SUPPORTING INFORMATION

For

Conservation planning for action: end-user engagement in the development and parameterization of a spatial decision support system

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INTRODUCTION

AUDIENCE AND CONTENT

This document provides additional methodological details for the associated manuscript. There is also a very brief discussion that that may be of interest to people implementing some of the methods, so they are included as well. To aid in the use of the document, hotlinks are provided from the table of contents and at the bottom of each page.

This document was written primarily for any readers of its associated publication that are interested in applying some of the ideas to their own work. Further, it was written for end-users in the Little Karoo and the Western Cape as a complement to the workshops and final result presentations. There is a fifty page document of raw notes and methods that is available upon request.

It is not the responsibility of the Journal to edit this supplementary material. It does not comply to all of the Journal's formatting standards. Similarly, this was written by the corresponding author, so any errors or omissions are due to his error and not the error of the paper's co-authors.

Further, a subsequent version of this supplementary material was made for a sister publication (Gallo et al. *in review*). That version does not have all the details below about the participatory process, but some of its technical details are more polished.

METHODS

Modelbuilder

All of the geo-processing for this project was done using ArcGis Modelbuilder. As mentioned, it allows you to program models without knowing a programming language. You drag and drop commands/tools onto a blank workspace, and connect them with arrows. You can program iterations, loops, and feedbacks too. You can nest models within models, and link them together. There is also a good interface for documenting your work and providing a help file for your model.

This is not an extension per se, rather, it is included as part of the ArcGIS Products. It is available in the ArcView version of ArcGIS 9.x. You can start using it by right clicking on the toolbox, and "add toolbox" then right click on the toolbox and "add model." A great way to quickly learn the modelbuilder graphic user interface (GUI) is through the ESRI Geoprocessing tutorial. In arcGIS this is in the help/Getting started/Tutorials section, and it can be viewed online by everyone at :
http://webhelp.esri.com/arcgisdesktop/9.3/index.cfm?TopicName=Geoprocessing_Tutorial

The fifty page document of raw notes has some troubleshooting notes and solutions, and is available upon request.

Data and Pre-Processing

Habitat Data

The vegetation map used for this analysis was created for the Little Karoo region through extensive field surveys during 2004 by local botanical expert Jan Vlok. Numerous site visits complemented remote sensing interpretation, and then individual polygons where hand drawn on 1:50 000 Landsat images and hand digitized (Vlok et al. 2005). A hierarchical classification system was used, in which sub-habitats (vegetation units) were nested within habitat polygons, which were nested within biome polygons. In areas that were transformed, the pre-transformation vegetation was estimated and mapped based on clues from the surrounding vegetation and micro-locations of low degradation, such as the corners of pastures. Local knowledge, where available, was also utilized.

Succulent Richness and Endemism

The richness of succulents and the degree of endemism of the succulents present were estimated for all the habitats in the region. The classification of habitats used was the "Biome_Hab" classification in the database (N=56). The local expert who made the habitat map (Jan Vlok) performed this exercise based on his field notes and expert knowledge. The results of his estimates are provided in Table 1.

Table 1. Succulent Richness and Endemism Values

Habitat Type	Estimated Succulent **Richness** (1=None, 10 = Max)	Estimated Succulent **Endemism** (1 = None, 10 = Max)
S KAROO Quartz Apronveld	9	10
S KAROO Quartz Asbosveld	8.5	10
S KAROO Quartz Gannaveld	8	8
S KAROO Gravel Apronveld	8	7
S KAROO Apronveld	9	6
S KAROO Randteveld	8	6.5
THICKET Arid Mos Succulent Karoo	8	6
THICKET Arid Mos Asbosveld	7	6
THICKET Arid + Spekboom + S Karoo	8	5
THICKET Arid + Spekboom + S Karoo + Sandolien	8	5
THICKET Arid + Spekboom + Sandolien	8	5

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Habitat Type	Estimated Succulent **Richness** (1=None, 10 = Max)	Estimated Succulent **Endemism** (1 = None, 10 = Max)
RENOSTER Mos Succulent Karoo	7	5
THICKET Arid Mos Renosterveld	7	5
THICKET Valley + Spekboom + S Karoo	7	5
THICKET Valley Mos Succulent Karoo	7	5
S KAROO Kalkveld	6	5
THICKET Thicket Mos Renosterveld	6	5
RENOSTER Arid Renosterveld	7	4
THICKET Arid + Spekboom	7	4
THICKET Arid + Spekboom + Fynbos	7	4
THICKET Valley + Spekboom	7	4
THICKET Valley + Spekboom + Renoster	7	4
THICKET Valley + Spekboom + Sandolien	7	4
S KAROO Asbosveld	6	4
S KAROO Gannaveld	6	4
THICKET Arid Mos Fynbos	6	4
THICKET Mos Sandolienveld	6	4
THICKET Mos Waboomveld	6	4
THICKET Thicket Mos Asbosveld	6	4
THICKET Thicket Mos Waboomveld	6	4
THICKET Valley + Spekboom + Fynbos	7	3
FYNBOS Sandolien Mos Renosterveld	5	4
RENOSTER Mesic Renosterveld	5	4
FYNBOS Arid Asteraceous	6	3
RENOSTER Mos Arid Fynbos	6	3
RENOSTER Mos Sandolienveld	3	3
RENOSTER Mos Waboomveld	5	3
FYNBOS Sandolien	5	3
FYNBOS Waboomveld	5	3
RENOSTER Mos Asbosveld	5	3
FYNBOS Grassy Mos Waboomveld	6	2
FYNBOS Arid Proteoid	5	2
FYNBOS Arid Restioid	5	2
FYNBOS Grassy	5	2
FYNBOS Restioid	5	2
S KAROO Scholtzbosveld	5	2
FYNBOS Mesic Proteoid Mos Waboomveld	4	2
FYNBOS Waboomveld Mos Forest	4	2
RENOSTER Mos Grassy Fynbos	4	2
RENOSTER Mos Proteoid Fynbos	4	2
FYNBOS Mesic Proteoid	3	2
DRAIN River	4	1
FYNBOS Ericaceous	2	2
FYNBOS Mesic Asteraceous	2	1
FYNBOS Subalpine	2	1
SOURCE Stream	2	1

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Species Data

CapeNature's in-house "State-of-Biodiversity" excel database was used for this project. There were approximately 70,000 species observation records in the database for the region. These are plant and animal species, and include listed or unlisted species. Several pre-processing steps were required:

The excel database was converted to a point shapefile.

The polygon of each observation was mapped.

- Each observation had a spatial precision documented, or was cross referenced to a reserve or sub-reserve polygon. The point shapefile was converted into a polygon shapefile, such that the boundary of each observation was mapped. Hence, if an observation took place within 100 m of a known coordinate, then it was represented by a circle with a 200 m diameter, centered at the coordinate.

All observations with a precision of less than 2 km were removed.

The status categories were standardized across all species.

- The database has three columns for status: IUCN Status, Red list Status, and the South Africa Rare Database.
- I first overlaid them into one Field, in which Red_list took precedence over SANDNAme, which took precedence over IUCN Name. (This prioritization is based on recentness of the classification list, and number of records; it would be ideal to instead take the most endangered listing of all three columns.)
- I then standardized the 30+ categories into the following seven categories: Critically Endangered or Critically Rare; Endangered or Rare; Vulnerable; Near Threatened; Least Concerned; Status Indeterminate; and Extinct. See Table 2.

Table 2. Standardization of Species Classifications

Status in Database	Standardized Status
CR	Critically Endangered or Rare
Critically Endangered (C2a)	Critically Endangered or Rare
Critically Rare	Critically Endangered or Rare
Data Deficient	Status Indeterminate
DD	Status Indeterminate
Declining	Near Threatened
EN	Endangered or Rare
Endangered (A3c)	Endangered or Rare
EX	Extinct
Extinct	Extinct
Indeterminate	Status Indeterminate
Insufficiently Known	Status Indeterminate
Least Concern	Least Concern
Lower Risk (near threatened)	Near Threatened
Near Threatened	Near Threatened
Near Threatened (A1c+2c)	Near Threatened
Near Threatened (A1c+2c, B1+2bcde, C1)	Near Threatened
Near Threatened (A1c+2cd)	Near Threatened
Near Threatened (A2c)	Near Threatened
Near Threatened (C1)	Near Threatened
Near Threatened (C2a)	Near Threatened
Near Threatened (D1)	Near Threatened
Not Threatened	Least Concern
NT	Least Concern
Rare	Endangered or Rare
VU	Vulnerable
Vulnerable	Vulnerable
Vulnerable (A1a, C1)	Vulnerable
Vulnerable (A1a+2b)	Vulnerable
Vulnerable (A1a+2b, C1)	Vulnerable
Vulnerable (A1ac+2bc, C1)	Vulnerable
Vulnerable (A1acd+2bcd, C1+2b)	Vulnerable
Vulnerable (A1acde+2bc)	Vulnerable
Vulnerable (A1ace)	Vulnerable
Vulnerable (A1c+2bc, C1)	Vulnerable

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Vulnerable (A1c+2c, C1+2a)	Vulnerable	Vulnerable (B1ab+2ab)	Vulnerable
Vulnerable (A1ce)	Vulnerable	Vulnerable (C1+2a)	Vulnerable
Vulnerable (A2c, C1)	Vulnerable	Vulnerable (D1)	Vulnerable
Vulnerable (B1+2abcd, C2a)	Vulnerable		

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I created and populated a new variable called number of observations per species in database

(The key was to use the free tool: "field_Mark_Duplicates_2.cal" from Easytools 5.0 from ET Spatial Techniques. The result was dissolved by taxon, taking the maximum value.)

