Democratizing Spatial Planning for Nature and People

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NATURE CONSERVANCY CANADA

LIBERO ERO FELLOWSHIP PROGRAM

Carleton UNIVERSITY

UBC THE UNIVERSITY OF BRITISH COLUMBIA

THE UNIVERSITY OF QUEENSLAND AUSTRALIA

The Why?

- Conservation planning = challenging
- Range of objectives and constraints
- Analytical tools tailored to specific tasks

Proposal:

Flexible, powerful framework

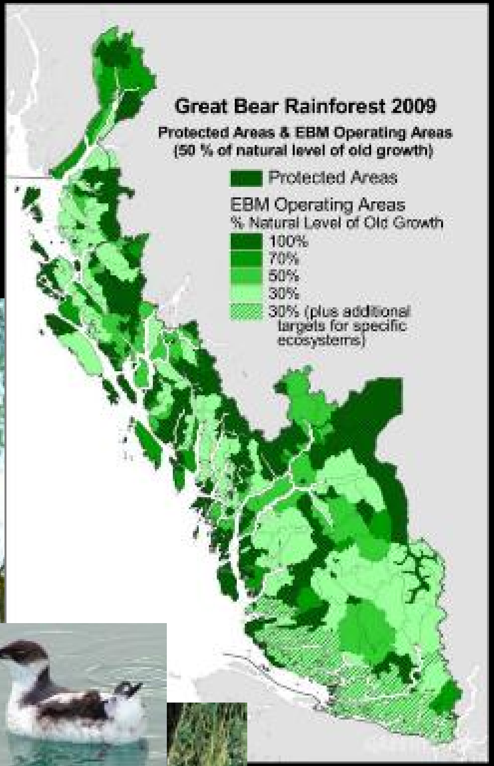
+

User friendly (browser) interface

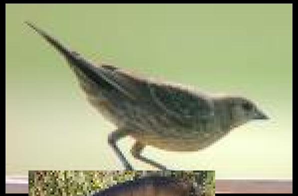
Traditional Goal of Conservation Area Design

Prioritize and Conserve ‘Intact’ or ‘Relic Ecosystems’

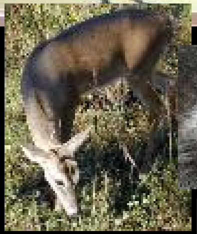
- Multiple criteria
- Decision support tools

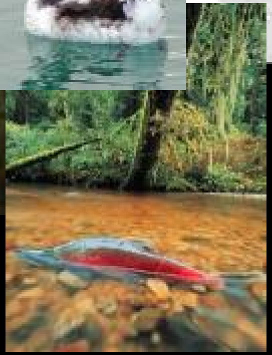


Impractical in Human-dominated Landscapes



- No Benchmark Ecosystems
- Biological Survey Data Often Biased
- Many Threats Hard to Map





Dry Forest / Savanna Habitats of the Georgia Basin

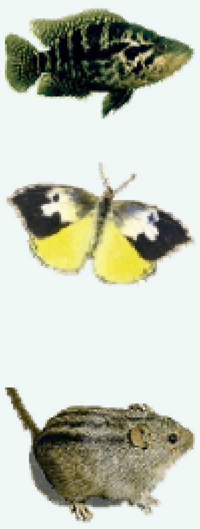
49% Converted to Human Use

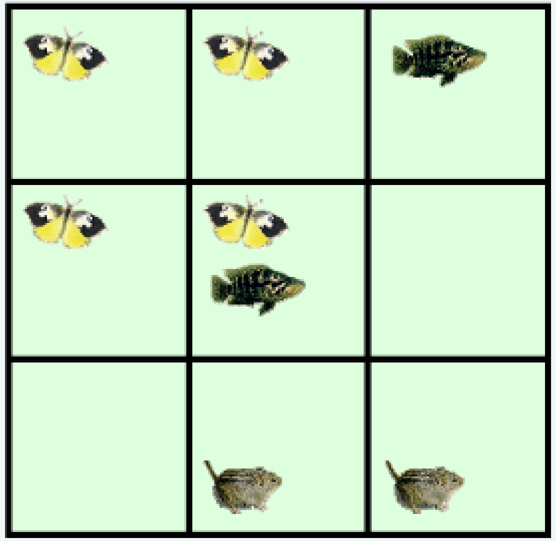
< 3% Pre-settlement Forest Intact

> 80% Privately-owned

>153 Species At Risk

- Most Imperiled Ecosystem in BC And Throughout the Pacific Northwest





Each planning unit costs 1

Boundary length modifier value = 1.5.

The species penalty factor for all three species is 10.

Illustrations by Bob Smith (DICE)

What problem do we want to solve?

Score of the configuration being tested =

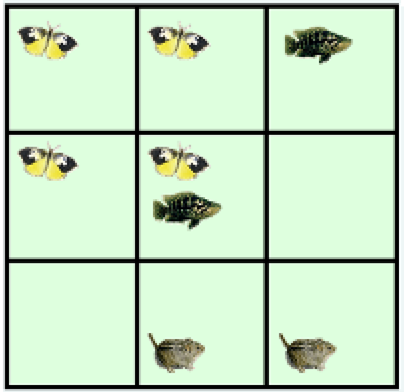
$$Cost$$

$$+$$

$$Boundary\ Length\ Modifier \times$$
$$Boundary\ Cost\ of\ the\ reserve\ system$$

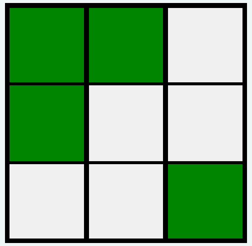
$$+$$

$$Species\ Penalty\ Factor\ \times$$
$$Penalty\ incurred\ for\ unmet\ targets$$

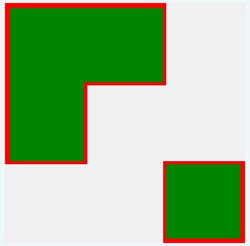


Measuring overall score

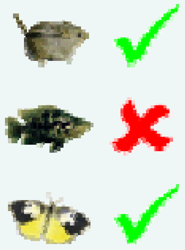
Total score



Total PU cost = 4



Boundary = 12 * 1.5

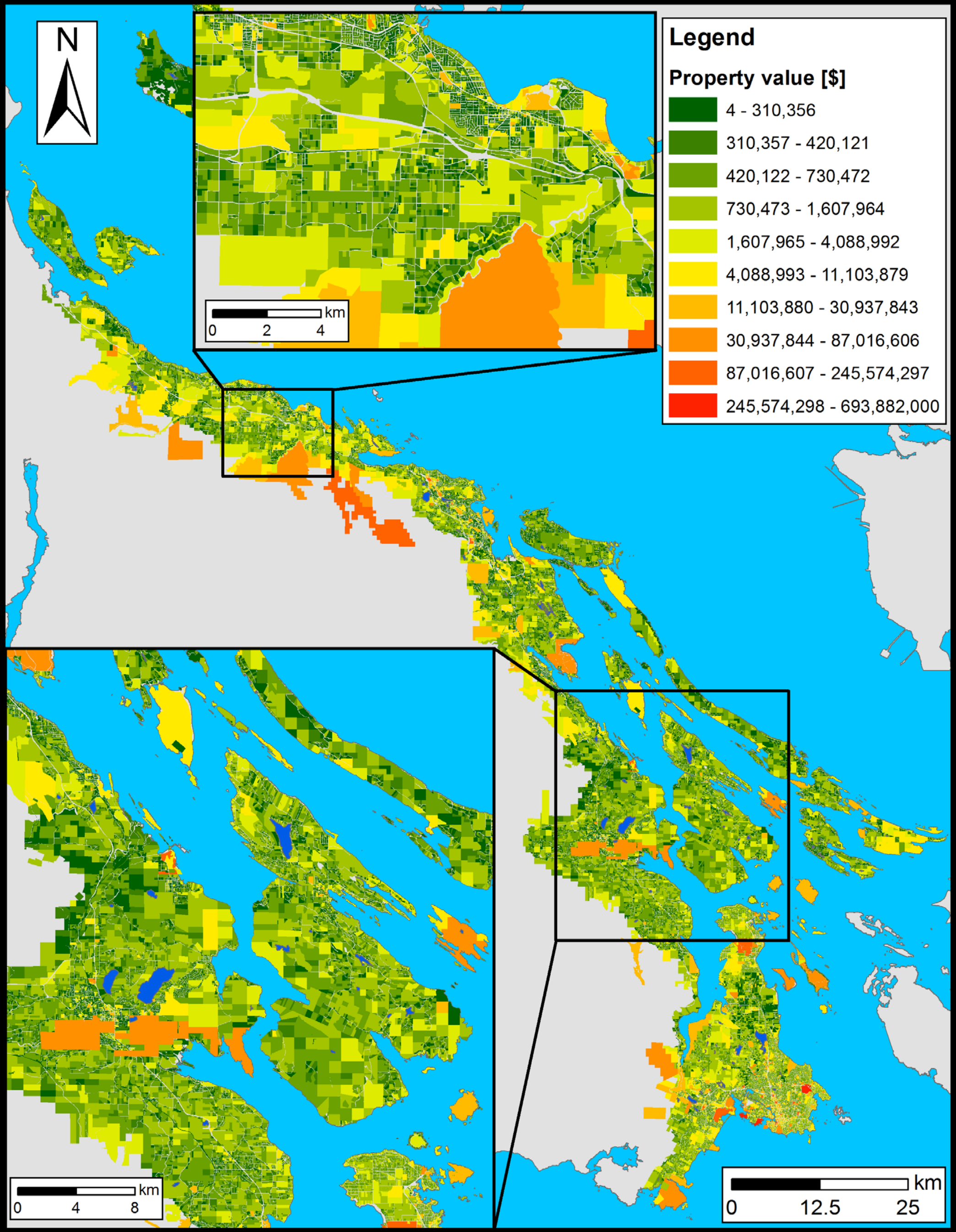


SPF = 10

32

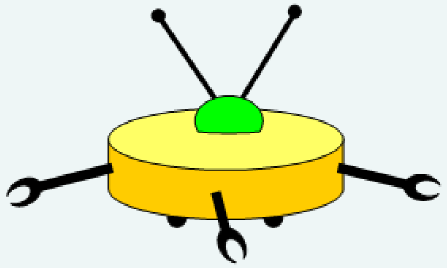
Planning units

- Land base of the planning area: ~198,000 properties
- Possible solutions for a reserve system: 2^198,000 > atoms in the Universe
- How to optimize prioritization?



