

The ConsNet Portal 1.0

Systematic Conservation Planning Primer

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M11: Multi-Criteria Analysis

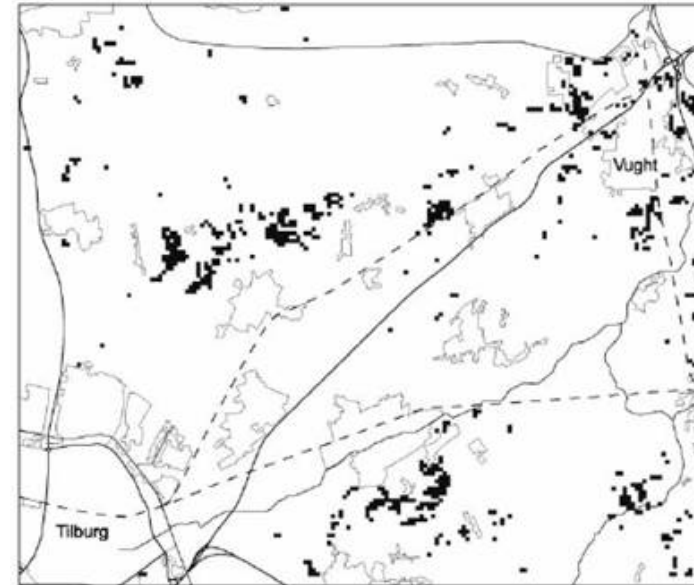
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Learning Objectives: This module demonstrates the use of the multi-criteria analysis in systematic conservation planning. Learners should acquire an understanding of different criteria used during conservation planning and of alternative approaches to incorporating these criteria in conservation decision-making.

- Designating land for biodiversity conservation must compete with other potential uses of land.
 - A prudential (pragmatic) argument for considering these other uses: not having political support can doom any conservation plan, no matter how well-conceived.
 - Examples will be discussed in **M12: Implementation of Conservation Plan**.
 - An ethical argument for these other uses is that certain stakeholders may have normatively justified claims on land other than designating it for biodiversity conservation.
 - Individuals or groups may be residents on the land or have traditional tenure rights.
 - Land may be necessary for agriculture, industrial, or residential development that is critical to the provision of adequate living standards for human residents.
 - Areas may be of cultural (for instance, religious) significance.
 - Systematic conservation planning must provide methods for the incorporation of such criteria whenever they can be modeled.
- Multi-criteria analysis (MCA) is used to incorporate such criteria during the planning process.
 - Sociopolitical criteria can obviously be incorporated in this way. These include:

- Economic costs, including the forgone opportunity when a piece of land is designated for conservation (as opposed to being used for extractive purposes).
- Social costs, especially with respect to the individuals affected by the plan—a rough measure may be the number of individuals affected. However, no such measure is exact.
- Most other sociopolitical costs are difficult to model precisely.
- However, spatial design criteria can also be incorporated using MCA.
 - Different potential conservation area networks can be ordered on the basis of size, shape, connectivity, etc.
 - Some spatial criteria, for instance, shape and connectivity, cannot be ranked according to a linear order.
- The question whether the relevant criteria can be accurately measured is important and should be discussed explicitly.
- MCA starts with the identification of a feasible set of *alternatives*, and the relevant *criteria*.
 - Alternatives: these are the things between which choices must be made in designing a conservation area network.
 - Individual areas may be the alternatives when a conservation area network is assembled, usually sequentially (e.g., by ranking using complementarity).
 - Entire conservation area networks may be the alternatives—most applications so far have used such a method.
 - In the rest of this Module, "alternative" will refer to both individual areas or entire networks, depending on which method is used.
 - Criteria: alternatives are chosen on the basis of their performance with respect to the relevant criteria (e.g., preferred shape or size).
 - Each alternative must at least be given a rank by the criteria, that is, given two alternatives, *A* and *B*, *A* must either be better than *B*, as good as *B*, or worse than *B*.
 - If alternatives cannot be ordered in this way by each criterion, then that criterion cannot be used.
 - Many multi-criteria analysis (MCA) methods make a stronger assumption: that each alternative be assigned a quantitative value by

Figure 11.1



- Most MCA applications in the context of conservation planning start with a set of potential conservation area networks each of which satisfies the targets of representation for biodiversity surrogates—these networks are the alternatives.
 - This method privileges biodiversity representation over the other criteria.
 - Whether this is appropriate depends on what biodiversity surrogates are being targeted and how important they are perceived to be.

