Iterative Modelling (Model V.2)

Menorca Biodiversity Conservation Project

To overcome the computational inefficiency of the V.1 Network Flow model, this iteration introduces a **Path Selection Strategy**. Instead of discovering paths dynamically, the shortest path from the nearest population core to every candidate site is pre-calculated using Dijkstra's algorithm on the grid graph.

Key difference from V.3: In this intermediate version, edge weights are still based on **topological distance** (hop count), assuming uniform travel costs between adjacent cells, lacking real geographic precision.

Sets and Indices

- I: Set of grid cells (nodes).
- E: Set of all edges connecting adjacent cells.
- S: Set of species $S = \{\text{atelerix, martes, eliomys, oryctolagus}\}$.
- $P_{i,s} \subseteq E$: Set of edges forming the shortest path to cell i for species s (Topological metric).

Parameters

- A_i: Area of cell i.
- $Q_{i,s}$: Habitat suitability.
- C_e^{corr}: Topological cost of edge e (assumed constant or proportional to adjacency).
- B_{total}: Budget.

Decision Variables

- $x_{i,s} \in \{0,1\}$: 1 if cell i is selected.
- $y_{i,s} \in \{0,1\}$: 1 if cell i is restored.
- $z_e \in \{0,1\}$: 1 if edge e is activated.
- $\text{stress}_i \in \{0,1\}$: 1 if conflict exists.

Objective Function

Maximize biodiversity score minus costs and stress (Identical to V.1):

$$\text{Maximize} \sum_{i \in I} \sum_{s \in S} W_s A_i \left(Q_{i,s} x_{i,s} + \Delta Q_{i,s} y_{i,s} \right) - \sum_{i \in I} P_{\text{stress}} \cdot \text{stress}_i - \sum_{e \in E} z_e \tag{1}$$

Constraints

1. Connectivity via Path Implication (New)

This constraint replaces the complex flow conservation laws. If a cell is selected, its specific pre-calculated access path must be paid for.

$$x_{i,s} \leq z_e \quad \forall i, s, \forall e \in P_{i,s} \tag{2}$$

2. Simplified Equity (Naive)

At this stage, a generic equity constraint was introduced to ensure species diversity, but without biological calibration (equal targets for all species).

$$0.10 \cdot \mathcal{A}_{\text{total}} \leq \sum_{i \in I} A_i x_{i,s} \leq 0.40 \cdot \mathcal{A}_{\text{total}} \quad \forall s \tag{3}$$

Where $\mathcal{A}_{\text{total}} = \sum_{k \in S} \sum_{j \in I} A_j x_{j,k}$.

3. Investment Logic

$$y_{i,s} \leq x_{i,s} \tag{4}$$

$$x_{i,s} \leq y_{i,s} \quad \forall s \in S_{\text{non-native}} \tag{5}$$

4. Budget Constraint

$$\sum_{i,s} C_{i,s}^{\text{adapt}} y_{i,s} + \sum_{e \in E} C_e^{\text{corr}} z_e \leq B_{\text{total}} \tag{6}$$

5. Biological Conflicts

$$x_{i,\text{martes}} + x_{i,\text{eliomys}} \leq 1 \tag{7}$$