Searching for life on Mars: a simulated annealing analogy

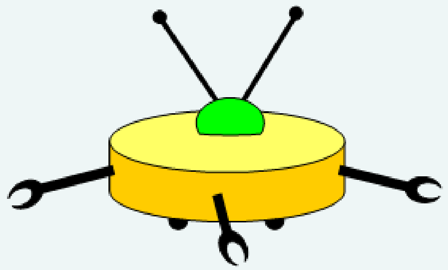
- Life will most likely to be found in low-lying areas
- Problem of finding the lowest-lying area on Mars using a robot is similar to finding the most efficient set of conservation areas (a lot of alternatives)
- How can simulated annealing help solve this problem?



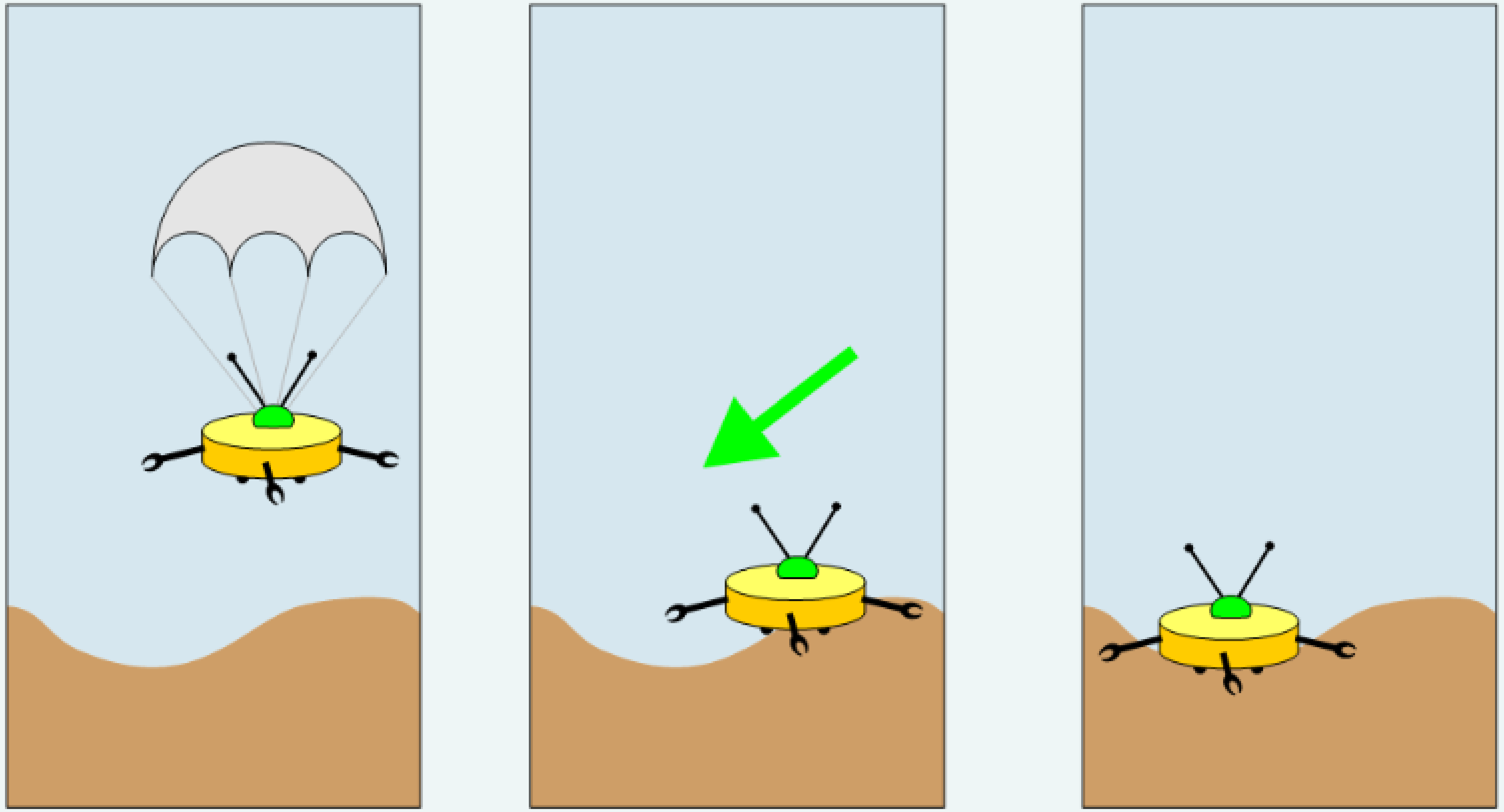
Source: Bob Smith (DICE)

Simulated Annealing

1) Measure the elevation of the ground directly beneath the robot body.
2) Randomly choose an arm and measure the elevation of the ground beneath the arm.
3) If the ground beneath the arm is lower than the robot base then move to the point measured by the arm.

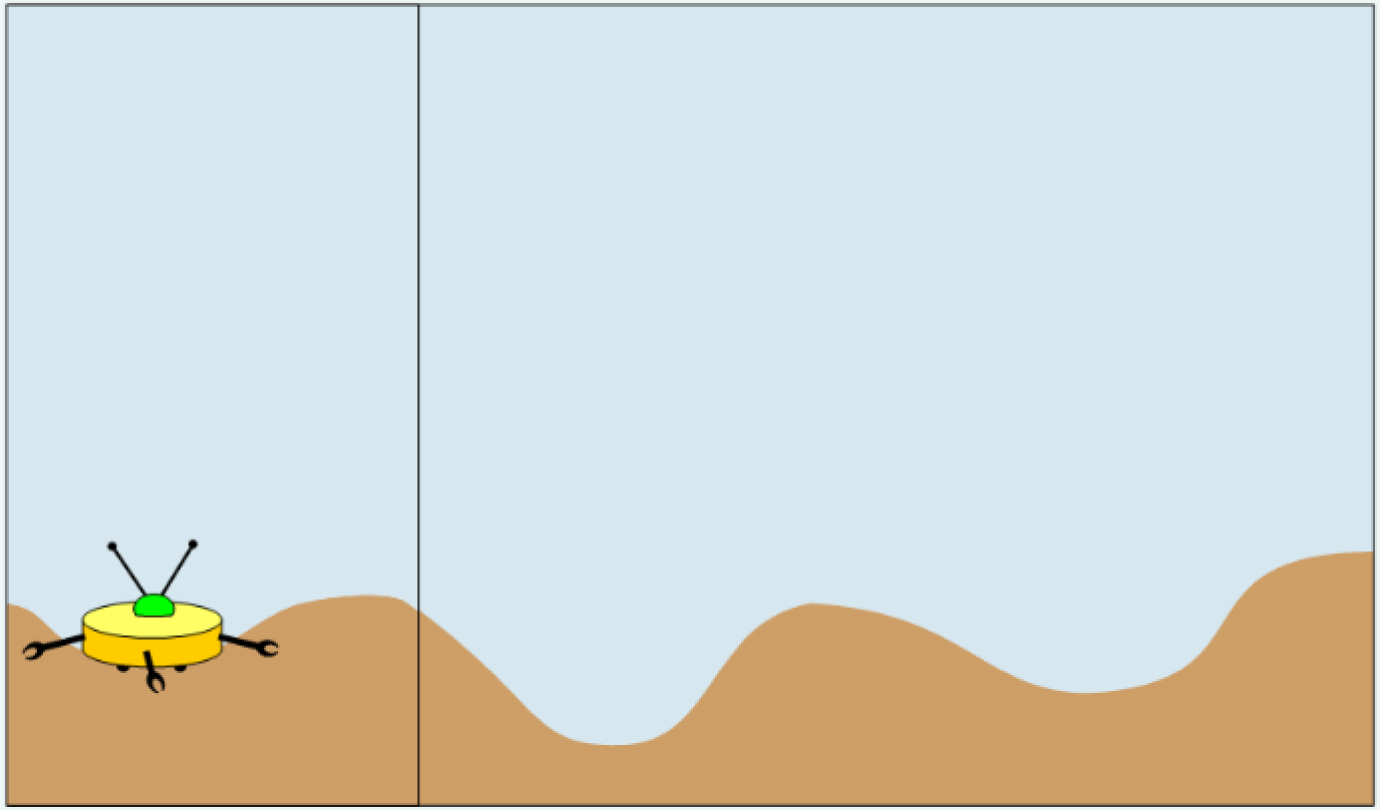


Source: Bob Smith (DICE)



Source: Bob Smith (DICE)

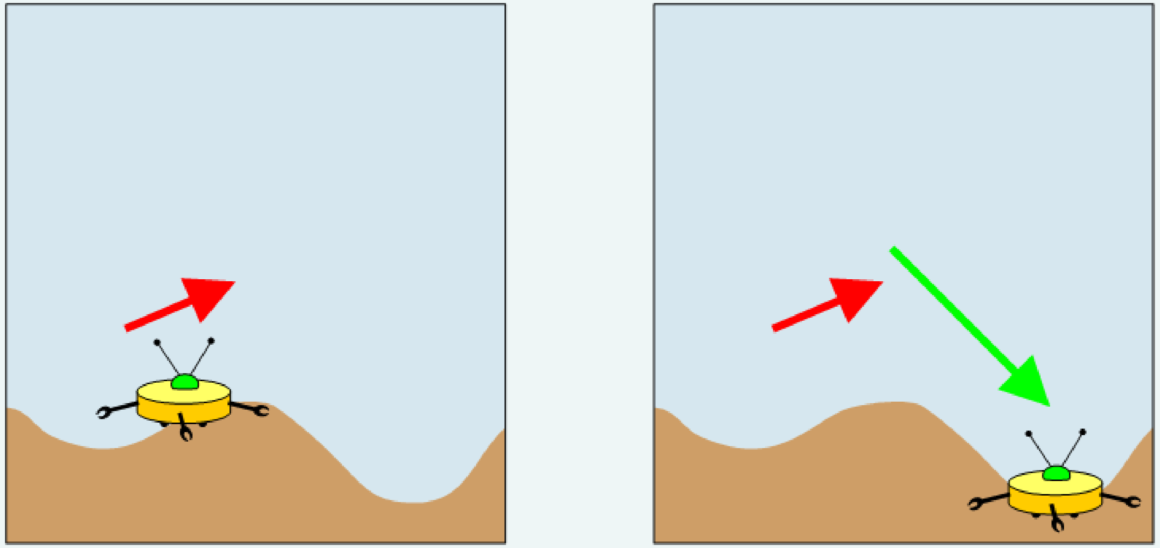
But…this is a flawed strategy as there are lower areas



