TECHNICAL BRIEF

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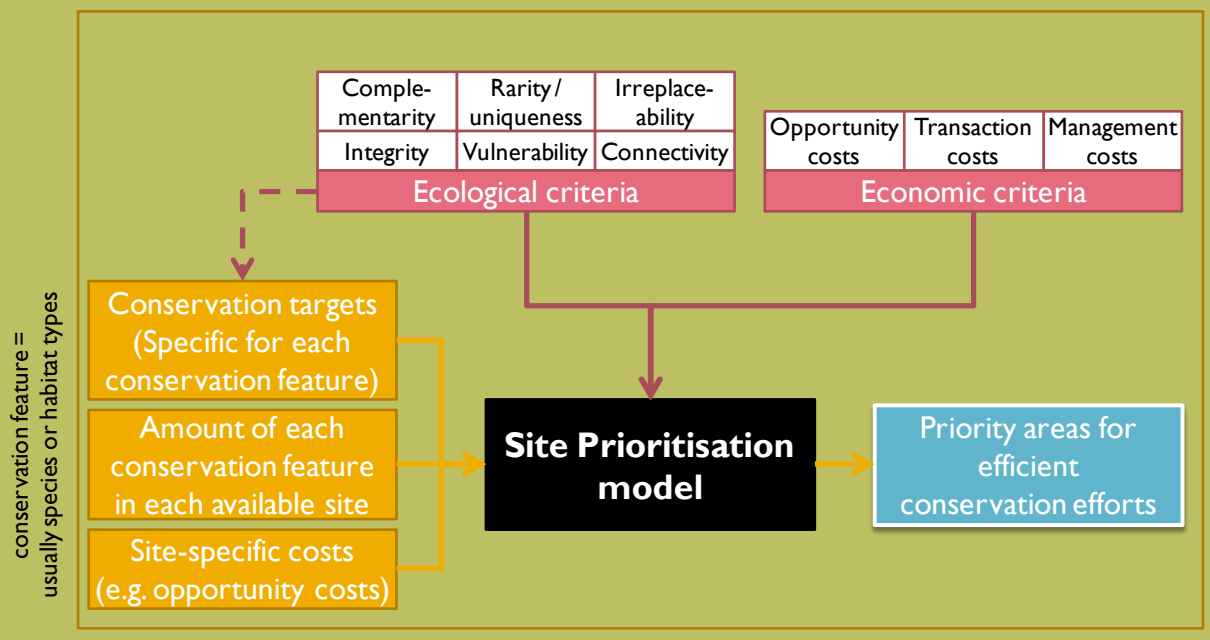
POLICYMIX - Assessing the role of economic instruments in policy mixes for biodiversity conservation and ecosystem services provision

Site prioritisation models and their suitability for assessing and designing policy mixes for biodiversity conservation and ecosystem services provision: a comparison of software packages

Stefan Blumentrath (NINA)



Site prioritisation models and their suitability for assessing and designing policy mixes for biodiversity conservation and ecosystem services provision: a comparison of software packages

Blumentrath, Stefan, NINA

Aim of this technical brief

In the last three decades, several computer models intended for supporting the identification of priorities for biodiversity conservation efforts have been developed. Because these kind models are being more and more applied in conservation practice, and because they hold potential for optimising conservation efforts, as well as targeting and assessing policies, this technical brief aims at giving an overview over existing site prioritisation models and their features. Because the choice of an adequate model depends first and foremost on the particular case and intended purpose, this review of existing models is primarily descriptive as a first step. It should provide a summary of information on the models, which can be evaluated by a potential user with regards to the requirements derived from her or his individual case study. While the text is focused on a general description of these kinds of models and the aspects to consider when choosing a model, the main comparison can be found in an attached spreadsheet. In a second step the models are evaluated with regards to requirements resulting from the objective of the POLICYMIX project to assess the role of economic instruments in policy mixes for biodiversity conservation and ecosystem services provision. For those interested more in depth and in background information the following book can be recommended:

Moilanen, A., Wilson, K.A., Possingham, H.P. (Eds.), 2009. Spatial Conservation Prioritisation - Quantitative Methods & Computational Tools. Oxford University Press, New York.