I calculated a spatial precision value for each observation

This value ranges from 0-1, and is assigned to every hectare (ha) on the landscape. A value of 1 indicates high certainty that the species was seen in the particular ha. A value near 0 indicates low certainty. I calculated the "Precision" field by taking the area of the most exact observation in the database (which was "nearest second"), and dividing this area by the area of the observation in question. Thus, when we convert to a grid, the most precise observations get a value of 1 for the hectare they lie on, and all others will get a lower value for the HAs they lie on.

Sites

The cadastre shapefile was provided by CapeNature, and has the polygons of all cadastres in the region, as well as a cadastre identification number. This was joined with a deeds database that had the name of the landowner for each cadastre. All the contiguous cadastres with the same owner were lumped together as a single property (site).

Conservation Targets

One of the challenging aspects of applying gap analysis is setting the targets. Targets here are the percentages of the total "original" extent of the habitat (not the current extent) that should be conserved (Pressey et al. 2003; Desmet & Cowling 2004; Pierce et al. 2005). This produces larger targets, in terms of extant vegetation, for habitats that have been severely transformed. It also decouples target percentages from further loss of vegetation (Cowling et al. 2003; Pressey et al. 2003).

Setting targets can be done arbitrarily such as the IUCN target of 10%. The targets used here were defined for the Little Karoo study region, for a different project, using a systematic approach (Vlok & Reyers Unpublished). Each target was habitat specific (as per the logic of Pressey et al. 2003), and derived using the slope of the species-area curve (Desmet & Cowling 2004). This benefited habitats with greater species heterogeneity. The percentage of species targeted for conservation needed to be determined. It was set at 75% following the precedent set by two other studies (Pierce et al. 2005), one of which had stakeholder consultation for the issue (Desmet & Cowling 2004). The targets were then re-scaled such that the highest one was 34%, as per the national standard.

Transformation Data

The transformation data was originally based on the work by Thompson et al. (2005; 2008). But after the September workshop, it was suggested to integrate the data created by Don Kirkwood of CapeNature.

The Thompson Data

The vegetation map does not document how degraded the habitat type is at a particular location. Habitat degradation data do exist for South Africa, but they are at the national resolution, and are not especially accurate (Rouget et al. 2006c). Fortunately, a fine-scale habitat degradation map was created based on inter- and intra-annual variation of remote sensing imagery (Thompson et al. 2005; Thompson et al. 2008). It was based on ecological theory: in this region, areas of degraded habitat will have more annual plants that need to go from seed to flowering body in one year. In such areas, there will be a large amplitude intra-annual

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variation in primary productivity. Pristine habitat will have a higher diversity of species, resulting in larger amplitude swings of productivity within the spring compared to the degraded vegetation. Because the amplitude thresholds are different for different habitat types, parameter values were defined for five different general habitat categories. Analysis of the 250 m resolution NDVI data (MODIS) and 30 resolution imagery (Landsat) using this theory resulted in a product that had an 86% accuracy level, which was far superior to the accuracy of the national level data (which was 64%) (Rouget et al. 2006c). The published data layer has a resolution of 100 m. Categories of pristine, moderately degraded, and severely degraded habitat were designated (along with cultivated, underwater, and urban land).

The Kirkwood Data

Meanwhile, Dr. Don Kirkwood of CapeNature was creating the "Integrated Biodiversity Layer" which included a transformation classification for the entire Western Cape. The province had a patchwork of existing transformation data layers, such as the Thompson layer, so the final product was a rule-based amalgamation existing product – sometimes quite complex, sometimes just one good transformation source with minor changes (e.g. updating the National Land Cover Database with Agricultural fields data from the Department of Agriculture). The shapefile: "intgr_lc_sources_&_conf_dd_wgs84.shp" provides details for what transformation layers were used where. The layer is published using 30 m resolution, and the designates which classifications are more certain than others. The methodology is forthcoming from Dr. Kirkwood (don@ecological.co.za).

The Little Karoo data is multiple source and multiple precision. It took the Thompson data as a starting point, and enhanced it with the NLCD and agricultural data. For areas/classes still known to be misclassified, the 2004/5 SPOT5 data was hand digitized (at 1:5000 or better) and manually classified. For the most part, hand digitization occurred for the mapping of quartz patches and riparian vegetation. (Quartz patches are vital succulent hotspots, but often misclassified as degraded by automated remote sensing.)

Integration

The layers were combined using a weighted overlay. The Kirkwood data was split into two layers: the uncertain data and the more certain data. Then, each land cover class was assigned a value between 0 and 1, with 1 being pristine. The Thompson layer was also classified from 0-1 (this classification was done as part of the September workshop). The Thompson Layer was given a weight of 0.667, the Certain Kirkwood layer a weight of 0.25, and the uncertain Kirkwood layer a weight of 0.083. The Thompson layer was given such a high weight because it was the layer that the end-users were most familiar and comfortable with. The 0-1 classifications are provided in Table 1.

Table 3. Numerical classifications for the different transformation layer categories.

Transformation Class	Layer	Partnership	Biodiversity	LHSKT	CN
No Natural Habitat	Kirkwood Transformation	0	0	0	0
Natural-Habitats	Kirkwood Transformation	1	1	1	1
Near Natural	Kirkwood Transformation	0.7	0.7	0.7	0.7
Degraded (severe)	Kirkwood Transformation	0	0	0	0
Possible Natural	Kirkwood Trnsfrmtn (Uncertain)	1	1	1	1
No Natural Habitat	Kirkwood Trnsfrmtn (Uncertain)	0	0	0	0
Degraded	Kirkwood Trnsfrmtn (Uncertain)	0	0	0	0
cultivated - severe	Thompson Transformation	0	0	0	0
moderate	Thompson Transformation	0.51875	0.65625	0.51875	0.65625
pristine	Thompson Transformation	1	1	1	1
severe	Thompson Transformation	0	0	0	0
urban - severe	Thompson Transformation	0	0	0	0

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water - severe	Thompson Transformation	0	0	0	0
unknown - boundary	Thompson Transformation	0.5	0.5	0.5	0.5

The above values were plugged into the SDSS and used in the habitat representation analysis. They became the default values for the species representation analysis, so they do not have to be entered twice. However, the end-user has the ability to override these defaults and enter in appropriate values. For instance, it could be argued that if a critically endangered species is known to use a particular location, this location should be conserved even if it is severely degraded. Due to the abbreviated September Workshop, only the default values were used for the species representation analysis.

"Protected" Areas

The statutory conservation areas shapefile was provided by Steve Holness of South African National Parks (SANParks). It was the 2007 beta version. It mapped the Type 1 reserves (statutory conservation areas that are owned and managed by the municipal and provincial government agencies). It also mapped Type 2 reserves, namely mountain catchment areas. These areas are on steep hillsides that are privately owned and have a variety or regulatory restrictions in order to protect water quality.

The private conservation areas database was originally provided by Lorena Pasquini (Pasquini 2007). It was updated by our team to account for changes in ownership and status (Gallo et al. 2009). We used the updated shapefile for this LHSKT/CN analysis.

The two databases were joined. There were some minor problems that arose because the two data sources were based on different assessor cadastre layers and projections, but these were resolved with adequate certainty. The details of this resolution are available upon request.

Cost Data

Philip Osano, Mathieu Rouget and others modeled the cost for purchase for all properties in the western Cape (Osano et al. unpublished). The data and paper are available from M. Rouget, and an update is underway. They used a stepwise Generalized Linear Model to look at 20 indicators of cost. A majority of the variation was explained by four indicators: mean annual precipitation, percentage of untransformed land, property area, and topographic diversity. They achieved an r^2 of 0.67. The modeled cost was calibrated for the year 2000.