- Such a strategy is called a "terminal stage protocol" (Sarkar 2004).
 - It is possible to use a mixture of iterative and terminal stage protocols.
 - Some criteria would be incorporated during area selection ("iterative") others at the end ("terminal")
- The first stage of MCA is to identify "dominated" solutions and exclude them from further consideration—see **Examples 11.2** and **11.3**.
 - One solution dominates another if it is better than the other by at least one criterion and no worse by any of the criteria.
 - There is thus an obvious sense in which the dominated solutions are worse than the non-dominated ones.
 - Note that finding non-dominated solutions makes no assumption beyond the ability to order the alternatives according to each criterion.
 - It does not assume that the criteria are independent of each other.
 - It does not assume that the alternatives can be given quantitative values by the criteria.
 - It does not assume any ranking among the criteria (let alone quantitative values).
 - The set of non-dominated solutions is given to decision makers who can decide between them using other considerations than those that have been explicitly modeled during the MCA.
 - If this set is small, nothing more needs to be done by the planning experts.
 - Non-dominated solutions are called Pareto-optimal solutions in economic theory.

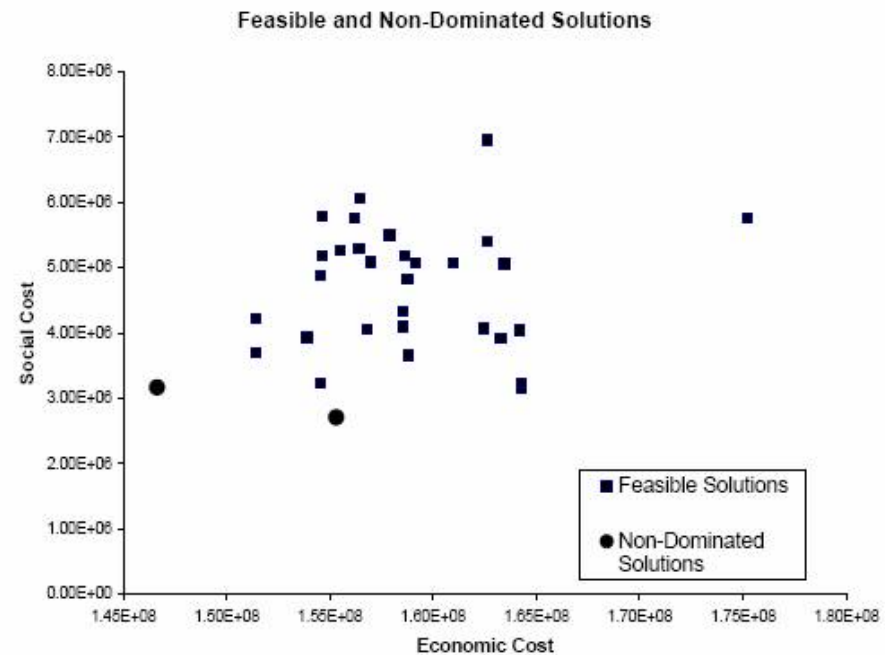
Example 11.2

Non-Dominated Solutions in Texas (Sarkar et al. 2000)

Modeled spatial distributions of 655 mammal species in Texas produced by the Texas GAP Analysis Project were used as biodiversity by Sarkar et al. (2000) in a multi-criteria analysis (MCA). These 655 species were used as biodiversity surrogates. These distributions were known for 1183 hexagons, each with an average area of 649 sq km. The goal of this planning exercise was to develop a method for minimizing social and economic costs while ensuring adequate biodiversity representation. 100 different

potential conservation area networks (the alternatives) were generated each using a representation target of at least 10 % of the distribution patterns of each species. These computations were done using the ResNet software package (Garson et al. 2002b). For each such alternative, two additional criteria were used: (1) the projected human population in 2020 in that set of hexagons; and (2) the total area of the set. Criterion (1) was interpreted as a measure of the social cost of conservation which should be minimized. Criterion (2) was taken as a measure of the economic cost of conservation which should also be minimized. There were two non-dominated solutions which are shown in the non-dominated plot of Figure 12.2. This part of the analysis was performed using the MultCSync software package (Sarkar et al. 2004a; Moffett et al. 2005). Such non-dominated plots are useful visual devices when there are only two criteria. If the alternative values are being minimized for both criteria, the non-dominated alternatives are those with no others in the lower left-hand quadrant below them. However, this visual method cannot be extended to more than two dimensions.