Available prioritisation models:

ConsNet Software Platform V. 1.10: http://uts.cc.utexas.edu/~consbio/Cons/consnet_home.html

C-Plan Conservation Planning System V. 4: http://www.uq.edu.au/ecology/index.html?page=101951

Habitat Priority Planner – Version 2.0 (HPP): http://www.csc.noaa.gov/digitalcoast/tools/hpp

MARXAN with Zones V. 1.0.1: http://www.uq.edu.au/marxan/index.html?p=1.1.1

ResNet 1.2 (together with ResNet GUI 2.1 (an ArcView 3.x extension)): http://www.consnet.org/manuals/ResNet.mnl-1.2.htm

Sites 1.0: http://www.biogeog.ucsb.edu/projects/tnc/toolbox.html

TARGET (or TD for targets and diversity) is one module of the DIVERSITY software package which forms part of the BioRap toolbox: http://australianmuseum.net.au/ onsen/dan-faith

WORLDMAP Software: http://www.nhm.ac.uk/research-curation/research/projects/worldmap/index.html

Zonation 2.0: http://www.helsinki.fi/bioscience/consplan/software/Zonation/Components.html

Site prioritisation models – meaning, aims and working principles

Conservation of biodiversity is a complex task, dealing with thousands of species and lots of different habitat types on the one hand and limited resources for conservation (but also a number of valuation concepts and criteria) on the other hand (see e.g. Margules & Pressey 2000). Additionally efforts for preserving or enhancing biodiversity have to be balanced with other conflicting, as well as supporting (land use) interests. All this is why priorities for protection of biodiversity are needed. But, because of the complexity outlined above, the identification of priorities is a task which is often likely to exceed the rational capacity of the human brain. This is why several software models have recently been developed to support the process finding rationally "good" priorities. These site prioritisation models attribute some kind of priority score to spatial units in the landscape. They do this by applying ecological (and sometimes also socio-economical) criteria on a possibly large amount of input data, framed by constraints and objectives defined (mainly) by the user.

The primary inputs for these models are usually data about the occurrence of species or taxa ("true surrogates"), as well as land cover types / habitat types data ("estimator surrogates") (see (Sarkar *et al.*, 2006): p.130). The user can define objectives and constraints for the selection or prioritisation process: e.g. regarding the representation of species or habitat types in the prioritisation, a given (maximum size) to reach representation targets or spatial constraints (rules for the spatial configuration) regarding the dispersal of the priorities. Then the model applies biological or ecological criteria like e.g. species richness, species diversity, rareness, threats and sometimes also socio-economic criteria like negative as well as positive costs (see (Sarkar *et al.*, 2006)).

The origin of these site prioritisation models can often be found in the aim of designing Conservation Area Networks (CAN). This is why these models are often called "Reserve site selection models" (or something similar).
But the prioritisation achieved by the application of this kind of models can be of use far beyond designing a system of protected areas. The prioritisation can be useful as a valuation of areas in excess of the CAN, providing a guide for targeting more broadly applied additional conservation efforts around and between the top level CAN-spots in larger area (with lower conservation intensity). For example, the model MARXAN was used to find not only priorities for biodiversity, but also other ecosystem services(Chan *et al.*, 2006). For these reasons in this review we use the more precise term "site prioritisation model".

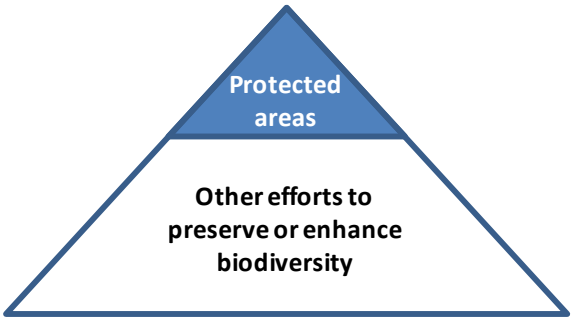


Figure 1: Possible application purposes for site prioritisation models

How to choose an adequate model

In general software models have to meet three requirements:

- They have to be sound from a technical and scientific point of view.
- Their results have to be useful and acceptable for the addressees (address their problems and demand for decision support).
- Their usability and technical solutions should foster (or at least not reasonably hamper) the intended usage.