I removed all the properties from the modeled database that had no natural habitat at all. I also removed the reserves. For the study area, the conventional wisdom is that rural property sells for about 2,000 Rand/HA (~$250/HA; there are about 7.5 Rand to the dollar). The median value of the remaining properties was 1,382 R/HA. However, there were some extreme outliers, giving the dataset a standard deviation of 3,293. The range was from 80 to 63,909. This was not very usable, and would overwhelm all the ecological modeling if combined as was planned. So, there were two problems. One is that the data were standardized to the year 2000 and not 2008, and secondly, there was a huge deviation in the modeled output.

Careful examination of several of the outliers showed that they were due to data overlay errors on small properties. I decided to do a root transformation so that the modeled properties kept their ranking, but the large outliers were contained. I tried several transformations, and compared them with the known property prices, and settled on the cube root transformation. But I also wanted the median of the transformed shapefile to be the same as the untransformed shapefile. Hence, I used the following:

$$\text{Cube Transformed Modeled Cost} = \sqrt[3]{\text{Modeled Cost of a Property}} * \left(\sqrt[3]{\text{Median Modeled Cost}}\right)^2$$

This resulted in a distribution that more accurately reflected the real-world data and conventional understanding of property prices. Figure 1 shows the histogram and some basic statistics, including the much more acceptable standard deviation of 725.

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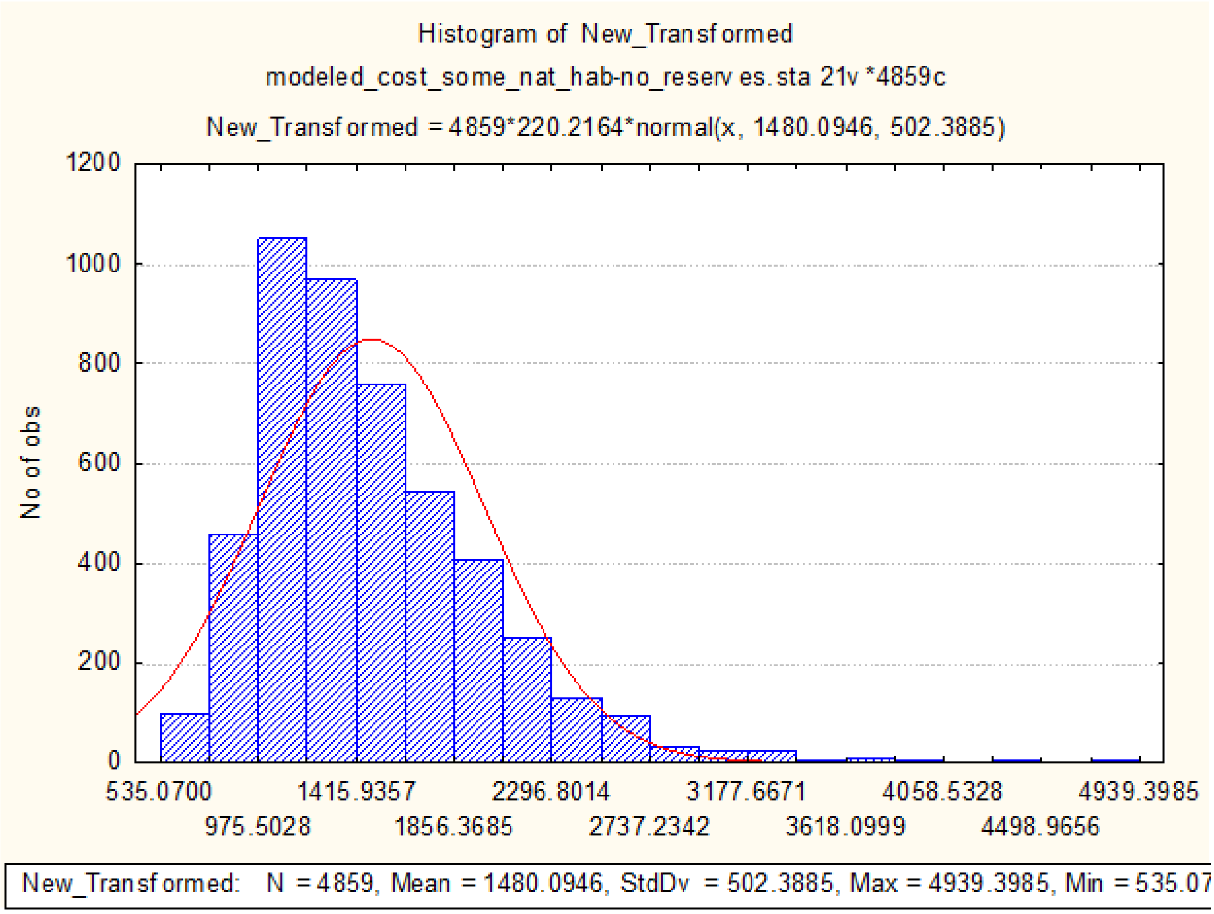
Figure 1. Histogram of the transformed cost model, before inflation is considered.



Management Cost

A new variable called adjacency was added to the sites shapefile. A GIS processing model was programmed in Modelbuilder for giving all sites that were directly adjacent to a statutory conservation area (also known as a Type 1 reserve) a value of 'adjacent' in the database.

Cost of Stewardship for each property

As mentioned, the SDSS is supposed to help with other decisions, not just the LHSKT/CN decision. We programmed in the ability to look at stewardship option (i.e. the current landowner maintaining ownership, but signing a contract that the land cannot be developed, for perpetuity.)

Based on meeting with Anita Wheeler in early winter, 2008. (Note: the stewardship department was working on a similar analysis province wide, which should be available for use for future studies.)

Start-up Costs

Initial extension work:

Per visit:

- Transport- R2.61 per KM = R 200
- Time- 2-3 hrs a visit, 1-4 hrs travel time = 5 hrs a visit X R 75 = R 375

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- = R575 per visit

Average number of visits needed to result in a ***signed*** *Contract Nature Reserve:*

- Needs to consider the unsuccessful "courtship" efforts

Successful courtship:

- For willing landowner: 4-6
- For hesitant but eventually wiling landowner: 10

Unsuccessful courtship:

- For unwilling landowner: 3
- For hesitatnt but eventually unwilling landowner: 10

Number of each type of landowner:

- Lets say that it is even. Therefore, it is an average of 14 visits.

Total initial extension work =

- R8050 per site

Legal Support

Provided by Capenature to landowner

- Consultation with lawyer R 200
- Rezoning and the new material deed: R 1000
- Public notification, newspaper, etc: R 2000
- Miscellaneous: R1000

Total

- R 4200 per site

Overhead

- Outreach materials, data management, etc
- R 12000 per staff perso per year divided by about 5 contracts a year = R2400

Total Start-up Costs= R 14,650

Maintenance

CN Staff

Management plan specific

- Advisory, Mapping, Compiling plant lists, etc..
- About 5 visits per 10 years
- R 287.5 per year

Auditing

- Annually by self, with every third year externally by CN Staff= 1-2 days of work
    - (Salary of ~R 600 per day)
- R 300 per year

Contracted to Public Works

- Working for water, DWAF, etc.
    - E.g. removing aliens, CN commits to 1st clearing, and 2nd and 3rd followup.
- CN channels the money to them.
- R 30,000 – R 60,000 for the first 5 years, less so after that.
    - This is influenced by the number of HA per site (there is some economy of scale, due to decreased relative transport costs)
- R 6 000 -12 000 per year for first 5 years, maybe R 15,000 or so for next 15 years
-
- Estimated Costs: $R\ 20\ 000 * \sqrt{number\ of\ years} + R\ 100 * HA * number\ of\ years$

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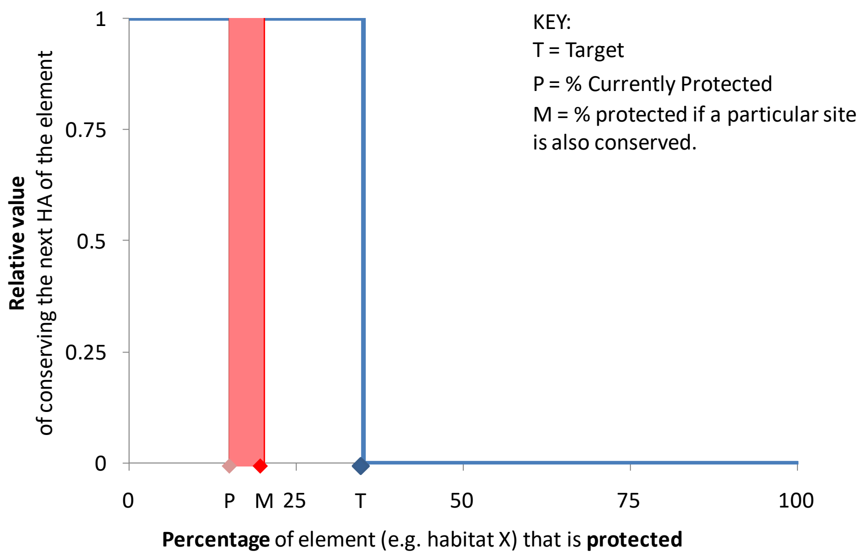
HABITATS REPRESENTATION USING FUNCTIONS OF DIMINISHING RETURNS

As mentioned in the main body, the SDSS uses functions of diminishing returns (Davis et al. 2006; Moilanen 2007; Wilson et al. 2007; Carwardine et al. 2009) for it habitat representation analysis.

