

1 Multi-objective integer programming formulation

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4 We will begin by recalling fundamental concepts in systematic conservation
5 planning. Conservation features describe the biodiversity units (e.g. species,
6 communities, habitat types) that are used to inform protected area estab-
7 lishment. Planning units describe the candidate areas for protected area
8 establishment (e.g. cadastral units). Each planning unit contains an amount
9 of each feature (e.g. presence/absence, number of individuals). A priori-
10 tisation describes a candidate set of planning units selected for protected
11 establishment. Each feature has a representation target indicating the mini-
12 mum amount of each feature that ideally should be held in the prioritisation
13 (e.g. 50 presences, 200 individuals). To minimize risk, we have a set of
14 datasets describing the relative risk associated with selecting each planning
15 unit for protected area establishment. Thus we wish to identify a prioritisa-
16 tion that meets the representation targets for all of the conservation features,
17 with minimal risk.

18 We will now express these concepts using mathematical notation. Let I
19 denote the set of conservation features (indexed by i), and J denote the set
20 of planning units (indexed by j). To describe existing conservation efforts, let

p_j indicate (i.e., using zeros and ones) if each planning unit $j \in J$ is already
 part of the global protected area system. To describe the spatial distribution
 of the features, let A_{ij} denote (i.e., using zeros and ones) if each feature
 is present or absent from each planning unit. To ensure the features are
 adequately represented by the solution, let T_i denote the conservation target
 for each feature $i \in I$. Next, let D denote the set of risk datasets (indexed by
 d). To describe the relative risk associated with each planning unit, let R_{dj}
 denote the risk for planning units $j \in J$ according to risk datasets $d \in D$.

29 The problem contains the binary decision variables x_j for planning units
 30 $j \in J$.

$$x_j = \begin{cases} 1, & \text{if } j \text{ selected for prioritisation,} \\ 0, & \text{else} \end{cases} \quad (\text{eqn 1a})$$

31 The reserve selection problem is formulated following:

$$\text{lexmin } f_1(x), f_2(x), \dots, f_D(x) \quad (\text{eqn 2a})$$

$$\text{subject to } f_d(x) = \sum_{j \in J} R_{dj} X_j \quad \forall d \in D \quad (\text{eqn 2b})$$

$$\sum_{j \in J} A_{ij} \geq T_i \quad \forall i \in I \quad (\text{eqn 2c})$$

$$x_j \geq p_j \quad \forall j \in J \quad (\text{eqn2d})$$

$$x_j \in \{0, 1\} \quad \forall j \in J \quad (\text{eqn 2e})$$

32 The objective function (eqn 2a) is to lexicographically (hierarchically) mini-
 33 mize multiple functions. Constraints (eqn 2b) define each of these functions
 34 as the total risk encompassed by selected planning units given each risk
 35 dataset. Constraints (eqn 2c) ensure that the representation targets (T_i) are

36 met for all features. Constraints (eqn 2d) ensure that the existing protected
37 areas are selected in the solution. Finally, constraints (eqns 2e) ensure that
38 the decision variables x_j contain zeros or ones.