The challenge for a potential user is to find the model, which is balancing these three requirements in the best way regarding the intended case study. For each of these requirements a summary of relevant information about each of the compared models is given in the attached spreadsheet:

http://policymix.nina.no/LinkClick.aspx?fileticket=0NW53P-gj-U%3d&tabid=3555

The scientific and technical soundness of the models can be compared by the ways and degree they apply ecological and/or socio-economic criteria relevant for the intended case study. When choosing a model, a central characteristic to consider is whether the concept of the model copes with the intended purposes. The core algorithms steer the models features and outputs (for a discussion of different algorithms see (Pressey *et al.*, 1996)) . A potential user should therefore have an idea about the intended role of the model within

- the analysis (chain) or
- decision making process.

To check if the models cope with the challenges of the complexity and uncertainties of the problems to tackle in reality one should take the following characteristics into account:

- the way conservation targets can be defined and the possibilities to frame the prioritisation process (see (Rodrigues *et al.*, 2000)),
- the conservation options the model can handle (e.g. different types of land use restrictions or possible alternatives among sites),

Finally, user-friendliness and technical aspects have to be considered. Besides its performance, the accessibility (e.g. licence costs), documentation, ease of use, flexibility, and data requirements of the model can be relevant factors.

Requirements for site prioritisation models resulting from the POLICYMIX case studies

The objective of the POLICYMIX project is to assess the roles of economic instruments in a policy mix for biodiversity conservation and ecosystem services provision. To be able to assess policy mixes the site prioritisation model of choice should allow for analysing a mixture of conservation options (different instruments in combination e.g. represented by different types of conservation areas). Furthermore, POLICYMIX aims at paying regards both to cost-effectiveness of policy instruments using e.g. opportunity cost-based approaches, as well as non-market values of ecosystem services and social criteria (such as poverty and fairness concerns). An adequate site prioritisation model should therefore provide the possibility to include economic, as well as social criteria, while identifying priority areas for both for biodiversity conservation and ecosystem services provision.

Because the POLICYMIX project is carried out with case studies in six different countries, with different spatial extent, different landscape characteristics, focussing on different instruments, flexibility is required if the model is to be applicable across case studies. Here flexibility will be relevant in to modes:

1. In evaluating a policy mix a combination of methodologies is needed (Barton et al. 2010). Assuming that the methodological sets will vary in the different case studies the site prioritisation models should be flexible with regards to how they can be integrated into the particular set of applied methodologies.
2. Due to the differences in the case studies, there will be differences in the conservation objectives and features (parts of biodiversity as well as ecosystem services) and criteria (e.g. social challanges). Furthermore, the data situation and the level of application and.

resolution will differ across case studies. The model of choice should therefore be flexible enough to be adapted to these differences.

Available and compared models

Without claiming that this overview is complete, nine different site prioritisation models for biodiversity conservation efforts can be found on the market. With regards to the definition in the first chapter the following software tools have been compared (see table 1):

MARXAN with Zones V. 1.0.1
MARXAN is possibly the most widely used conservation planning software in the world. Because of its complexity its usage may be challenging, but the model and the way to apply it are well documented. It produces not one optimal, but several (alternative) "good" or near optimal prioritisation solutions while taking ecological and socio-economic criteria into account. A unique feature of MARXAN with Zones is that it can handle different conservation options by means of different types of conservation "zones". Here contributions to conservation targets as well as costs can be defined for each type of zone individually.

Sites 1.0
Sites 1.0 was based on SPEXAN (an early version of MARXAN). It has been removed from the authors webside after Hugh Possingham and Ian Ball updated the SPEXAN module into MARXAN. MARXAN is therewith a successor of Sites 1.0, which is why the latter is not reviewed in detail.

ConsNet Software Platform V. 1.10
The main functionalities and outputs of the ConsNet Software Platform are comparable to MARXAN (though it does not account for different zones). The unique feature of this model is the integrated multi-criteria-analysis, which can be completely controlled by the user.