Source: Bob Smith (DICE)

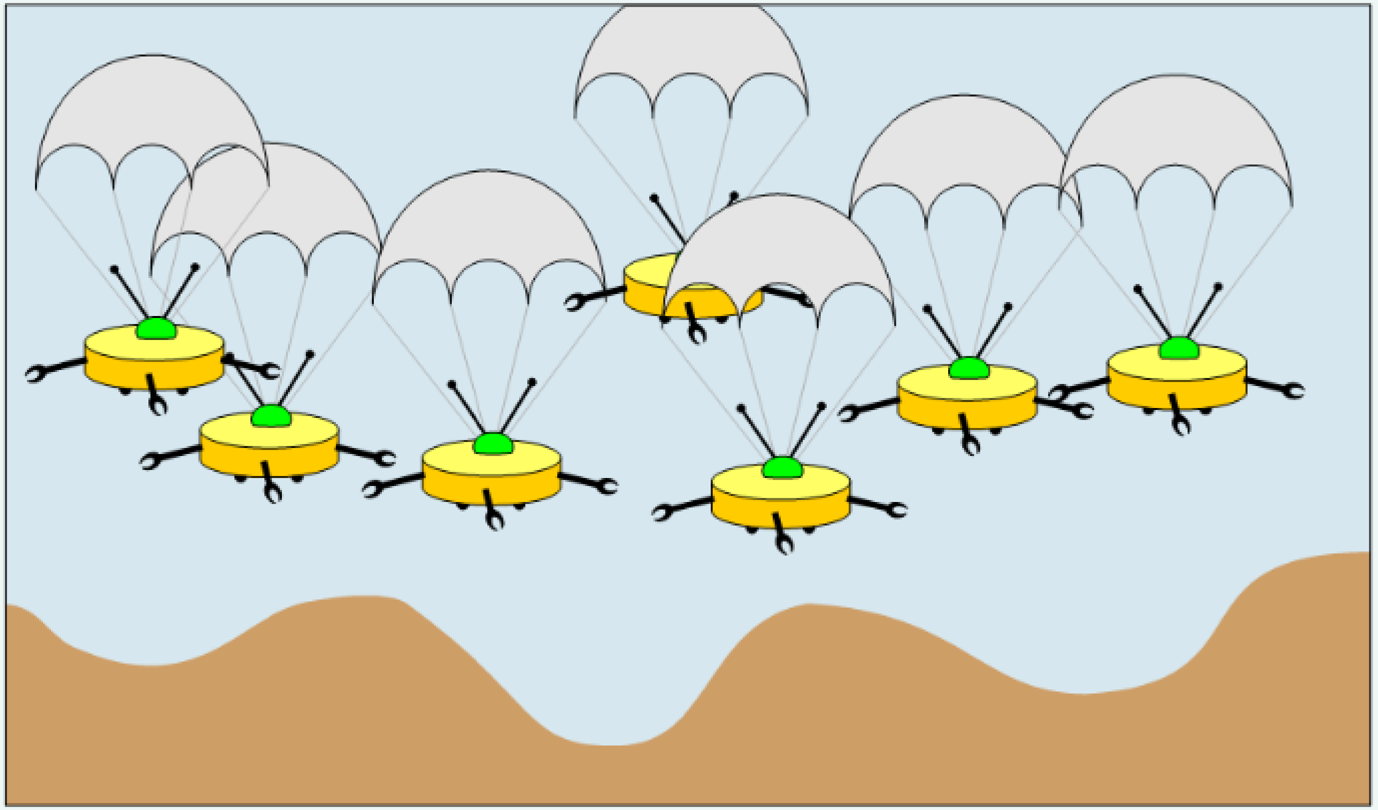
Random backward steps

- Moves up a slope to try to move into neighbouring, lower-lying valleys
- Backward steps are more common at the beginning of the simulated annealing process



Source: Bob Smith (DICE)

Repetition



Many robots (runs) results in many good solutions.

Source: Bob Smith (DICE)

Where do we start?

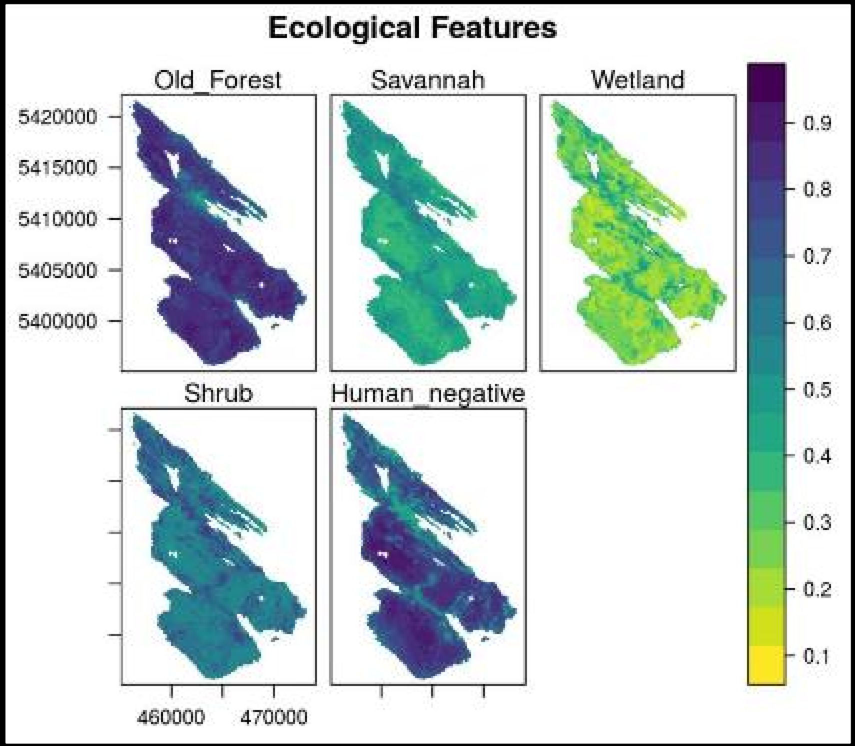
- Conservation planning = challenging
- Range of objectives and constraints
- Analytical tools tailored to specific tasks

Flexible, powerful framework

+

User friendly (browser) interface

prioritizr.net



Hanson JO, Schuster R, Morrell N, Strimas-Mackey M, Watts ME, Arcese P, Bennett J, Possingham HP (2019). prioritizr: Systematic Conservation Prioritization in R. R package version 4.1.4.

Why R ?

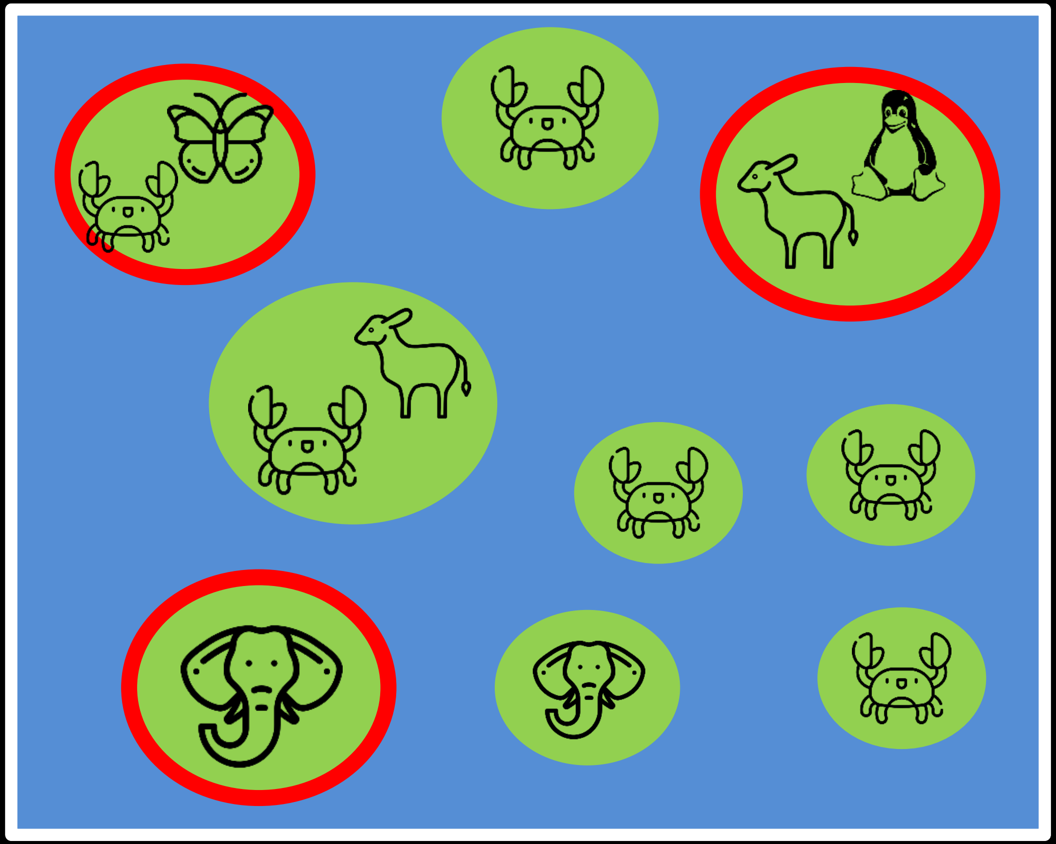
- It’s free
- Reproducibility
- Flexible interface
- Diverse package ecosystem
- So many resources: Stackoverflow, tutorials, blogs, twitter, slack channels, mailing lists

Decision science

- Goal: what is our vision for the future?
- Objective: what quantity are we maximizing/minimizing to help achieve the goal?
- Constraints: what things must our solution do to help achieve the goal?
- Decisions: what actions could we do to maximize/minimize the objective?

Case-study: Reserve design

- Goal: conserve biodiversity
- Objective: min. # of islands
- Constraints: sufficient habitat for each species
- Decisions: which places should be protected?