To summarize, the traditional target based approach typically gives the same marginal benefit of conserving a habitat if it has none of its extent covered versus if it has nearly reached its target. Then, after the target has been met, there is no benefit to conserving more of that habitat. The diminishing returns curve is represented by the blue line in Figure 2. The total benefit gained from protecting site M can be conceptualized by the area in pink.

Figure 2. The traditional target based approach.



The diminishing returns function is continuous, rather than stepwise (Figure 3); as more of the habitat is conserved, less benefit is accrued for conserving a unit of area.

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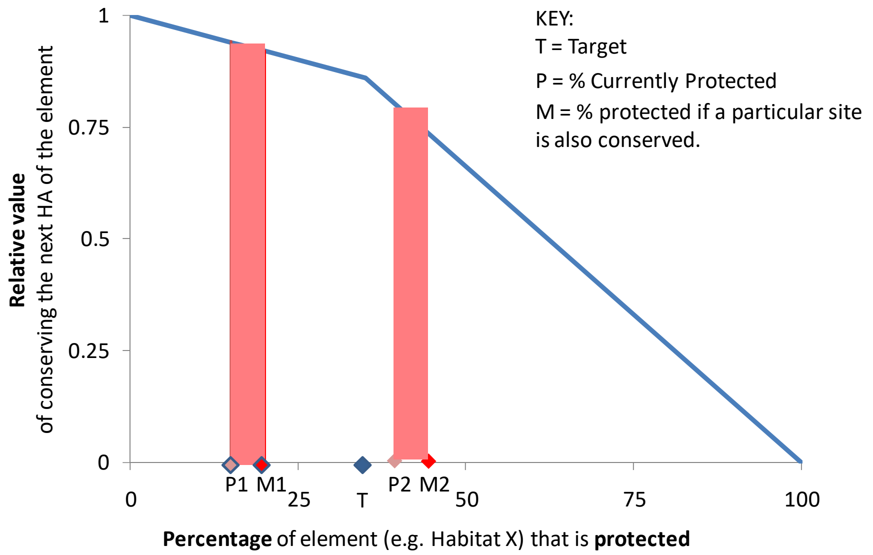
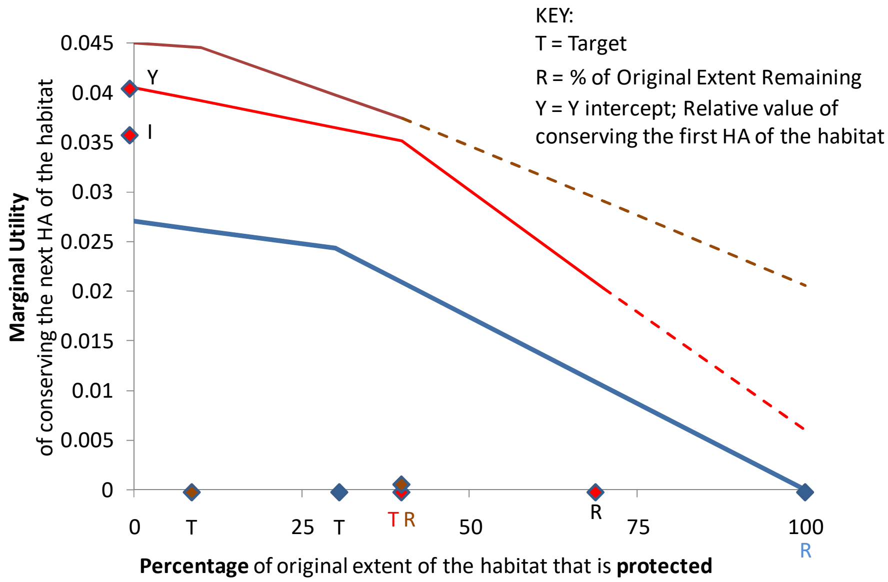
Figure 3. Diminishing returns function of Habitat X and marginal benefit of conserving site M at times 1 and 2.



The shape of the diminishing returns curve is computed automatically for each habitat based on several variables (Figure 4). There are many ways of determining the conservation target (T), including the method described earlier. The Y intercept is a function of how much of the habitats original (pre-transformation) extent is still remaining. The relative difference on the Y axis between the habitat type with the most habitat destroyed and the one with the least is currently a user-defined parameter. (In this case, these two habitats are representee by the brown and blue lines, and the ratio is set at 0.6). (Eventually, the Y-intercept, Y, can be automatically derived based on a variety of factors, including relative endemism and species richness.) The height of the inflection point on the curve (I) is a function of T and also of the amount of original extent remaining. The steepness of the curve on the right side of the inflection point is again a function of the amount of original Regions that have data regarding threat of future degradation can use these data in helping define Y and I.

Figure 4. Three example diminishing return curves, each associated with a different habitat type. Habitat targets (T) are 10%, 30%, and 40%, and the percentages of original extent of each habitat that are remaining (R) are 40%, 100%, and 70%, respectively. Moving into the dashed lines would require habitat restoration.



The concept of "condition weighted area" allows management type and degree of degradation to be included in calculating the relative amount of a habitat that is protected, and in calculating the benefit (for that habitat) of protecting any new site (Figure 5). Imagine the original extent of the habitat was 100,000 HA. 16,000 HA are currently conserved in Statutory Conservation Areas (SCAs) (dark grey). Imagine the end-users have parameterized private conservation areas as being 50% as good as SCAs in preserving the integrity of this habitat. 18,000 HA are conserved in Private Conservation Areas (PCAs) (light grey with solid boundary), so their condition weighted area (CWA) is only 9,000 HA. Hence, the CWA of the habitat that is protected (X) is 25,000 HA. A site is available for conservation through purchase and is 5,000 HA. The marginal value of conserving this property is the area of the light grey polygon with the dashed line.

The above example assumes that every hectare of habitat already conserved and under consideration is in pristine condition. If any of the land in these conservation areas is not in pristine condition, the CWA would be decreased according to the user-defined degradation parameters. For instance, if the weight for moderately degraded habitat were 0.75, and the site under consideration was all moderately degraded habitat, then x would only be 3,750 instead of 5,000, so the size of the dashed polygon would be considerably smaller, and hence, the marginal benefit of conserving the property would be smaller.

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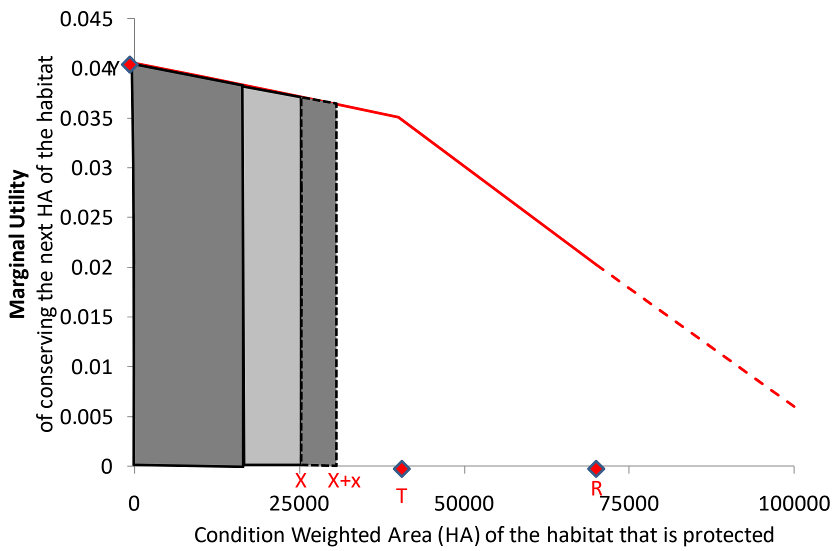
Figure 5. The valuation of a hypothetical protection scenario for one of the above habitats.



The habitat representation analysis was done three times. Once using biomes (n=6), once using habitats (n=19), and once using vegetation units (n=365). The results were then combined using a weighted sum. This method is useful in several ways. There is uncertainty involved in defining and mapping vegetation units, and this can lead to very misleading priorities. Secondly, habitat representation resolution correlates with different evolutionary time-scales, which are all important to consider.