Figure 11.2



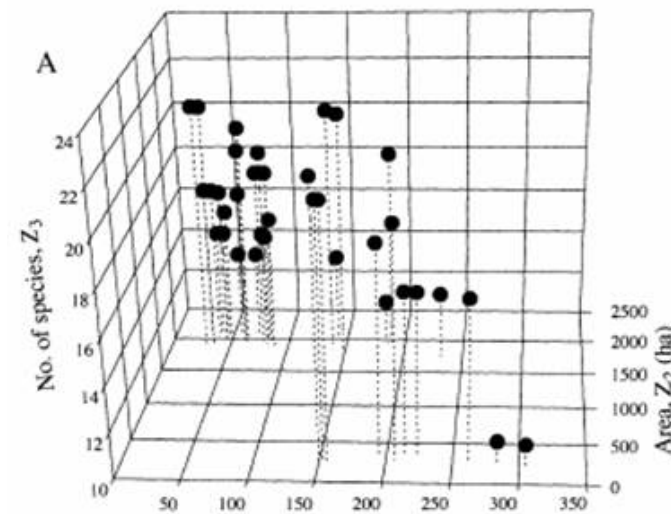
Example 11.3

Connectivity, Area, and Representation in Nova Scotia (Rothley 1999)

Rothley (1999) computed the set of non-dominated solutions with the goal of identifying five forest nature reserves from a set of 20 potential reserves to supplement two existing national parks in Nova Scotia, Canada. Three criteria were used: (1) connectivity; (2) total area; and (3) representation of rare plant species. The goal was to maximize all three criteria in the finally selected set. There are 15 504 possible combinations of five reserves from a set of 20. Numerical values were assigned to each of the alternatives on the basis of each of the criteria. Connectivity was measured by the inverse of the distance between two included potential reserves. Area measurement is straightforward. Representation was measured by the number of rare species present in the five potential reserves. An optimization algorithm was used to reduce this set of 15 504 alternatives to 36 non-dominated alternatives. Figure 11.3 show the non-dominated alternatives.

Figure 11.3

Non-dominated Alternatives (Dominated Solutions Not Shown).



- Finding non-dominated solutions may not be enough if there are too many such solutions.
 - Political planners, who will ultimately be responsible for deciding if a conservation area network will be implemented (see **M12: Implementation of Conservation Plan**) may want further refinement of the solutions, that is, for some additional order to be imposed.
 - Typically, the number of non-dominated solutions grows with the number of criteria (Sarkar and Garson 2004).

- The reason for this is partly that the best solution according to any criterion is a non-dominated solution.
 - However, even with a very few criteria, there can be many non-dominated solutions (e.g., consider Figure 11.2 and imagine that there are a large number of points with nothing below and to the left of them, each of which would represent a non-dominated solution).
 - However, moving beyond the non-dominated solution requires, minimally, an ordering of the criteria.
 - There are many MCA methods that allow refinement of the non-dominated set; only two of which will be discussed here.
- There are two common MCA methods that have been used for refining the set of non-dominated solutions: Multiattribute Value Theory (MAVT) and the Analytic Hierarchy Process (AHP).
- Both methods assume:
 - Each alternative can be given a quantitative value by each criterion.
 - The criteria can be given relative quantitative values reflecting their importance.
 - The criteria are essentially independent (difference-independent) of each other.
 - Given these assumptions a value function is constructed and evaluated for each alternative, and then used to compare them.
 - This value function must be elicited from the user (decision-maker) by asking the user a variety of questions with respect to the importance of the alternatives and criteria.
- MAVT is an extension of standard utility theory (from economics) to situations in which several criteria have to be used. The standard utility theory proposes that utility can be calculated by defining the utility of each possibility and constructing a **weighted average**.
- Its advantage is its theoretical basis — that of a well understood economic theory.
 - The disadvantage is that the value function (the decision maker's value function) is often difficult to assess in practice. The decision maker must place values on all alternatives and all criteria. This is hard to do consistently when there are a lot

of alternatives and criteria.