Design <u>your</u> problem

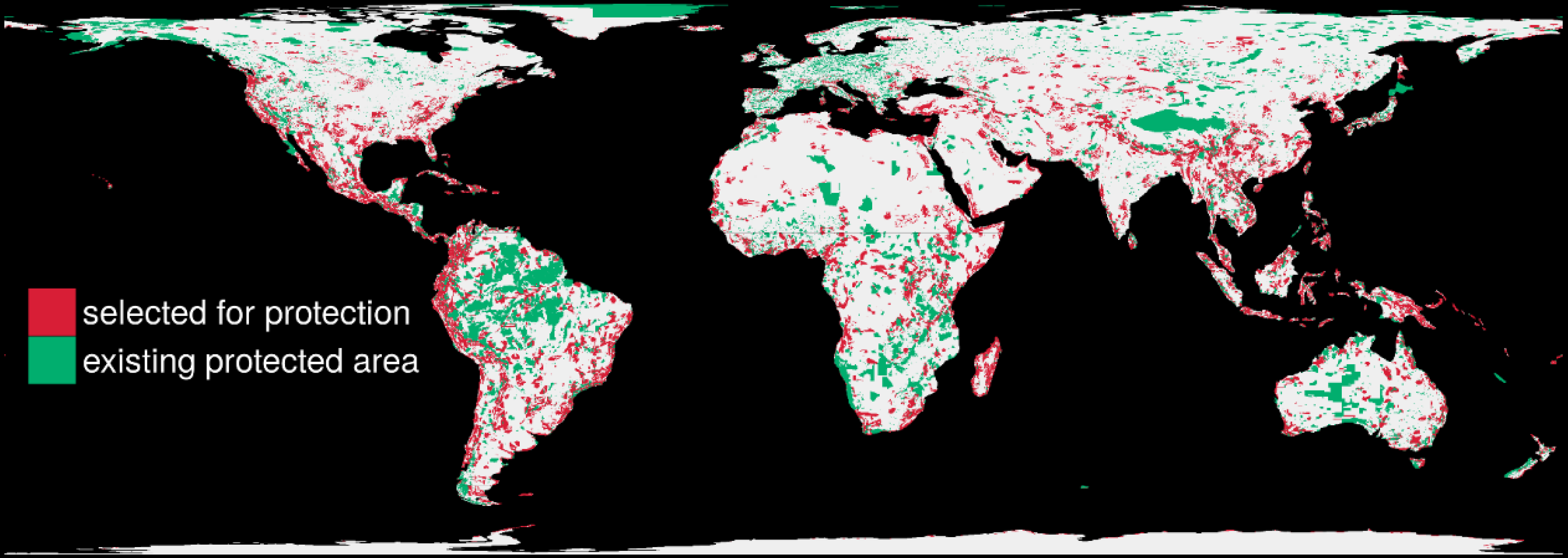
Mental model

```
problem <- data +
           objective +
           constraints +
           penalties

solution <- solve(problem)
```

Code

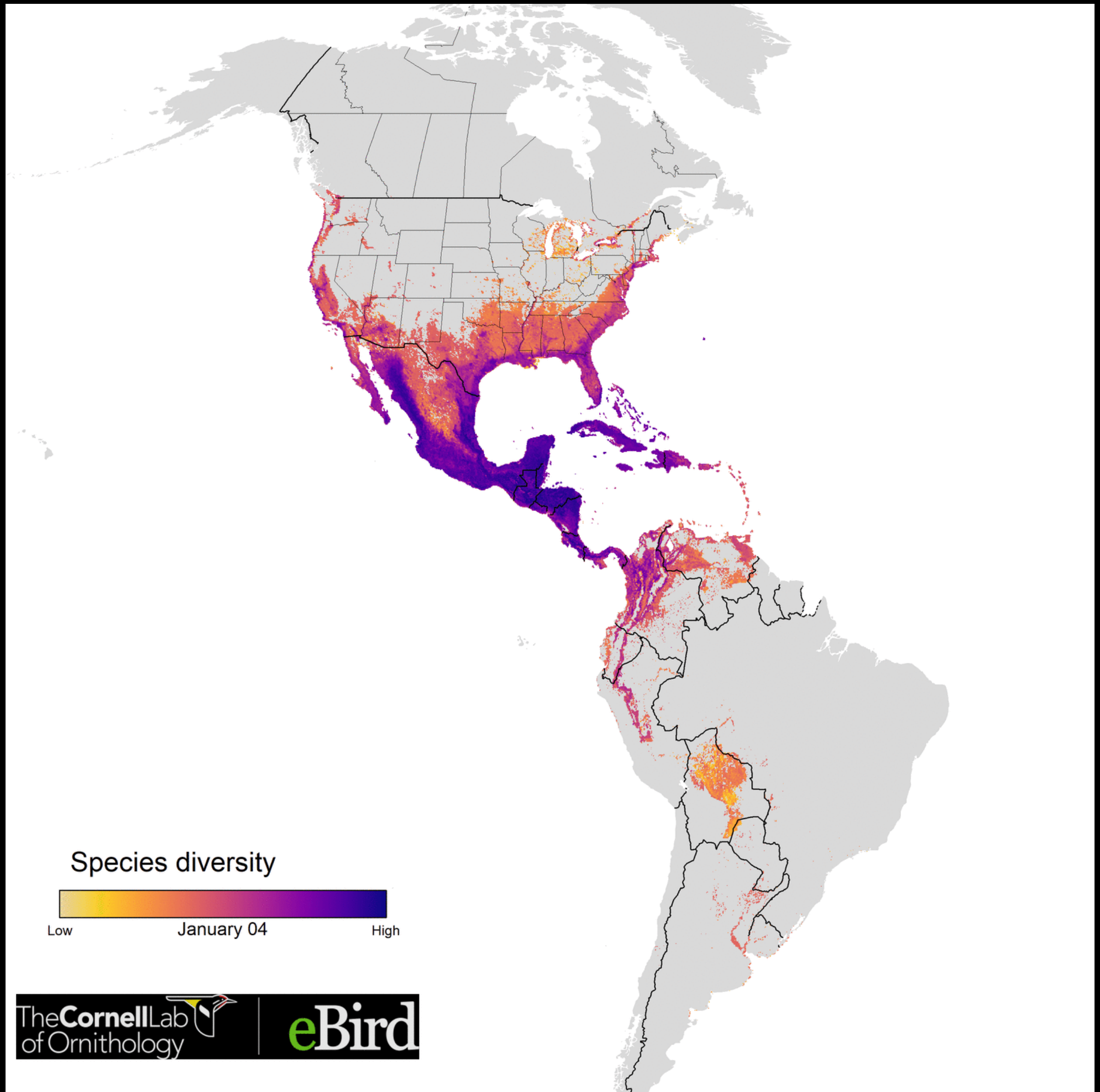
```
p <- problem(cost, features) %>%
    add_min_set_objective() %>%
    add_relative_targets(0.1) %>%
    add_boundary_penalties(5)

solution <- solve(p)
```

Solve it fast!



1.5 million planning units + 22,644 species: 76 minutes

Optimizing the conservation of migratory species over their full annual cycle



117 species
73 million km^2
1.7 million unique locations
14 million checklists

≤ 30,420 features
1.05 million planning units

Analysis powered by:

Schuster et al. (2019) Nature Communications

Facilitate Consensus Decisions on Protection

BRITISH COLUMBIA
Ministry of Environment

The Nature Trust
of British Columbia

NATURE CONSERVANCY CANADA

BRITISH COLUMBIA
Ministry of Forests, Lands and Natural Resource Operations

CDFCP
COASTAL DOUGLAS-FIR & ASSOCIATED ECOSYSTEMS CONSERVATION PARTNERSHIP

HAT
Creating Conservation Legacies

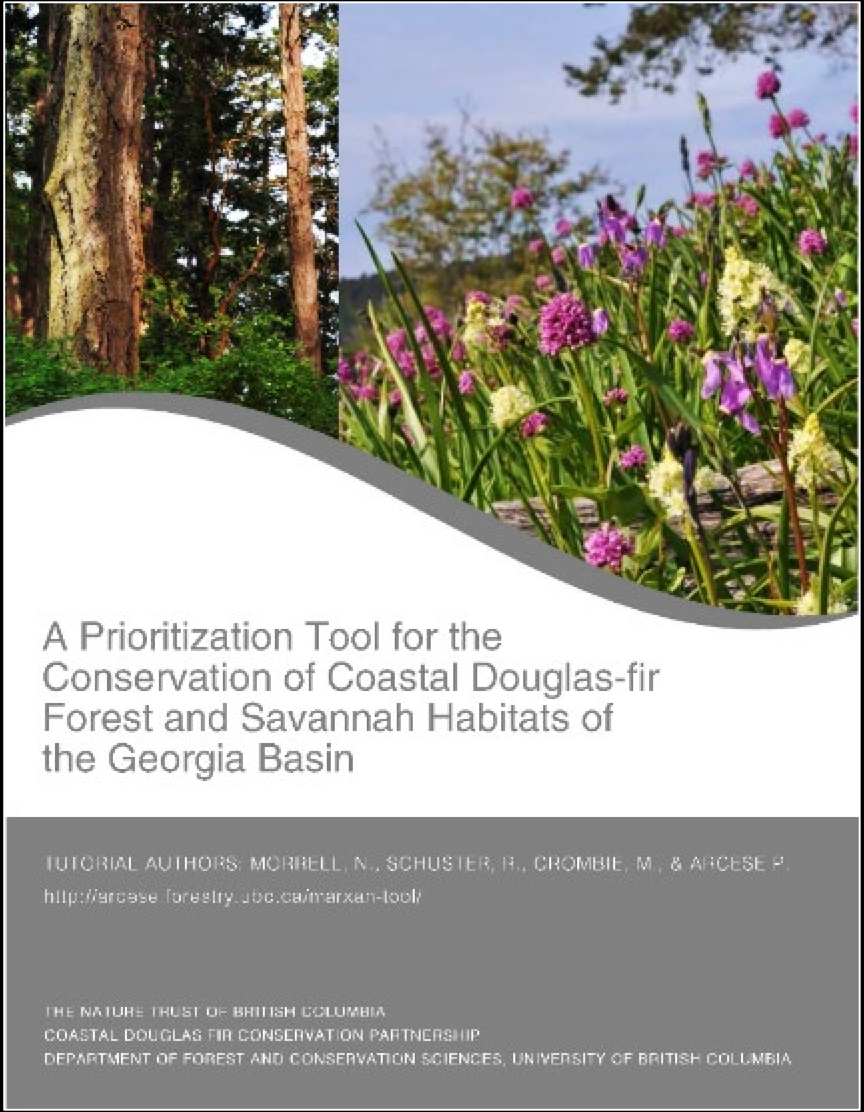
Canada

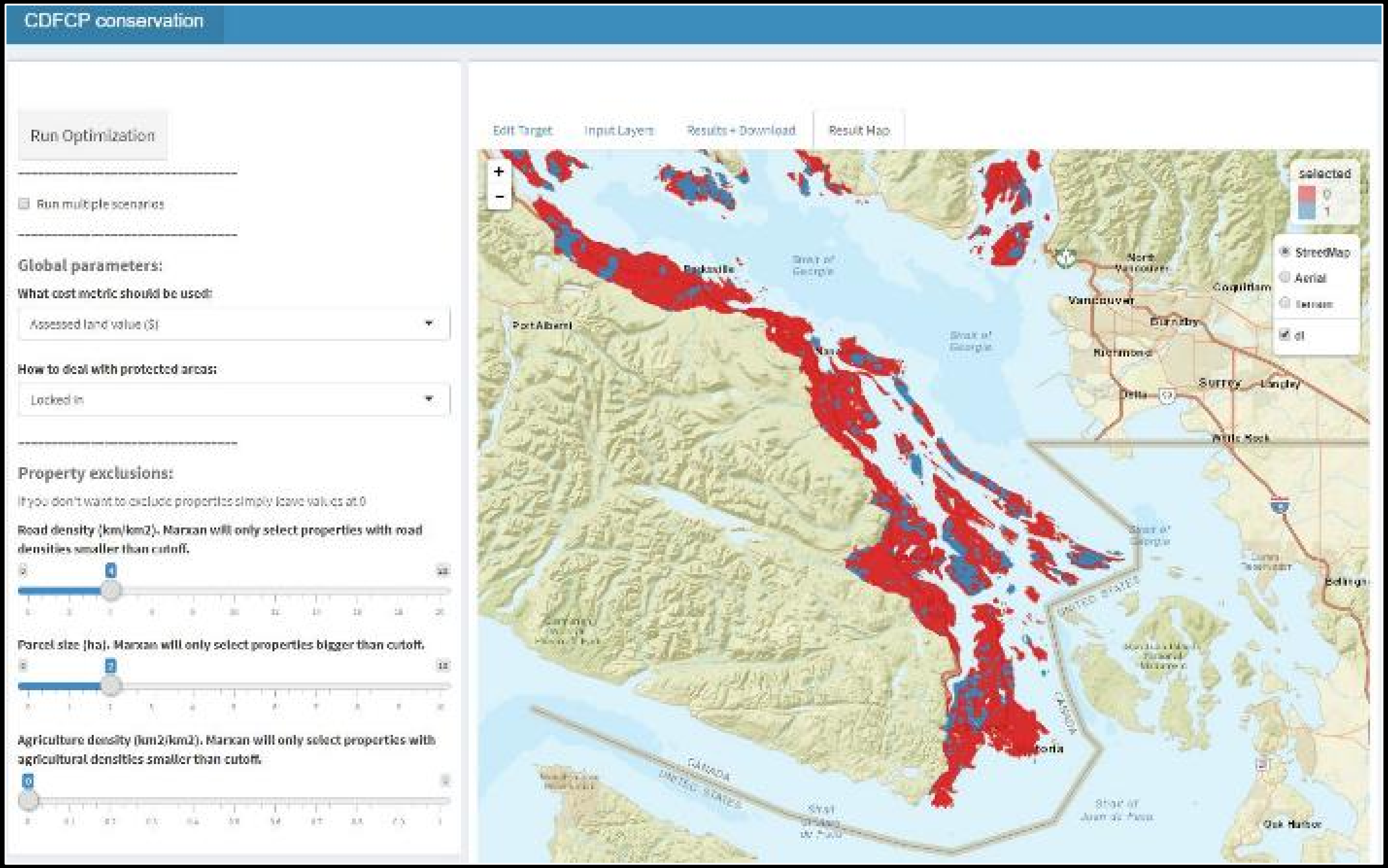
Environment and Climate Change Canada
Environnement et Changement climatique Canada
Canada

Greater VICTORIA School District

C·V·R·D

Making prioritizr user friendly:



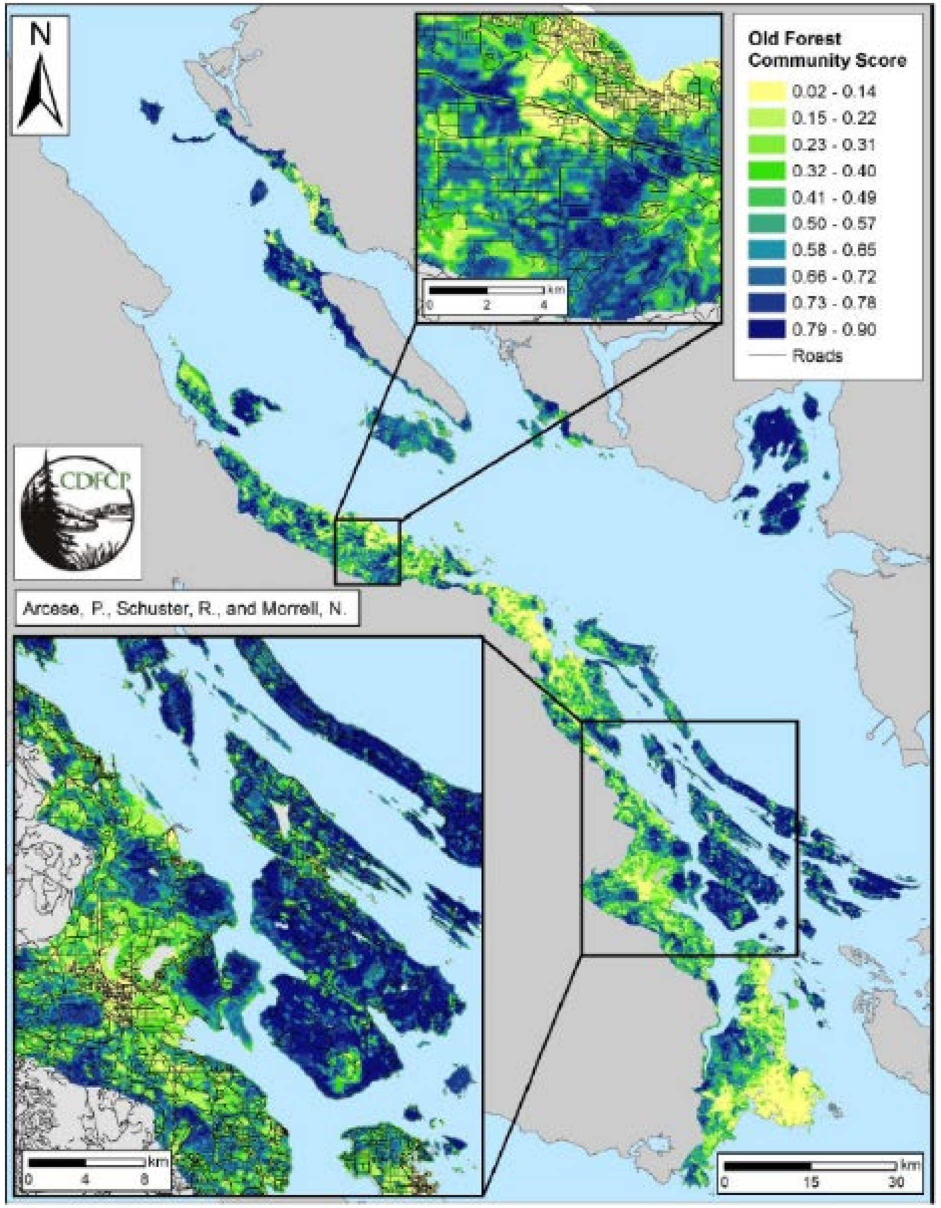


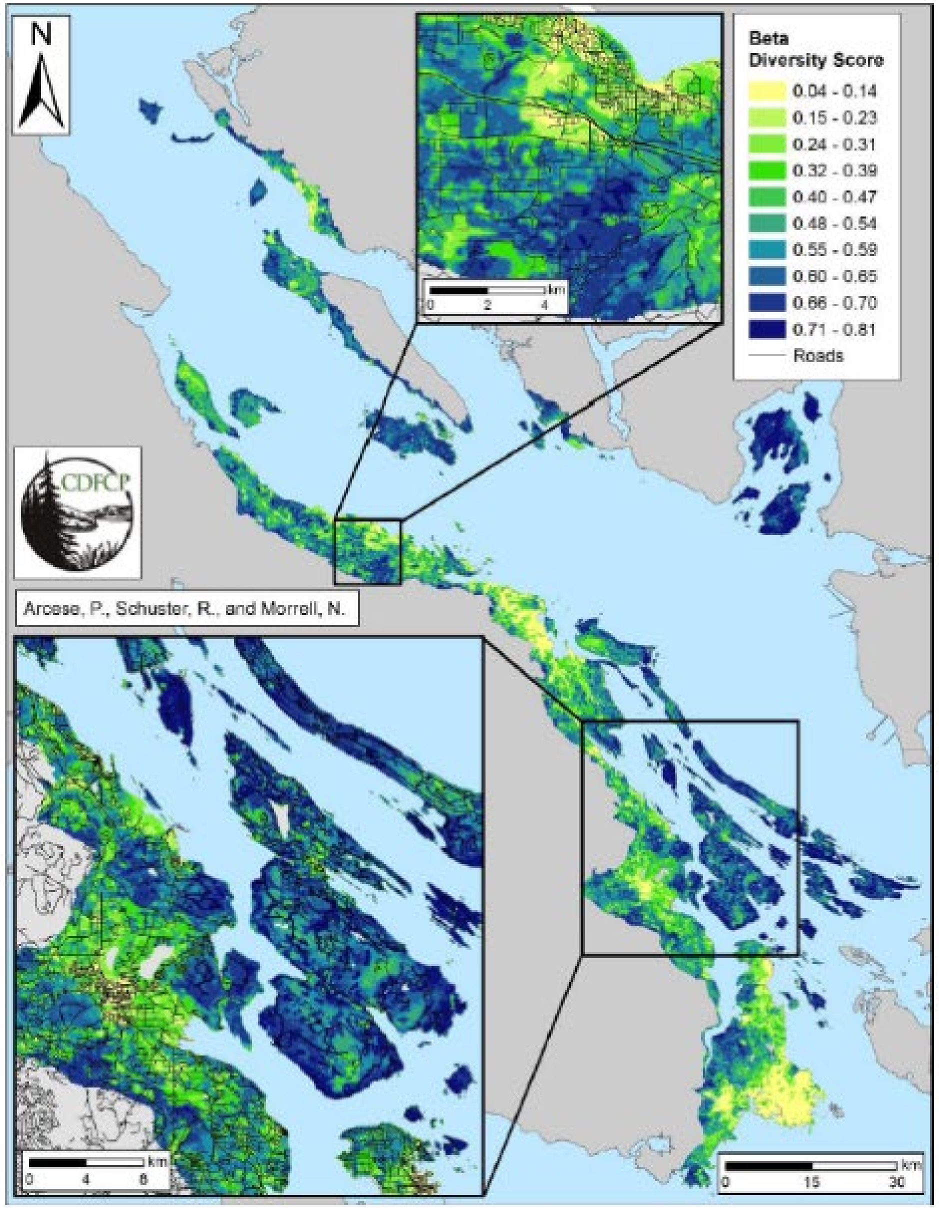
Old Forest Birds
Savannah Birds
Beta Diversity
Wetland Birds
Shrub Birds
Human Commensal Birds
Inverse of Hum Com Birds
Standing Carbon
Carbon Sequestration Potential
TEM Element Occurrence
SEI Coastal Bluff
SEI Herbaceous
SEI Older Forest
SEI Riparian
SEI Second Growth Forest
SEI Sparsely Vegetated
SEI Woodland
SEI Wetland