An additional enhancement that is in progress is giving the end-user the option of increasing the significance of target achievement. In this enhancement, the marginal value curve drops vertically at T for a user defined distance before resuming its decline to the right. The mathematical equations and more detail about all of the above are in a manuscript/article that is in progress. If you are interested in these, and/or in possibly collaborating in co-authorship, please contact John Gallo.

Species Representation using Functions of Diminishing Returns

Conservation targets did not exist for species in the study region. The model was programmed to allow the end-user to parameterize the relative value of conserving each class of listed species (i.e. endangered versus threatened species). Further, the end user could define the rate of diminishing returns for the most endangered classification, and all the other rates were determined as illustrated in Figure 6. The end-users opted for an abridged agenda for the September workshop, so these parameters were not discussed. The default values are illustrated in Figure 6, and were used in the SDSS. There were about 66,000 records in the database, of which about 10,000 were used in this analysis.

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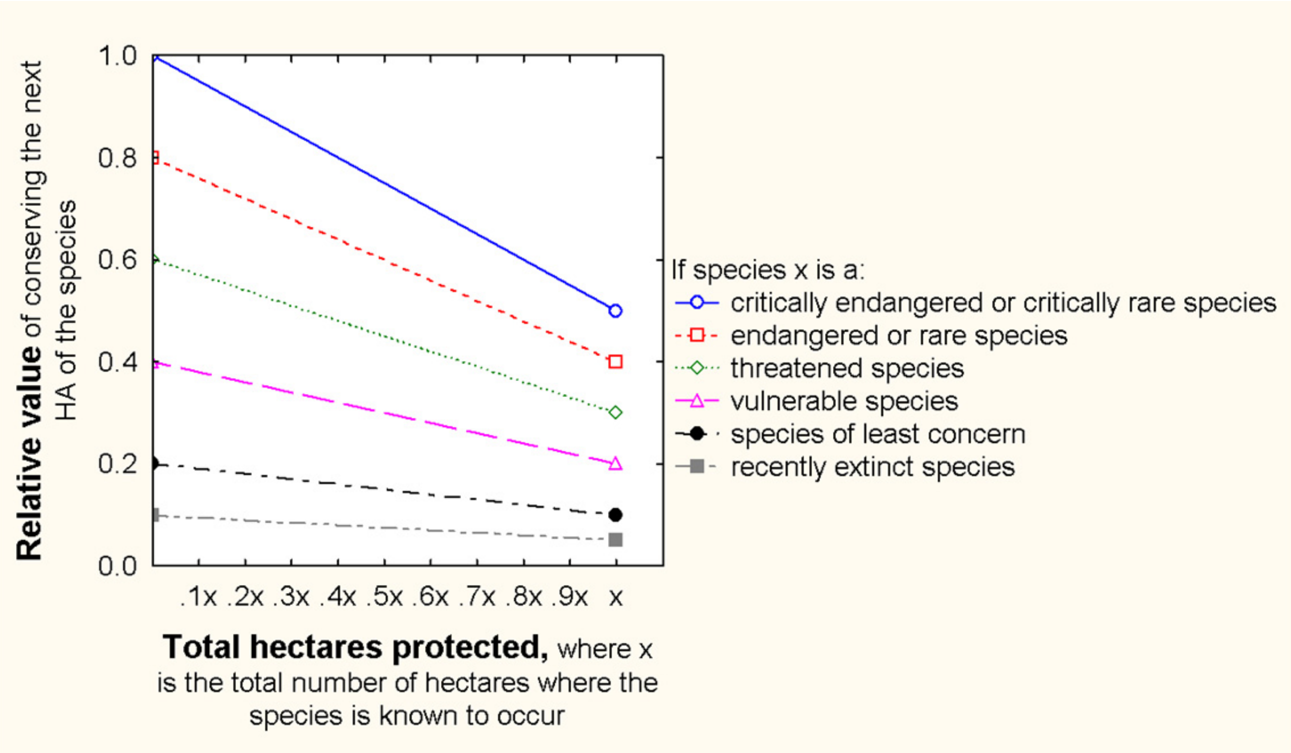
Figure 6. Diminishing returns curves for the various listed species. The SDSS default parameter values are displayed.



Succulent Species Representation Analysis

Because of the objective of conserving succulent species, a separate analysis was performed on succulent species only. Unfortunately, there were only about 600 records in the database, and many of these were for species that did not have a listed status. However, the LHSKT mandate is to conserve succulent richness, not just rareness or endemism. Thus, all of these records were used. This analysis was combined with the all species analysis in a weighted sum. The succulent records were included in the all species analysis as well. So in essence, this weighted sum gives higher weight to the areas where succulent species are known to occur. The next iteration of the project should improve this section of the methodology by first bolstering the species database bases on local expert knowledge (field work would be useful, but not required), and then developing a robust way of dealing fairly with more common succulents.

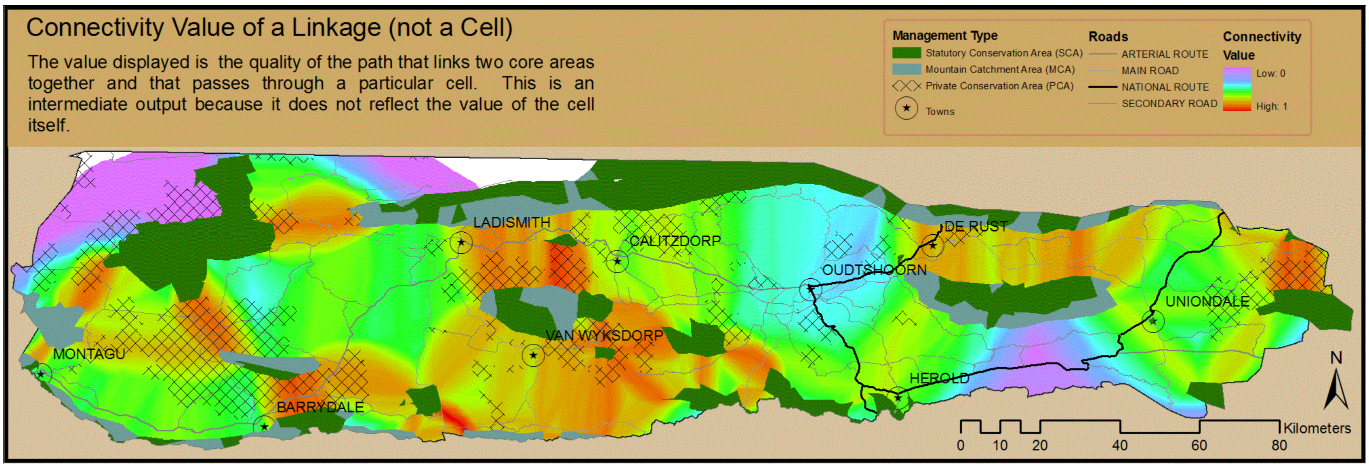
Connectivity Analysis

The habitat connectivity value of every ha on the landscape was estimated using the gated least-cost path methodology (Lombard & Church 1993; Singleton et al. 2001; Gallo 2007). This value indicates how important the particular ha is in maintaining the connectivity among wild core nature reserves. The least cost path (LCP) analysis is the foundation of the methodology (i.e. Ferreras 2001; Rouget et al. 2006b). Such an analysis identifies the narrow path between any two core reserves that has the least "cost" or resistance for biodiversity movement. For instance, moving across pristine habitat has low cost, and moving across a road or other paved surface has a very high cost. (Experts and/or the GIS Analyst must classify the cost of each land cover type in the database.) The cost of a path between two reserves is the sum of the cost of each cell in that path. The LCP algorthim finds the path that has the lowest cumulative cost. The gated least cost path analysis (GLCP) looks at every cell on the landscape, and asks, what would the cumulative cost be of the LCP that was required to go through that cell (or gate)? The answer to that question becomes the GLCP value of that cell. The query is asked of every cell in the landscape. (We used 1 ha cells.) In this way the entire landscape gets a connectivity value for the particular pair of reserves, so the width of corridors, and secondary corridors can be identified. The algorithm repeats the above for every other pair of reserves on the landscapes, and then overlays all of the results. For every cell, it selects the reserve-pair GLCP result with the highest value. As more reserves are considered, the method becomes exponentially more cumbersome. In previous years I did this manually, but for this SDSS I programmed a model to do the above analysis automatically. Some of the procedures were not possible in the Modelbuilder environment, so Python was necessary. John Sterritt of ESRI assisted greatly in this endeavor.