- AHP is a method which asks users to compare criteria on a ratio scale. (How many times is one criterion more desirable than another?)
 - Its advantage is that the elicitation process is transparent and easy to carry out. In other words, the questioning process of the decision maker(s) is straightforward, and therefore making the decision maker(s)' values transparent.
 - The question that users must answer is the ratio by which one criterion is preferable to another (twice, four times, one-fifth, etc.) usually on a scale from 0 to 9.
 - The disadvantage is that it allows the possibility of rank reversal: introducing a new alternative may change the relative ranks of previously considered alternatives. This is usually regarded as undesirable.
 - It also become cumbersome if there are very many criteria.

- A modification of the AHP (mAHP) permits taking advantage of the strengths of both methods.
 - The modification constructs the value function in a different way.
 - The result is that mAHP produces the same rankings of the alternatives as MAVT.
 - However, it uses the transparent elicitation procedure of the AHP.
 - mAHP is available in the MultCSync software package (Moffett et al. 2005).

Example 11.4

Multi-Criteria Analysis for North-Central Namibia (Moffett et al. 2006)

Moffett et al. (2006) used the mAHP for planning in North-Central Namibia, the study region consisting of Etosha National Park (shown in gray in Figure 11.4a, b) and the land between it and the border with Angola. Data were provided by the Ministry of Lands, Resettlement and Rehabilitation of Namibia. The goal was to generate a plan incorporating six criteria (see below) while representing 10 % of the habitat of each vegetation class in selected areas including the Etosha Park. Besides Etosha there were 119 different cells under consideration. These cells varied in size from 0.02 sq km to 1 225.89 sq km, with an average area of 517.95 sq km. All 35 different vegetation classes from this region were used as biodiversity surrogates. The ResNet software package was used to generate 94 different solutions or alternatives satisfying biodiversity representation targets.

Besides biodiversity representation, they used six other criteria: (1) area; (2) human population; (3) number of summer cattle; (4) number of winter cattle; (5) farming; and (6) number of wildlife. An optimal solution was supposed to minimize the values of criteria (1) through (5) while maximizing the value of criterion (6). Each alternative was assigned a quantitative value for each of the six criteria. This set of criteria was that which local Namibian experts had deemed to be the most relevant. The non-dominated solution was computed using the MultCSync software package and consisted of 49 alternatives, clearly too many for use without further refinement. Personnel from the Namibian Ministry of Lands, Resettlement and Rehabilitation provided the pairwise comparisons of the criteria which were used to assign weights to the criteria. The highest ranked alternative is shown in Figure 11.4a; another slightly different highly ranked alternative is shown in Figure 11.4b. Note the differences between them which will aid decision makers to introduce further considerations.