Native Plant Species Richness
Fish
Herptiles
California Buttercup
Contorted-pod Evening Primrose
Dense Flowered Lupine
Dense Spike-primrose
Foothill Sedge
Oregan Forestsnail
Maoun's Meadowfoam'
While Meconella
Coast Microseris
Marbeld Murrulet
Fragrant Popcorn
Sand-verbena Moth
Area

Old forest community

Beta diversity





CDFCP tool tutorial (p.15+)

http://arcese.forestry.ubc.ca/marxan-tool-cdfcp/

Table 1. Descriptions of the biodiversity feature layers included in the CDFCP tool. Target values for each of these layers can be specified in the table found under the 'Edit Target' tab in the CDFCP tool interface.

Old Forest Birds (OF)	A composite distribution map based on probability of occurrence of birds associated with old forest habitat (Schuster and Arcese 2014). See Appendix A.
Savannah Birds (SAV)	A composite distribution map based on probability of occurrence of birds associated with savannah habitat (Schuster and Arcese 2014). See Appendix A.
Shrub Birds (SHR)	A composite distribution map based on the probability of occurrence of birds associated with shrub habitat. See Appendix A.
Wetland Birds (WET)	A composite distribution map based on probability of occurrence of birds associated with wetland and riparian habitats (Schuster and Arcese, unpublished). See Appendix A.
Human Commensal Birds (HUM)	A composite distribution map based on probability of occurrence of birds associated with urban and rural human landscapes (Schuster and Arcese, unpublished). When targets are set for this feature, the tool will seek planning units least likely to host commensal species. See Appendix A.

Coastal Douglas-fir
& Associated Ecosystems
Conservation Partnership

Conservation Strategy 2015

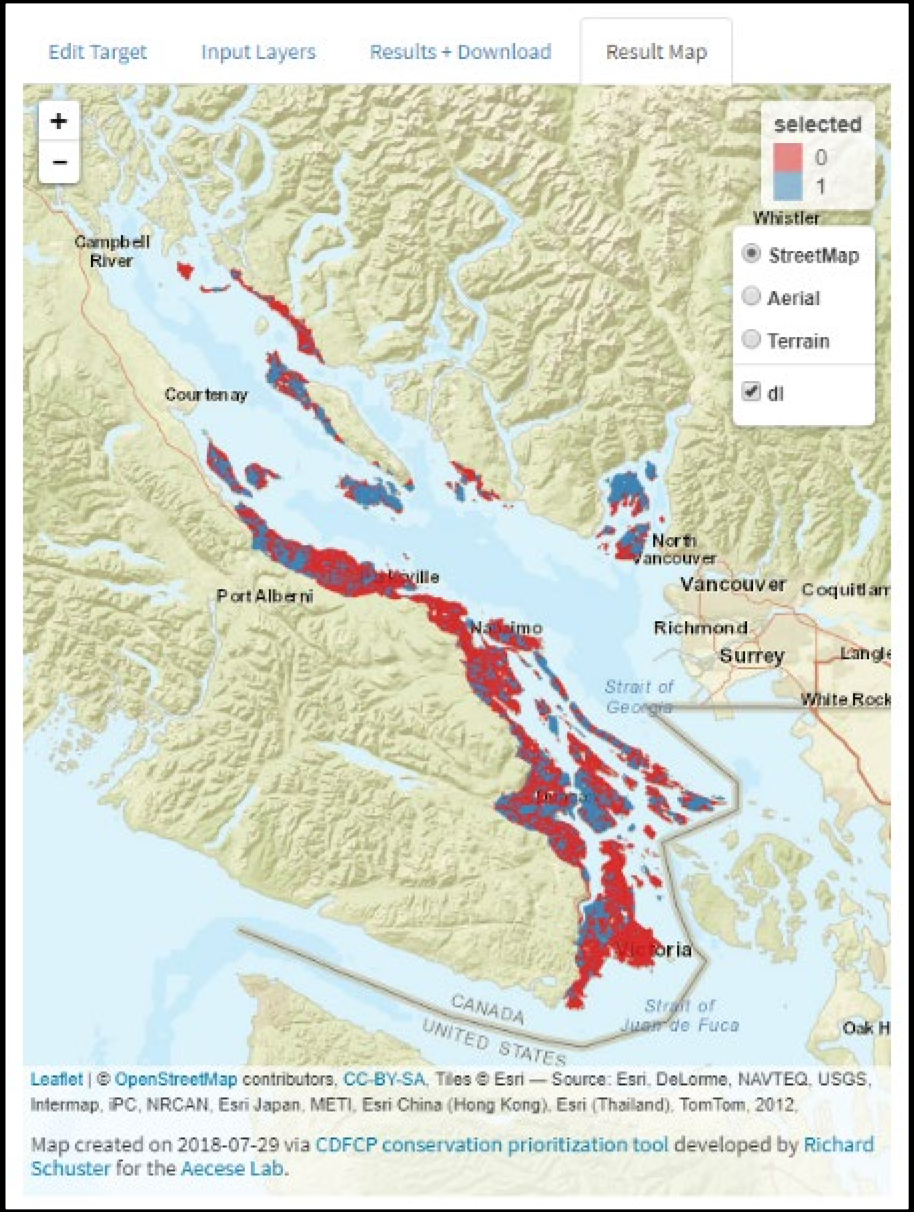
Applications?

CDFCP
COASTAL DOUGLAS-FIR
& ASSOCIATED ECOSYSTEMS
CONSERVATION PARTNERSHIP

Acquire Biodiverse Parcels

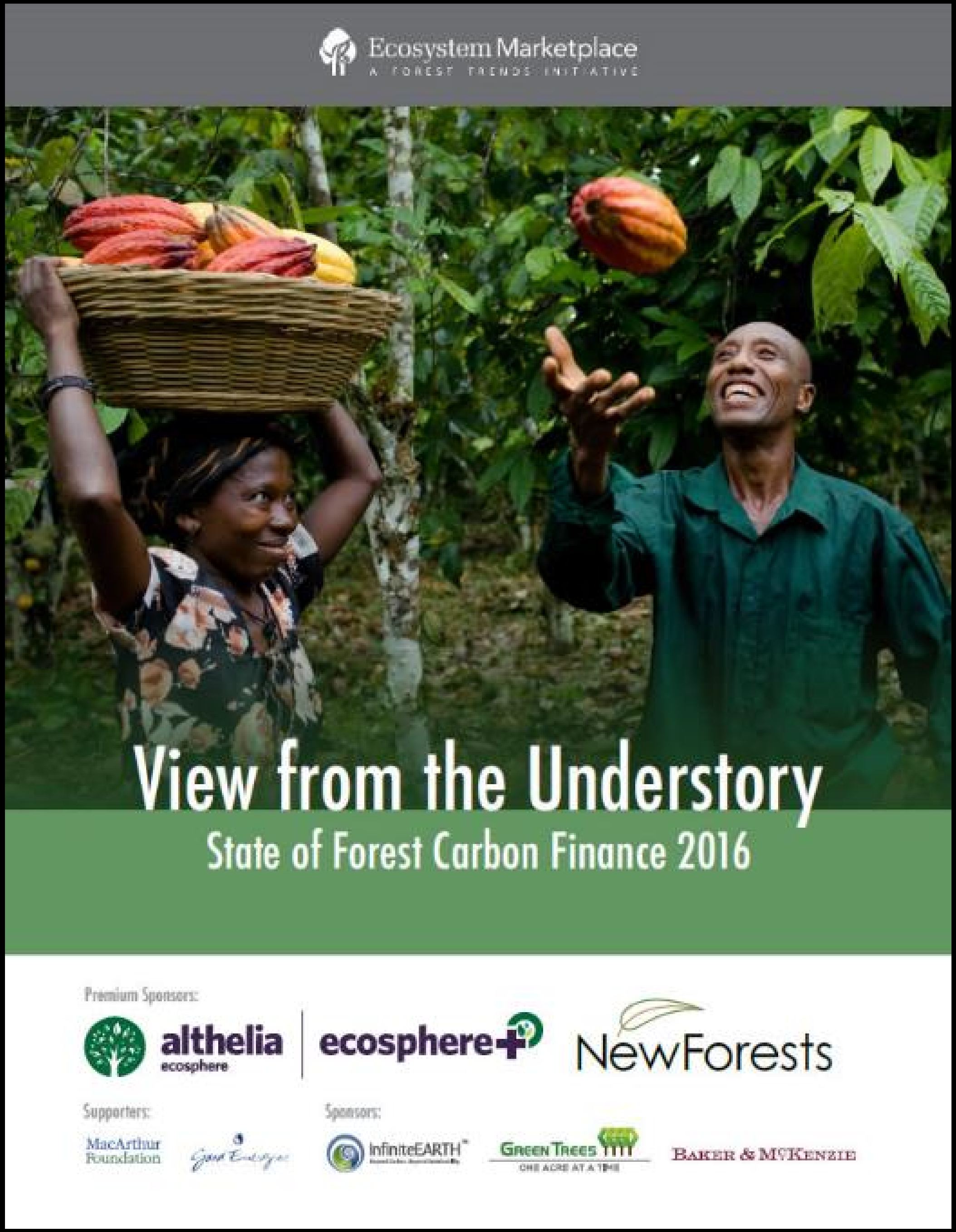
Minimize Management Costs, Maximize Return on Conservation Investments

Develop Contact Lists to Engage Private Landowners in Conservation at Landscape Scales