For the Little Karoo analysis, the core wild lands to connect were defined as all the SCAs in the region over a certain size threshold. I programmed this threshold to be a user defined parameter in the model. In this case, I used 500 ha to allow for consideration of smaller species. The cost surface can be defined for a particular focal species, (or set of species). Or it can be based on the conservation value as determined by the rest of the model (Rouget et al. 2006a), which is what I did here. (i.e. locations that scored well in the habitats representation and/or species representation analyses received a low cost) Additionally, I added a roads layer, and gave higher traffic roads a higher cost than lower traffic roads. The cost surface also needs an artificial moat of high cost placed at the edge or reserves to keep the algorithm from giving high values to lands near the backside of reserves {Gallo, 2007 #227}.

Finally, a subjective decision needs to be made when overlaying the results from different pairs of core reserves, as I did here. I programmed a user-defined parameter to allow for this decision. Namely, should the final connectivity value simply be the GLCP value, or should it be that value divided by the Euclidian distance. Or should it be a blend between the two? The first technique will have the site selection model favor corridors that are short, and the second will favor long ones. This decision was programmed in as a user-defined parameter. The parameter allows the user to select one or the other, as well as a weighted balance between the two. The default parameter, which is what was used in this study, is a balance between the two. The composite connectivity score is mapped in Figure 7. In retrospect, I think I should have multiplied the cost surface by the transformation composite, and given the roads a higher impact. (The crux of this methodology is the cost surface.)

Figure 7. Connectivity value of each path of cells between a pair of core reserves



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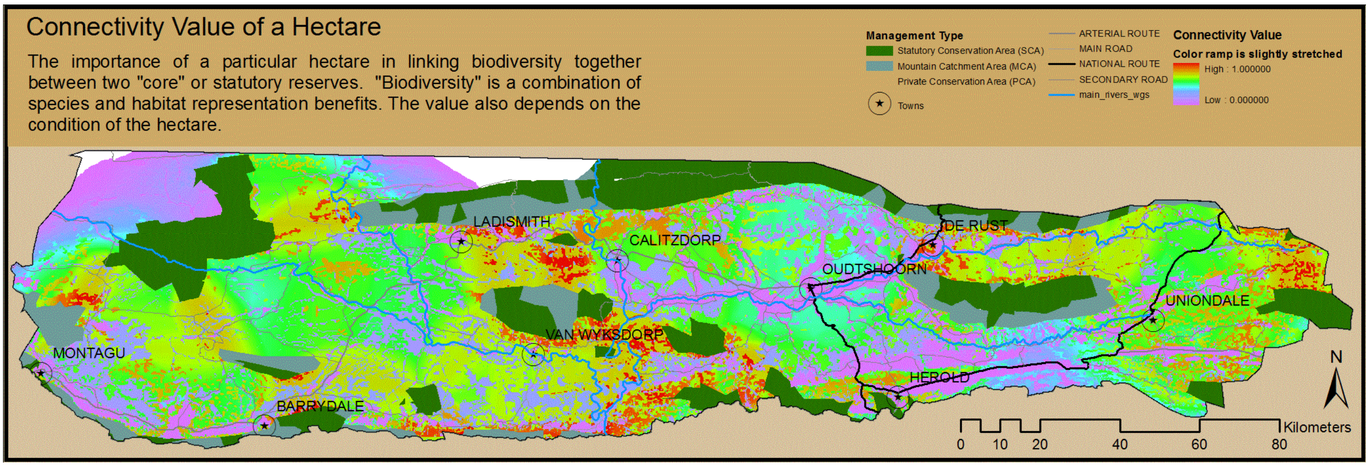
Then, I accounted for the "stepping stone" function of many corridors. In other words, species often move from one viable habitat to the next, passing quickly through the inhospitable habitat in between. Put another way, what are the most important pieces of a wildlife corridor for conservation right now? This is a complex challenge and only partially addressed here. It was accounted for by combining the connectivity score with the transformation value, with the output illustrated in

Figure 8. The mathematical equations and more detail about all of the above are in work that is in progress. If you are interested in these, and/or in possibly collaborating in co-authorship, please contact me.

Figure 8. Estimated connectivity value of each cell



Modeling Purchase and Management Costs

Purchase Costs: accounting for inflation since year 2000

In order to examine the accuracy of the model and to help transform the prices to 2009 levels, I gathered data regarding recent current listing prices of properties at various stages of selling. CapeNature staff provided such data for 42 cadastres. Each one of these was then transformed using the transformation equation, and compared to the cube transformed modeled price of the same cadastre.

$$\text{Cube Transformed Listed Cost} = \sqrt[3]{\text{Listed Cost of a Property}} * \left(\sqrt[3]{\text{Median Modeled Cost}}\right)^2$$

The mean ratio among all of these cadastres and their modeled price was 2.32, or a 232% cumulative inflation rate from 2000 through 2008. (If N (the number of known listing prices) were higher, then the median used could come from this sample rather than the model.) This analysis was compared to known inflation rates to see if it was realistic. Property values in the Little Karoo have increased faster than the general inflation rate of the country. Some of the workshop participants say this rate of increase has been about double the rate of inflation. Using the CIA World Factbook inflation rates of the South African Consumer Price Inflation Rate, a double inflation rate from 2000 to 2008 would be a cumulative value of 225%, very close to the 232% estimated via the small sample of known properties (

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Table 4). I decided to make the inflation rate a parameter adjustable by the end-user, with a default value of 232%. The resulting histogram is displayed in Figure 9. These calculations were presented at the September Workshop and 232% was agreed upon for this iteration of the model.

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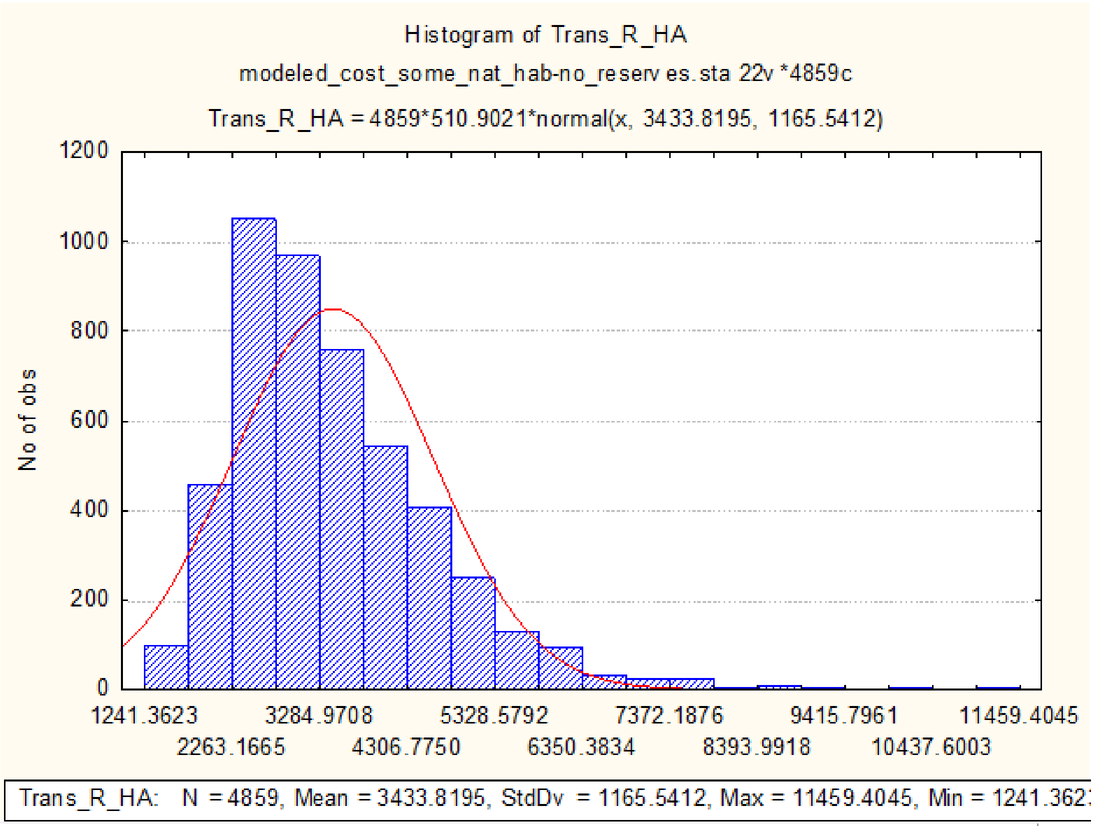
Table 4. Calculation of the land price inflation in the Little Karoo from 2000-2008

Year	SA Consumer Price Inflation Rate	Hypothetical R1000	2 X Consumer Inflation Rate	Hypothetical R1000	
2000	7	1070	14	1140	Comparing modeled Data with the asking (list) price of 42 cadastres.
2001	6.6	1141	13.2	1290	
2002	9.2	1246	18.4	1528	
2003	9.9	1369	19.8	1830	
2004	5.9	1450	11.8	2046	
2005	4.5	1515	9	2231	
2006	4	1575	8	2409	
2007	5	1654	10	2650	
2008	11.4	1842	22.8	3254	
Total For 8 yrs:	84%		225%		232%

Figure 9. Histogram of the transformed cost model, with inflation from 2000-2008 estimated at 232%.