Figure 11.4a

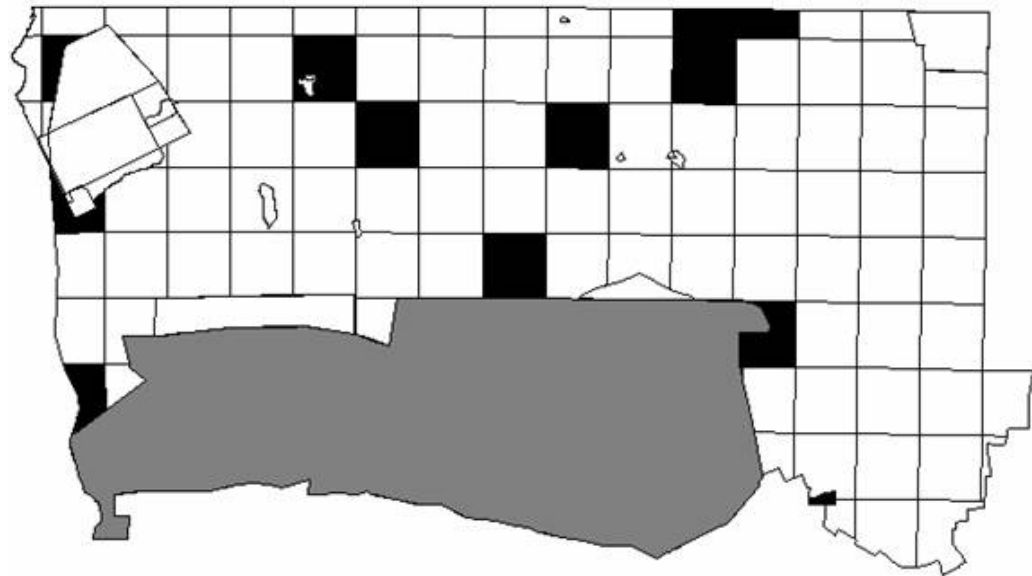
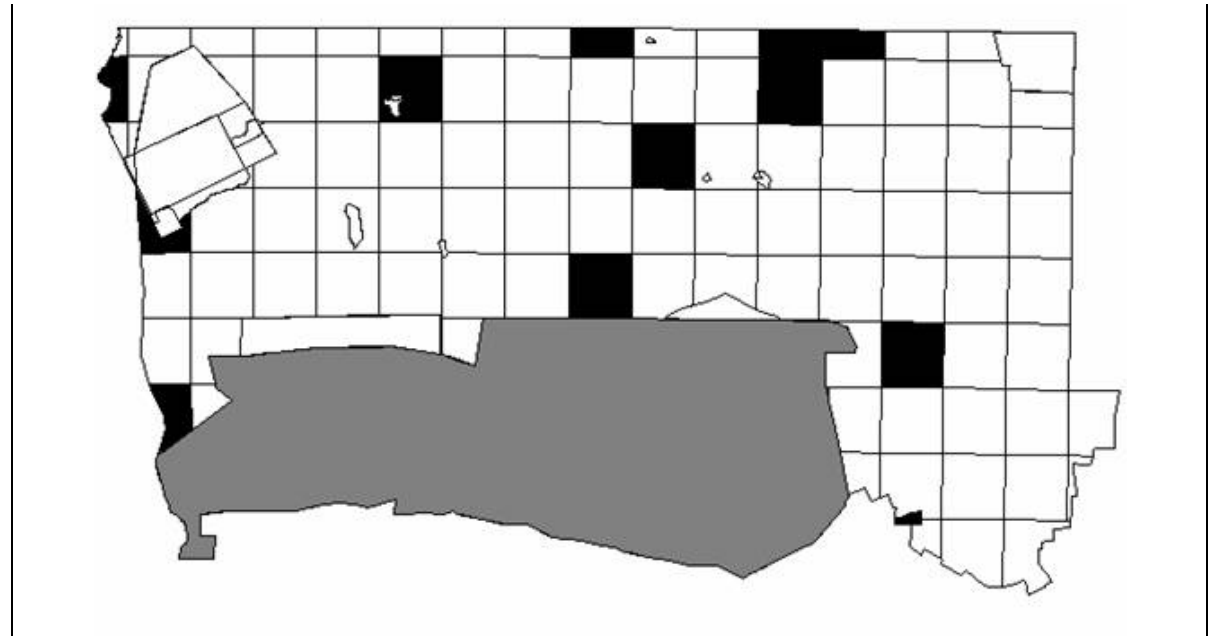


Figure 11.4b



- Not all criteria relevant to designating land for biodiversity conservation can be incorporated through multi-criteria analysis.
 - These methods assume, at the minimum, that the criteria can be modeled in such a way that all alternatives can be placed in a linear order.
 - There are many relevant criteria that cannot be modeled in this way. Examples include:
 - Sites of religious value: stakeholders may be unwilling to order them. Any imposed order would be arbitrary.
 - Scenic beauty: ordering *all* sites in a linear order is usually arbitrary.
 - Wilderness value: though there have been many attempts, ordering *all* sites in a linear order in this way will probably be regarded as arbitrary.
 - Social cost: even quantifying social cost may not be possible in many situations.
 - Arbitrarily ordering and quantifying alternatives will make a plan unconvincing—this may lead to problems when implementation is envisioned.
 - The political process—public debate, attempts at compromise, etc.—should be used to take such criteria into account.

Assess Your Knowledge

M1: Introduction to Conservation Area Networks
M2: Systematic Conservation Planning Overview
M3: Stakeholder Identification and Involvement
M4: Data Compilation, Assessment, and Treatment
M5: Surrogacy Identification and Analysis
M6: Conservation Targets and Goals
M7: Review Existing Conservation Areas
M8: Place Prioritization
M9: Vulnerability and Persistence Analysis
M10: Network Refinement Protocol
M11: Multiple Criteria Analysis
M12: Implementation of Conservation Plan
M13: Periodic Network Reassessment
M14: Conclusion and Review - Future Directions

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Module Glossary

[Welcome Page](#)