Payments for Ecosystem Services

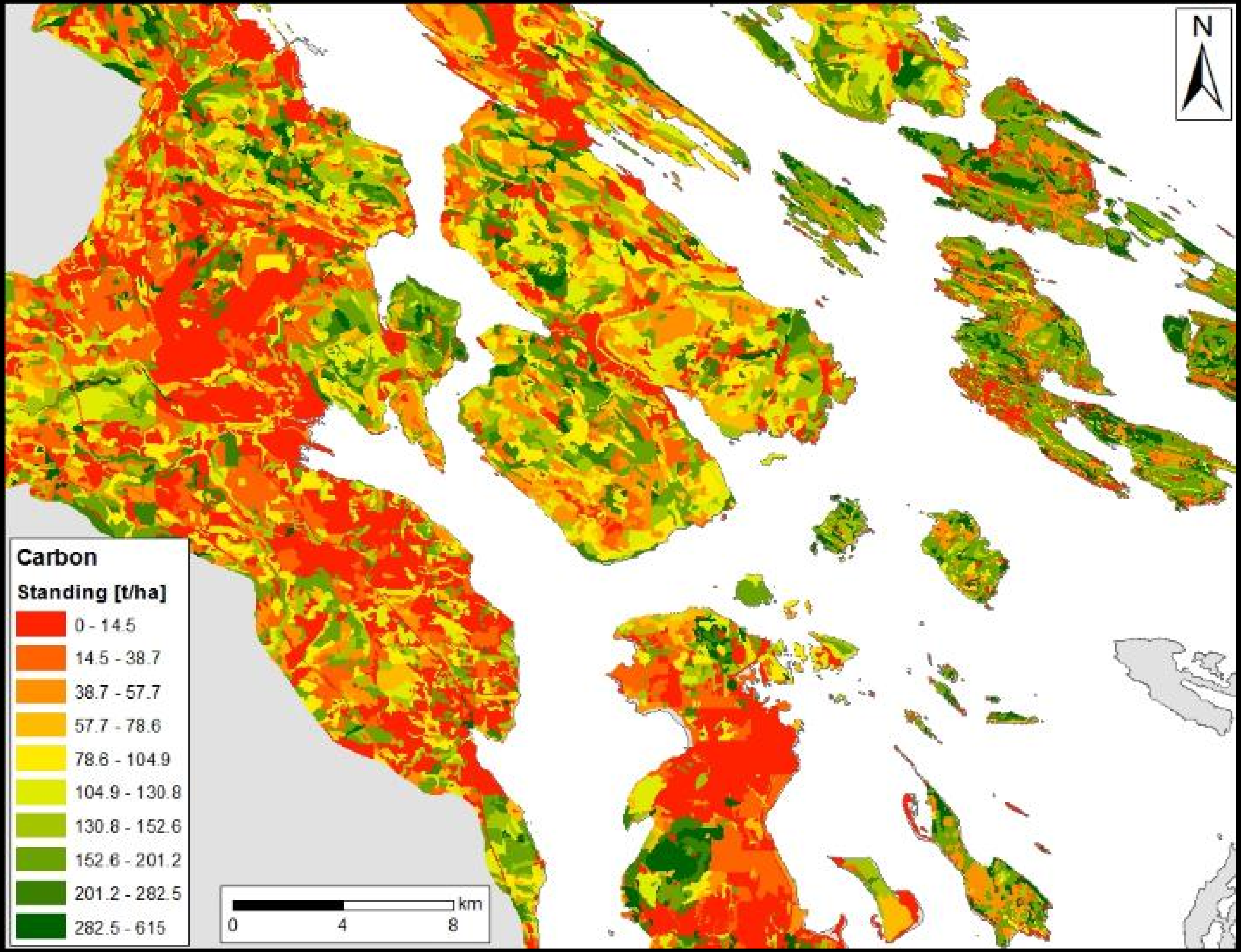
$6 Billion Invested to 2016 in Carbon



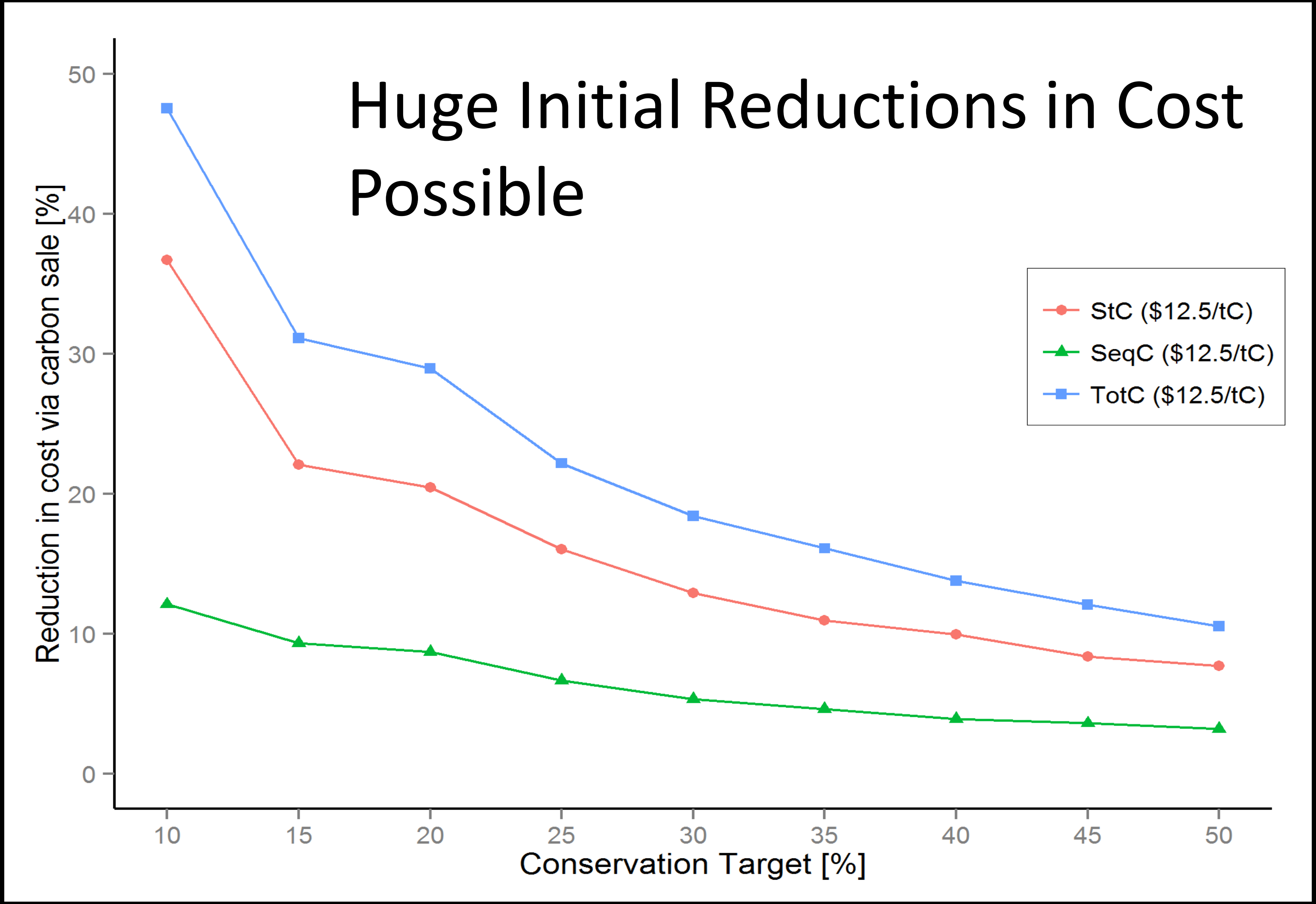
Synergies: High Value Forests Have Standing Carbon In Excess of 200 t/ha

Standing Carbon in High Value Forests in the Georgia Basin is Currently Worth $4-10K/ha

~3-15% of Acquisition Cost



Biodiversity - Carbon



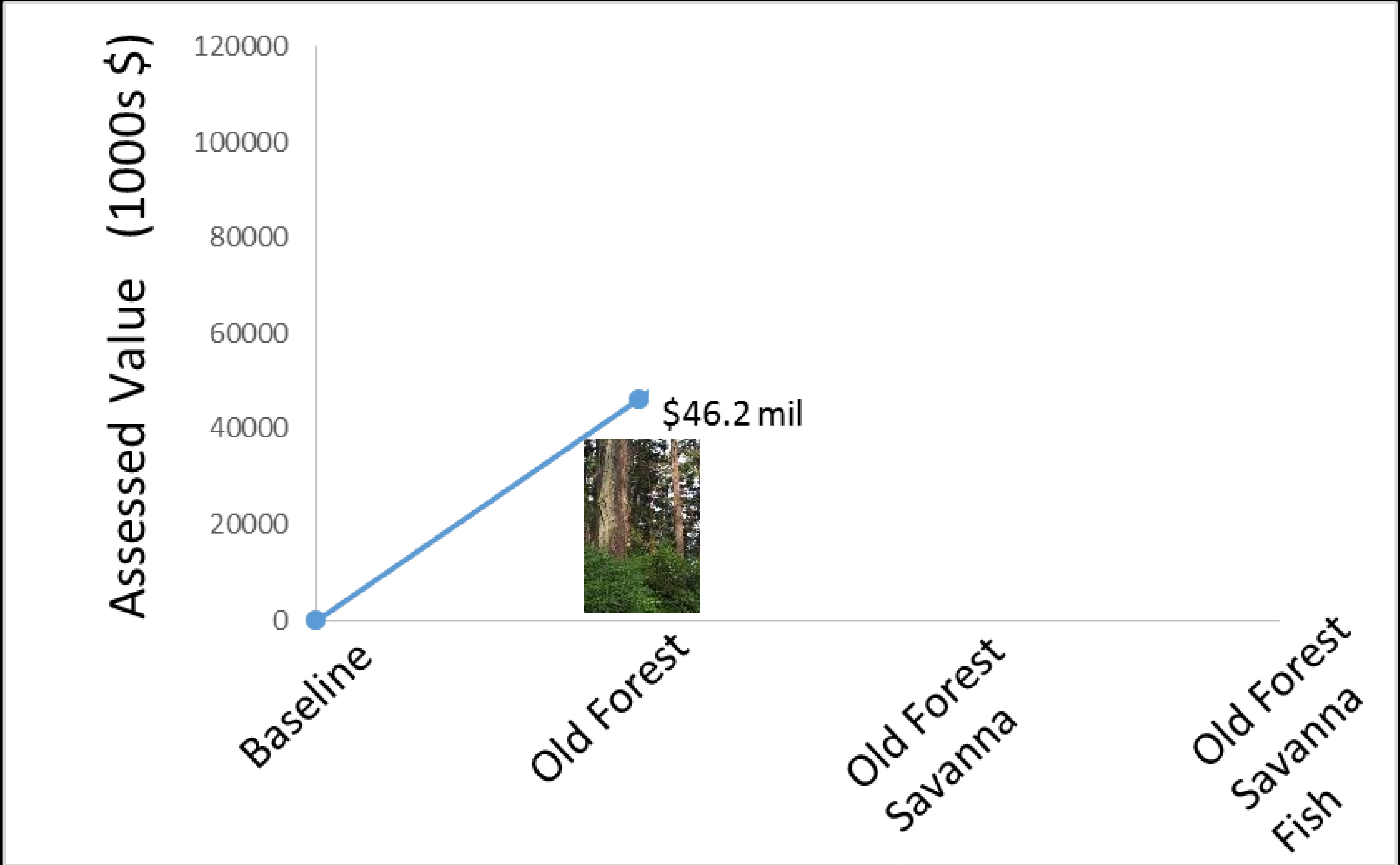
Strategic Investment for 'Co-benefits'