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The median value of this final output is 3197 R/HA (~$400 /HA) which is a bit higher than conventional wisdom would dictate. One reason for this is that the model considers all properties that have some natural habitat (a value of .01 according to the new transformed layer). These properties include many sub-urban and agricultural lands, which have a higher price than the rural lands typically under consideration for conservation, so in this respect the median price seems reasonable. A second reason for the high median price is that the inflation rate was based on the listing price of the properties, not the actual sale price, which can often be less. Hence, end-users should know that the uncertainty of the modeled price may be skewed to the downside. Fortunately, the relative price of all the properties is the same, regardless of the inflation factor used. This relationship is usually more important than absolute value in prioritizing properties for conservation.

Calculation of Management Costs

Management of a property by CapeNature is much less expensive if the property adjoins a current reserve. The cost is primarily a function of the property size. If a property is isolated, cost increase substantially. Some cost amounts occur (such as transportation of maintenance crews to and from the site) regardless if the site is 100 HA or 1000 HA. After discussions with managers and revisions at the workshop, the modeled management cost of sites adjacent to reserves is 30 R/HA per year (one Rand is usually worth between $0.10 and $0.14). Isolated sites are estimated to cost 60 R/HA plus 60,000 R a year flat cost regardless of property size. Management cost was then multiplied by 30 years to get the total management cost. These three values are user-defined parameters in the model.

This is the only place that contiguity with reserves is incorporated into the SDSS. Future iterations might want to have this in the biodiversity benefit set of criteria as well.

Combination of Criteria

Multiple criteria were combined using a weighted sum. To do this, each criteria is normalized to have values that lie between 0 and 1. The minimum and maximum value of a criteria are determined, and every value is normalized according to the following equation: (x-min)/(max-min). This way there will be a 0, a 1 and values in between.

There are drawbacks to every normalization technique. In this case, a concern lies in criteria that do not have much variation across the landscape. For instance, imagine all places are of medium importance , plus or minus a little. Thus, it is not that important to preserve one place over another compared to other criteria variances. After this normalization, however, this will no longer be the case. The places that are slightly more important will become highly more important. Thus, it is important for the end-users to look at this distribution when choosing the weights between criteria. This needed to be done manually for this iteration of the model, but future iterations should provide this information automatically.

The multi-criteria framework is hierarchical, so the output layer of a multicriteria analysis was often used in another analysis. However, before it was used, it was normalized.

Combining succulent richness/endemism with habitat representation

Parameter 6 in the parameters table of the primary publication combines the succulent richness/endemism weighted sum with the combined habitats representation (biomes, habitats, and vegetation units) according to the following equation:

$$P_6 * succulent\_habitat\_score * combined\_habitats\_representation + combined\_habitats\_representation * (1 - P_6)$$

In the future, it is advised to use the weighted sum:

$$P_6 * succulent\_habitat\_score + combined\_habitats\_representation * (1 - P_6)$$

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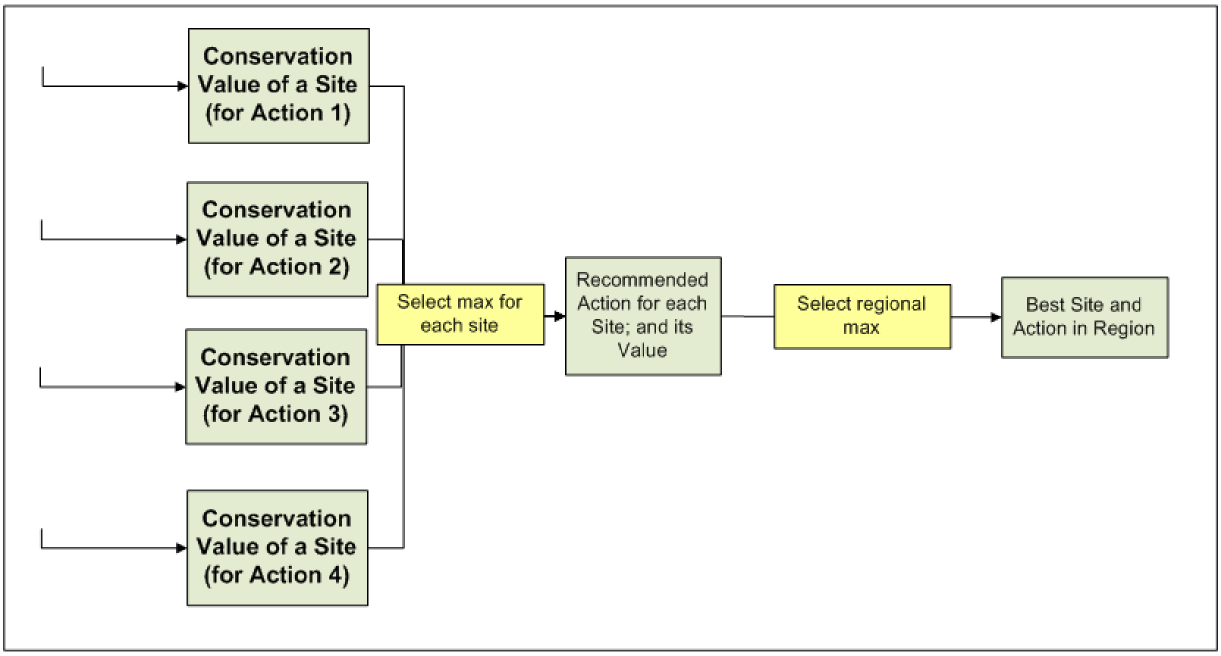
EXTERNAL ANALYSIS: PRIORITIES FOR STEWARDSHIP ACTIONS

CN requested that the SDSS provide support for prioritizing where to do stewardship actions. This information was useful in figuring out where to prioritize for purchase with LHSKT. For instance, if the SDS identified two properties in the long list that had similar rankings, it would be good to know if one of those was much more suitable for stewardship than the other.

The cost surface was substituted by the stewardship cost surface. Further, all the parameters were adjusted for the action of stewardship instead of acquisition {Carwardine, 2008 #917}. For instance, a narrative could exist such that stewardship was worse at protecting endangered species than acquisition would be, but just as good at maintaining habitat connectivity. Hence, the weights of these criteria would be adjusted accordingly.

We ran the analysis with the stewardship cost and parameter schema, and compared the result with the partnership schema analysis according to (Figure 10). We assigned acquisition to be "Action 1" and stewardship "Action 2." We did not consider an Action 3 or 4. At first we were surprised with the result, stewardship was a better "bang for your buck" than acquisition for every property greater than 100 ha, and nearly every property in the region. This was partially due to the large uncertainty associated with costs, but could also be a corroboration of what many people have been saying about stewardship being the most viable conservation strategy for the moment…

Figure 10. Schematic of how to combine models of diffrent implementation actions



THE "MAXIMIZE SHORT TERM GAINS" HEURISTIC

The "maximize short term gain heuristic" (Figure 11) (also known as a greedy heuristic) that was referred to in the paper can operate based on a single schema, or multiple action/parameter schemas as per Figure 10. The challenge of this approach to estimating efficiency is that it takes much computer processing power. In future iterations of the model, the end-user should get options for decreasing processing time (while also decreasing optimality). An example of this would be to allow the model to select the top N sites (N is user defined) before re-iterating. Ideally, the user could also define which sub-modules re-iterate. For

