parts of the year, increasing vulnerability to runoff and erosion.
  + Intensive plowing and monoculture practices reduce ecological stability.
  + Practical Role: Limited flood mitigation potential, often contributing to runoff.

**31100: Broadleaved Forest (Weight: High, e.g., 0.8)**

* **Reasoning:**
  + Forests are highly effective in water retention, soil stabilization, and reducing flood impacts.
  + Broadleaved forests, in particular, have dense canopies and root systems that enhance infiltration and reduce surface runoff.
  + Practical Role: Major contributor to flood resilience and biodiversity conservation.

**32100: Coniferous Forest (Weight: Moderate, e.g., 0.7)**

* **Reasoning:**
  + Coniferous forests provide similar benefits to broadleaved forests but may have less biodiversity and water retention capacity, depending on soil type and climate.
  + Practical Role: Moderately effective in flood mitigation, especially in upland areas.

**33100: Mixed Forest (Weight: High, e.g., 0.75)**

* **Reasoning:**
  + Combines the benefits of both broadleaved and coniferous forests, offering diverse ecological functions.
  + Practical Role: High resilience due to vegetation diversity, water retention, and soil stability.

**42100: Semi-Natural Grassland (Weight: Moderate, e.g., 0.6)**

* **Reasoning:**
  + Grasslands can absorb and slow down water flow, reducing runoff in areas with light vegetation.
  + They are less effective than forests in water retention but still provide soil stabilization.
  + Practical Role: Moderate contributor to resilience in non-forested areas.

**42200: Alpine Grassland (Weight: Moderate-Low, e.g., 0.5)**

* **Reasoning:**
  + Alpine grasslands are often found in high-altitude areas with rocky soils. While they stabilize slopes, their water absorption capacity is limited.
  + Practical Role: Moderate resilience contributor in mountainous regions.

**51000: Heathland (Weight: Moderate-Low, e.g., 0.5)**

* **Reasoning:**
  + Heathlands consist of low vegetation that can reduce runoff but are less effective than forests or grasslands.
  + Practical Role: Modest contribution to resilience in areas with low-intensity land use.

**71100: Inland Marshes (Weight: High, e.g., 0.9)**

* **Reasoning:**
  + Marshes act as natural water storage systems, absorbing large amounts of water during floods.
  + They are also critical for filtering sediments and maintaining biodiversity.
  + Practical Role: Key role in floodwater absorption and resilience.

**71220: Peat Bogs (Weight: Very High, e.g., 0.95)**

* **Reasoning:**
  + Peat bogs store massive amounts of water due to their sponge-like soil composition.
  + However, they are fragile ecosystems that degrade quickly if mismanaged.
  + Practical Role: Extremely effective in reducing flood impacts and storing water.

**72100: Salt Marshes (Weight: High, e.g., 0.9)**

* **Reasoning:**
  + Salt marshes buffer coastal areas against storm surges and absorb floodwaters.
  + They also provide habitat for diverse wildlife.
  + Practical Role: Essential for coastal flood resilience and biodiversity.

**81100: Natural Water Courses (Weight: High, e.g., 0.85)**

* **Reasoning:**
  + Rivers and streams manage natural water flow and prevent waterlogging.
  + Their resilience contribution depends on natural vs. modified conditions (e.g., canalization reduces effectiveness).
  + Practical Role: Significant in channeling floodwaters and reducing impacts.

**82100: Natural Lakes (Weight: High, e.g., 0.85)**

* **Reasoning:**
  + Lakes store large volumes of water and buffer against extreme runoff events.
  + They also regulate water flow downstream.
  + Practical Role: Critical in absorbing excess water during floods.

**Summary of Weight Rationale**

* High weights (>0.75): Ecosystems that excel in water storage, flood mitigation, and soil stability (e.g., forests, wetlands, lakes).
* Moderate weights (0.5−0.70): Ecosystems with moderate absorption and stabilization capacity (e.g., grasslands, coniferous forests).
* Low weights (<0.5): Ecosystems with limited flood mitigation capacity or intensive management reducing resilience (e.g., croplands, arable land).

**Flood Risk Categories in the Analysis**

The classification of **Flood Risk Categories** in the dataset is derived from the **total flood exposure** calculated based on the areas exposed to **high**, **medium**, and **low probability floods**. These probabilities correspond to specific **flood return periods** and associated **water depths**, as defined below:

**Flood Hazard Layers**

1. **High Probability (floods\_HP\_2019)**:
   * **Description**: Areas with frequent flooding events expected to occur once every **10–20 years**.
   * **Depth Extent**: Includes water depths classified as:
     + **1**: <0.5 m
     + **2**: 0.5–1.5 m
     + **3**: 1.5–2.5 m
     + **4**: >2.5 m
     + **5**: Larger water surfaces (e.g., reservoirs).
   * **Planning Context**: Used for near-term planning (e.g., 2022–2027).
2. **Medium Probability (floods\_MP\_2019)**:
   * **Description**: Areas expected to experience flooding once every **50–100 years**.
   * **Depth Extent**: Shares the same classification structure as high probability but covers less frequent flood events.
   * **Planning Context**: Relevant for medium-term planning (e.g., urban zoning and regional flood defenses).
3. **Low Probability (floods\_LP\_2019)**:
   * **Description**: Areas exposed to extreme flooding events expected once every **500 years or less frequently**.
   * **Depth Extent**: Typically includes the most severe water depths (>2.5 m) and broader water surfaces.
   * **Planning Context**: Informs long-term risk reduction strategies.

**Flood Risk Category Calculation**

In the analysis, the flood risk for each settlement is classified using the **total area exposed** to all three flood probabilities

**Flood Risk Classification Ranges**

1. **High Risk**:
   * **Threshold**: Total flood exposure area > **10 km²**.
   * **Interpretation**: Settlements with extensive exposure to flooding, likely requiring immediate interventions such as embankments, flood barriers, and emergency plans.
   * **Examples**: Coastal or low-lying settlements with significant overlap of all three flood probabilities.
2. **Medium Risk**:
   * **Threshold**: Total flood exposure area between **5–10 km²**.
   * **Interpretation**: Areas moderately exposed to flooding, where targeted mitigation measures, such as improved drainage and zoning, may suffice.
   * **Examples**: Areas with scattered flood-prone zones.
3. **Low Risk**:
   * **Threshold**: Total flood exposure area < **5 km²**.
   * **Interpretation**: Limited flood exposure, but still requiring attention in the context of rare extreme events.
   * **Examples**: Elevated or well-protected settlements.

**Practical Integration with Depth Categories**

The classification of flood risk is inherently linked to **water depths**:

* Higher **total flood exposure** correlates with **frequent and deeper water inundation**, particularly in **High Risk** areas.
* **Depth classifications** (m\_kl\_dub) provide additional granularity to prioritize specific zones for intervention:
  + **Shallow depths (<0.5 m)**: May only disrupt roads and agriculture.
  + **Moderate depths (0.5–2.5 m)**: Likely to impact buildings and infrastructure.
  + **Severe depths (>2.5 m)**: High potential for structural damage and loss of life.

**Final Notes**

This classification system provides a robust framework for integrating flood exposure into impact assessments. It informs:

1. **Urban planning** (e.g., safe housing zones).
2. **Emergency preparedness** (e.g., evacuation routes).
3. **Ecosystem-based adaptation** (e.g., restoring floodplains for natural water retention).