ResNet 1.2 (together with **ResNet GUI 2.1** (an ArcView 3.x extension))
ResNet 1.2 and its graphical user interface ResNetGUI 2.1 have been replaced by ConsNet 1.0. The authors characterise the software as now obsolete and do no longer support ResNet 1.2. ResNet 1.2 is therefore not reviewed in detail.

C-Plan Conservation Planning System V. 4
The C-Plan Conservation Planning System aims at identifying priority sites in the landscape by means of iterating automatical and manual (accepting or rejecting the automatically selected planning units based on negotiation) site selection processes. It is a unique feature of C-Plan that it is set up for this kind of interactive iteration process, though most of the other models could be applied in a similar manner. Unfortunately, the software C-Plan is based on is out of date.

ZONATION 2.0
ZONATION 2.0 aims at hierarchically prioritising the whole landscape in terms of their priority for biodiversity conservation. Because of its focus on finding ecologically optimal solutions socio-economic criteria are deliberately disregarded (except for costs caused by the protection of a planning unit). On the other hand it is the most sophisticated model regarding ecological criteria, e.g. especially in terms of applicable connectivity measures. Furthermore it is the only model that accounts for species interaction.

TARGET (or "**TD**" for targets and diversity) is one module of the **DIVERSITY software package** which forms part of the **BioRap toolbox**)
TARGET searches for an optimal solution for fulfilling user defined conservation goals, based on a trade-offs approach. Here the user can weigh the importance of opportunity costs in contrast to complementarity, as the main biodiversity indicator in TARGET. A unique feature

of this software is the possibility to use "preference areas", planning units that, all else being equal (costs and biodiversity value), should be preferably included or excluded from the priority area set.

Habitat Priority Planner – Version 2.0 (HPP)
The Habitat Priority Planner is a lean and easy to use extension to ESRIs ArcGIS software. It was designed with stakeholder engagement in mind and supports the user in selecting priority areas logically. This is why the Habitat Priority Planner does not apply any mathematical optimisation to the conservation problem. Its use requires a licence for both ArcGIS and its extension "Spatial Analyst".

WORLDMAP Software
The WORLDMAP assigns scores for diversity, rarity, and conservation priorities (complementarity) to cells of a regular spaced raster. A mayor disadvantage of the WORLDMAP software is that it has to be adapted by the authors in order to be applicable on other scales or other regions (tailormade versions). The latest updates of WORLDMAP are from 2001, while the the underlying operative systems (Windows 95 – NT) have gone out of date. It seems that the development of the tool has been stopped.

In addition several add-ons to or decision support systems integrating MARXAN (and C-Plan) can be found on the market. They are mainly complementing it with a graphical user interface and (amongst others) some GIS functionality. Such software tools are **Zonae Cogito** (www.uq.edu.au/marxan/download-zonae-cogito) an open source GIS for MARXAN and C-Plan, **PANDA** (www.mappamondogis.it/panda.htm) and **NatureServe Vista** (www.natureserve.org/prodServices/vista/overview.jsp) providing ArcGIS 9.x integration for MARXAN, as well as **CLUZ** (www.kent.ac.uk/dice/cluz/index.html) an ArcView 3.x extension for MARXAN.

Recomandations regarding the suitability of existing prioritisation models for assessing policy mixes

While of course all of the reviewed models have their advantages and disadvantages, MARXAN and the ConsNet Software platform appeared to be the most promising approaches for assessing and designing policy mixes for biodiversity conservation and ecosystem services provision. They outperform the other approaches with regards to the POLICYMIX case study focus mainly because of their flexibility (regarding e.g.the possibilities to define conservation targets, input data or use of their outputs) and their opportunities to take economic and social criteria into account. While MARXAN is preferable for the definition of opportunity costs of different conservation options (zones) with differing effectiveness, a prominent strength of the ConsNet Softwareplatform is the included Multi-Criteria-Analysis technique. Furthermore, both models are up to date in terms of technical solutions (while development is ongoing), very well documented, can be easily downloaded from the internet without a need for licence costs or the need for additional, expensive software, and extensive documentation and support is provided.