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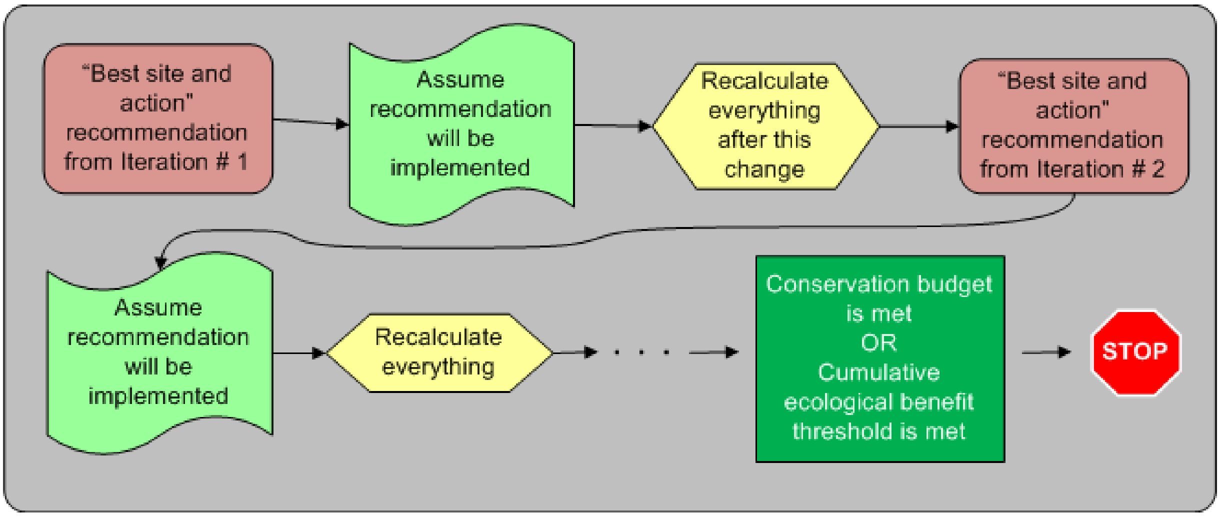
instance, the habitat representation module was twenty times faster than the species representation analysis, and 100 times faster than the connectivity analysis. It might be the best time/optimality compromise to have the habitats representation analysis reiterate every time, but the species only after 10 sites, and the connectivity after 20 sites.

Figure 11. Schematic of how the "Maximize short term gains" heuristic operates



PARTICIPATORY PROCESS

There are many different issues to take into consideration when defining a process for choosing weights and parameters. The SDSS is designed with the principle of engagement, so there needs to be a process for allowing the end-users to have some say in the weights of the model. This not only allows the end-product to better suit the goals and objectives of their organization, it also provides a mechanism for them to learn and understand the model. Some of the outstanding questions include:

How can the pitfalls of an ad hoc process for choosing weights alluded to in Regan et al. (2006) be avoided? (Such as strong personalities skewing the results).

How can expert knowledge be combined effectively with the local knowledge of end-users?

What if some end-users do not understand some of the more technical scientific parameters/weights, will they make the 'wrong' answer and ruin the results?

If some end-users feel humble about their opinion compared to other experts, can they give it a lower weight?

If some participants get a higher 'weight of respect' score than others, then how is this done in a fair manner and one that does not humiliate anyone?

How are the weights from different organizations combined so that user-useful products ensue?

If the different organizations have different strategic missions, how do unaffiliated experts like Jan Vlok participate?

How do we mitigate for "intuitive lawyers" that will try to game the system and exaggerate their weights to steer it towards their desires? (Regan et al 2006).

Stakeholder Groups

Participants for Workshop 1:

CapeNature:

AnneLise Vlok, Alan Wheeler, Tom Barry, Anita Wheeler

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Leslie Hill Succulent Karoo Trust:
Therese Brincate, and Matthew Norval
Unaffiliated experts:
Jan Vlok, Richard Cowling, and Mandy Lombard
Facilitator:
John Gallo

Participants for Workshop 2:
CapeNature:
AnneLise Vlok, Alan Wheeler, Ivan Donian, Tom Barry, Anita Wheeler, Tony Marshall
Leslie Hill Succulent Karoo Trust:
Timm Hoffman, Therese Brincate, and Matthew Norval
Unaffiliated experts:
Jan Vlok, Richard Cowling, and Mandy Lombard
Facilitators:
John Gallo, and Wendy Gallo

The structured discussion used in designing the weighting process

The start of the second workshop included a structured discussion for designing the participatory process for the rest of the workshop. Basically, there were a series of choices to be made, as follows. These choices are documented here as food for thought for any other practitioner in a similar situation. The results of these decisions for the Little Karoo effort are provided in the methodology section of the linked publication.

(1) The major decision was if each organization would identify a set of weights that best met their goals and constraints, or for the two organizations to derive a single set of weights that seemed to best meet both organizations' goals simultaneously. Under the first option, two different priority maps would be produced. These would then be used to make a single priority map, perhaps through combination of the average of the organization specific values for a site, the variance between the values, and structured negotiation. Ideally, both sets of weights are created.

  a. If the first option was chosen, then would the discussion that preceded giving each criterion a weight be among the entire partnership or privately among each group?

(2) After discussion of a criterion, either (A) each individual would write down their preferred value of the weight on their scoresheet, or (B) the "group" (as defined above) would come to a consensus on the weight through discussion.

  a. If (2A) was chosen, would participants want the option of using "opinion weights"? These give positive or negative weight to the vote of each person according to the following structure. Each user could give a down-weight to all of their answers, or just the ones that they felt less sure about. They could also give an up-weight to others. Individuals could not give themselves higher weight or others lower weight. Other efforts may want also offer the options of using analytical hierarchy process (Marinoni 2004), a "consensus convergance model" (Regan et al. 2005), or some other approach for determining weights (Steele et al. 2007). Due to the pre-screening of the partnership that occurred in the first workshop and subsequent discussions, we removed these options from the agenda in order to decrease the time needed to determine a process, and a final set of weights. We included the opinion weighting option in pursuit of trust and fairness, key variables for consensus and the acceptance of any unfavorable outcomes (Smith & McDonough 2001).

b. Should each participant's vote have a weight based on the number of participants present from each organization? In other words, should the averaging occur for individuals or for organizations? (For example, if there are 10 people present representing organization A, and 2 people present representing organization B; should the votes of these 2 participants have 5 times as much weight?) I suggested that the standard approach would be to have each organization have the same weight. In retrospect, this option should not be provided, and if they ask for it, then consider it.

(3) External science advisors are not necessarily aware of the goals and constraints of each organization in a partnership. It was assumed that the scientists would participate in the discussions about each weight, but how would their personal opinion be tallied into the final weights? If the average between organizations was being used, would each scientist provide a weight value for each organization? Would they provide a weight representing their own agenda? How would these be incorporated? Would a scientific expert reference map be created?Would the partnership be allowed to adjust weights after they viewed the intermediate and final spatial outputs presented at the workshop? If so, how would that process be structured? Similarly, can weights be adjusted after the workshop if significant errors are discovered?

The Estimated Parameter Schemas

The representatives that were asked about the estimated weights were Anne Lise Vlok for CN, and Timm Hoffman for LHSKT.

ADDITIONAL DISCUSSION

Future Research: Getting an Indication of Variance

Many ecologists would agree that conserving the best habitat in a region, (however "best" is defined) is of very high import. The practice of averaging the conservation value of all the hectares of a site and using this answer to make decisions has a potential drawback. This is a good indicator of the value of the site, however, it misses a nuance: if a site has some fantastic habitat but also some really poor habitat, it might have the same mean score as a site with an even coverage of good habitat. This was pointed out by the end-users, and we provided an additional output that was beyond the scope of the publication: the standard deviation (an indication of the variance among the hectares of a site) was found for each site, and added to the mean. This was used as an "experimental" reference, and deserves further examination. Also, other more suitable measures of variance may be preferred.

Discussion of the Spatial Output Combination Approach

By programming all the geo-processing of the SDSS, an additional process for the workshop setting is now more feasible, and deserves further thought. The approach is to provide spatial outputs for the organization-specific schema in addition to the output from the consensus-based schema. They could also be used as references for a structured negotiation in the workshop setting in which the organizations could add

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and remove properties to the partnership schema long-list. The outputs could also be combined into a single map that shows, for each site, the average value from the organization specific outputs, the variance, and the organization most interested. (Variance could be represented using saturation). Such an approach should be treated with caution, however, because it has a subtle reversion from a team-based mentality back to self interest. Adequate time for negotiation is advised, because this process explicitly shows which organizations are conceding more than others in accepting the partnership schema weights. For instance, our correlation analyses indicate that the partnership output more strongly favors CN goals than LHSKT goals.

In light of the differences between the consensus weighting approaches used in the study, and the spatial average approach alluded here, the most robust approach may be to combine both, (and maybe even the variance output as well) in one final weighted combination. Each participant would make a weighting schema for their organization, and one for the partnership. There would then be a map for each approach, for each organization, and for a combination of all approaches. But it is also important to keep in mind the principle of balancing scientific rigor with social process. Simply creating the consensus weights is a huge improvement over no SDSS at all. If doing too many variations overwhelms the participants, or slows down the process too much, then any marginal improvement will be paled by the associated lack of implementation.

Discussion about Process

An additional improvement to the process, depending on group dynamics, might be to have the whole process setting agenda start with a discussion and anonymous vote on how the process decisions would be made, such as via group consensus or via anonymous vote.

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