Standing / Sequestered Carbon

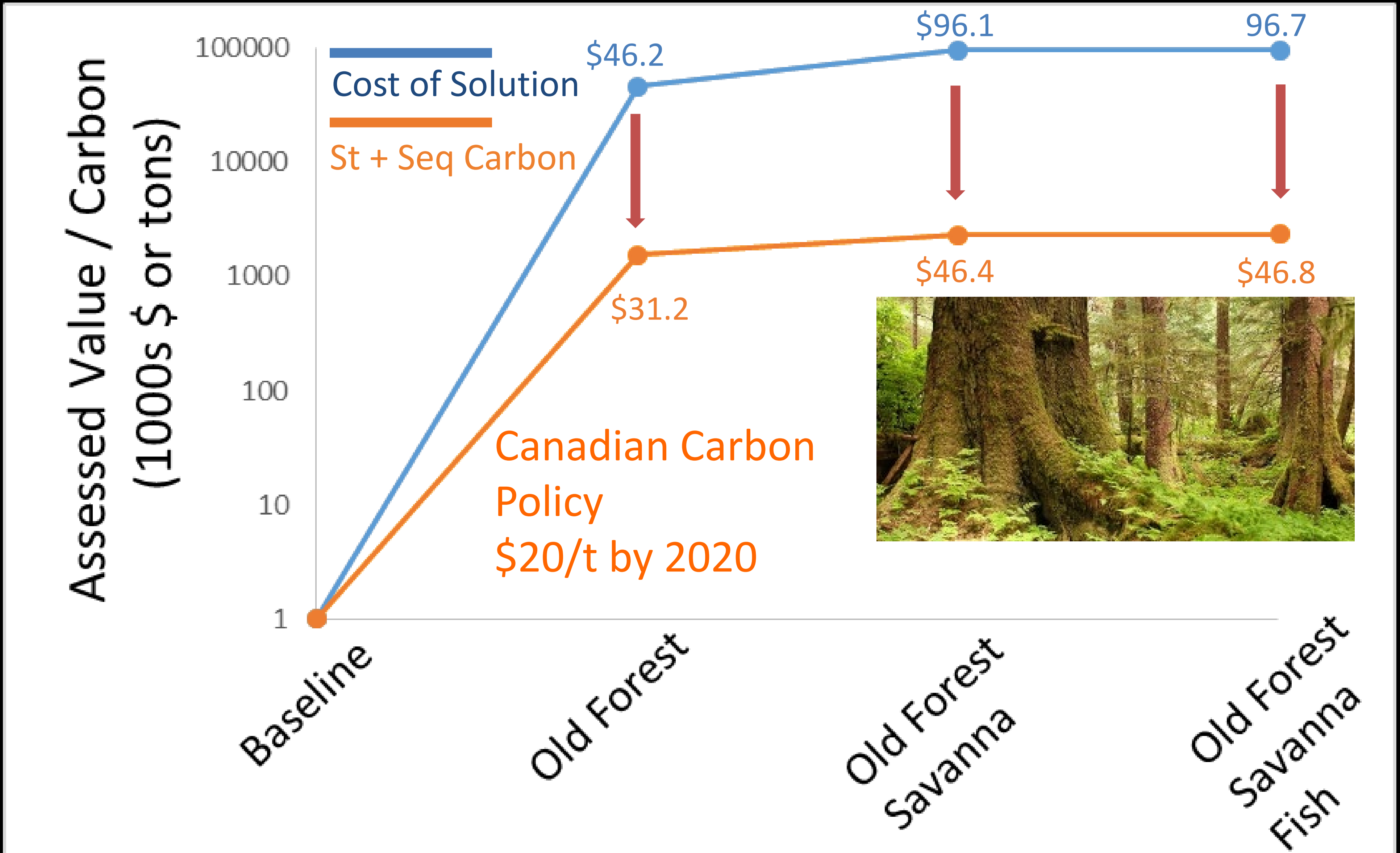
Water Quality / Supply

Beneficial Farm Practices

Coastal Douglas-fir Carbon Co-Benefit



Coastal Douglas-fir Carbon Co-Benefit



Climate Adaptive Planning for British Columbia

- Recently started 3 year project
- Leads: Oscar Venter and Peter Arcese
- Partners:

Pacific Institute For Climate Solutions
Knowledge. Insight. Action

NATURE TRUST BRITISH COLUMBIA

BRITISH COLUMBIA Ministry of Environment

BC PARKS FOUNDATION

BRITISH COLUMBIA Ministry of Forests, Lands, Natural Resource Operations and Rural Development

CPAWS CANADIAN PARKS AND WILDERNESS SOCIETY NORTHERN ALBERTA

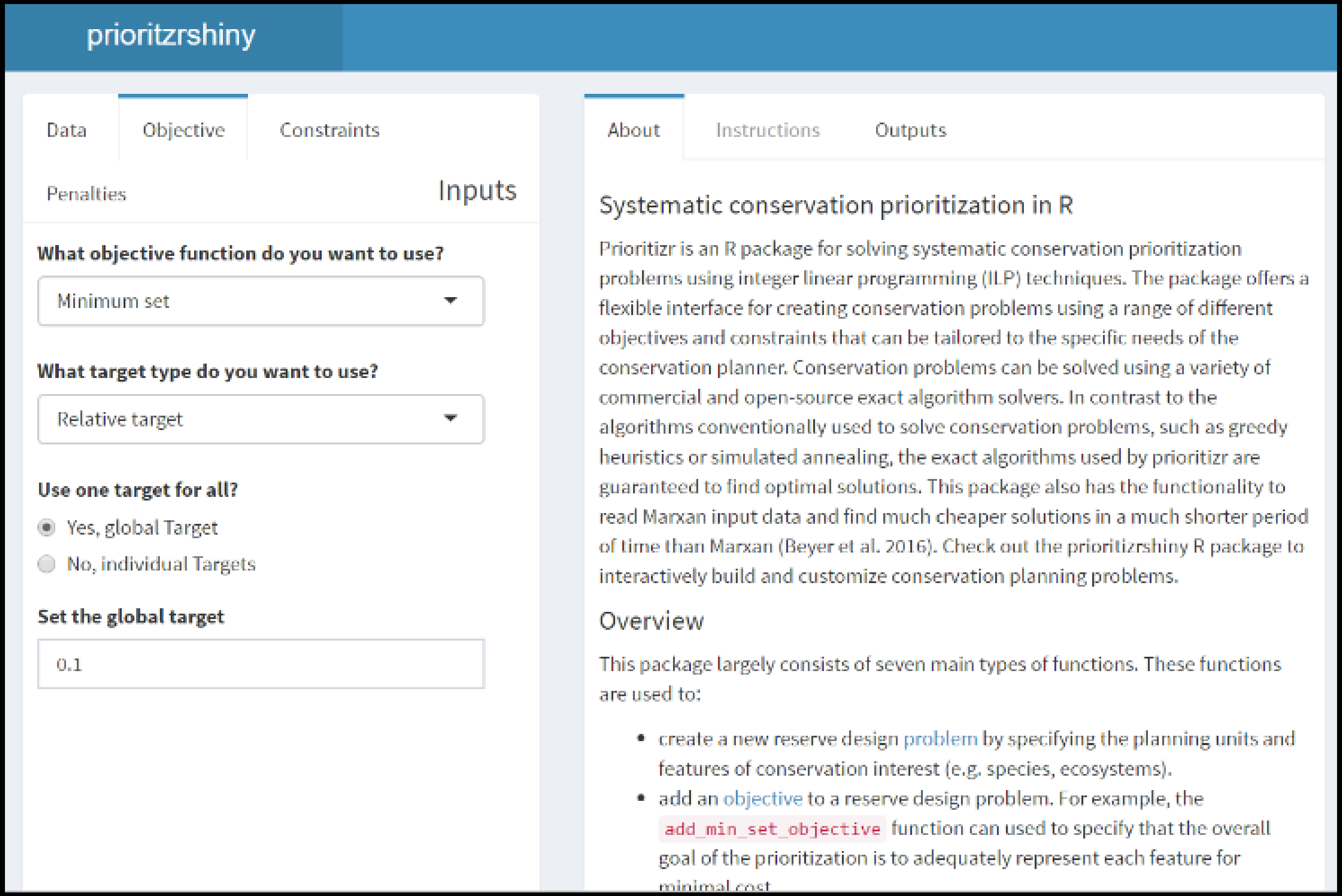
What’s next?

prioritizrshiny (in development)

Code

```
p <- problem(areas, feats) %>%
  add_min_set_objective() %>%
  add_relative_targets(0.1) %>%
  add_boundary_penalties(5) %>%
  add_binary_decisions() %>%
  add_rsymphony_solver()

solution <- solve(p)
```

User interface



NCC – Carleton partnership

- **Tools for prioritization of conservation investments**

- Phase 1: Modernize NCC's conservation prioritization methods
  - Systematic Reserve Acquisition Prioritization tools
  - Tools aimed at optimizing stewardship decisions

- Phase 2: democratize conservation decisions beyond NCC

Take home message

Flexible + powerful framework

+

User friendly browser interface

=

A novice stakeholder can devise a high-quality, data-driven spatial plan in just one hour.

prioritizr.net

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