Nevertheless, none of the existing models met all of the POLICYMIX requirements fully. These lacks are subject of further research and development (see Sarkar et al. 2006).

Model	Reference	Target definition	Ecological criteria	Socio-economic criteria and constraints	Handling different conservation options	Stakeholder involvement	Usability and technical solutions	Documentation and support	Accessibility
MARXAN with Zones V. 1.0.1	http://www.uq.edu.au/marxan/index.html?p=1.1.1	+	+	+	+	o	++	++	++
Sites 1.0	http://www.biogeog.ucsb.edu/projects/tnc/toolbox.html	MARXAN is therewith a successor of Sites 1.0, which is why the latter is not reviewed in detail.							
ConsNet Software Platform V. 1.10	http://uts.cc.utexas.edu/~consbio/Cons/consnet_home.html	++	+	++	-	o	++	++	++
ResNet 1.2 (together with **ResNet GUI 2.1** (an ArcView 3.x extension))	http://www.consnet.org/manuals/ResNet.mnl-1.2.htm	ResNet 1.2 is a predecessor of the ConsNet Software Platform and is therefore not reviewed in detail.							
C-Plan Conservation Planning System V. 4	http://www.uq.edu.au/ecology/index.html?page=101951	+	+	+	-	+	-	+	o
Zonation 2.0	http://www.helsinki.fi/bioscience/consplan/software/Zonation/Components.html	o	++	-	-	-	+(+)	++	++
TARGET (or **TD** for targets and diversity) is one module of the **DIVERSITY** software package which forms part of the **BioRap toolbox**	http://australianmuseum.net.au/7onsen/dan-faith	+	o	o	-	o	o	-	-
Habitat Priority Planner – Version 2.0 (HPP)	http://www.csc.noaa.gov/digitalcoast/tools/hpp/	-	-	o	-	+	o	+	-
WORLDMAP Software	http://www.nhm.ac.uk/research-curation/research/projects/worldmap/index.html	-	o	-	-	-	--	o	--

++ = major strength; + = strength; o = neither strength nor weakness; - = weakness; -- = major weakness

Final remarks

Finally, methods are neither wrong nor right, they are adequate or not. Their proper use is up to the user. Besides the more technical considerations of choosing the most adequate model, one should be aware, that most of the site prioritisation models apply some kind of mathematical optimisation to a well defined conservation problem. But in real-life environmental planning well-defined problems are very rare (if they can be found in general). The main challenge when using these kinds of models is therefore not to handle the technical parts, but to translate the individual conservation problem into the formal, technical framework of the particular model. From the field of planning theory it is known that the phase of problem definition is the most crucial one with regards to possible solutions. This is why the most important steps of the prioritisation process have to be taken long before a mathematical model is applied. This complex task of structuring the conservation problem touches questions like:

- Who should contribute to defining the conservation targets?
- What are the relevant conservation goals with regards to biodiversity and ecosystem services?
- What kind of social, economical and ecological criteria should be taken into account and how should they be included into the prioritisation process?
- What kind of data is available and can be used therefore?

Of course proper usage of the site prioritisation models requires carefully preparing relevant input datasets (which calls for at least some kind of knowledge in geographical information systems (GIS)) as well as learning the proper usage of the software and it`s options. This takes time. Depending on the ambition level, the amount of applied criteria and data (and the quality and availability of the latter) this can last from several days to months. And in this context, beyond the qualities of the different models, the user should be critical concerning the validity of the results and the possible conclusions they allow for. Here for example the quality of the input data has to be considered (because the quality of the results of any computer model is constrained by the quality of the input data).

Literature:

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The POLICYMIX Policy and Technical Brief series translates the results from the project into practical and useful information for policy makers and managers. The Briefs are also available online: http://policymix.nina.no

About POLICYMIX. POLICYMIX focuses on the role of economic instruments for biodiversity conservation and ecosystem services provided by forest ecosystems. POLICYMIX evaluates the cost-effectiveness and benefits of a range of economic versus regulatory instruments in a variety of European and Latin American case studies.

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