prioritizr

Systematic conservation planning in R

Session 2

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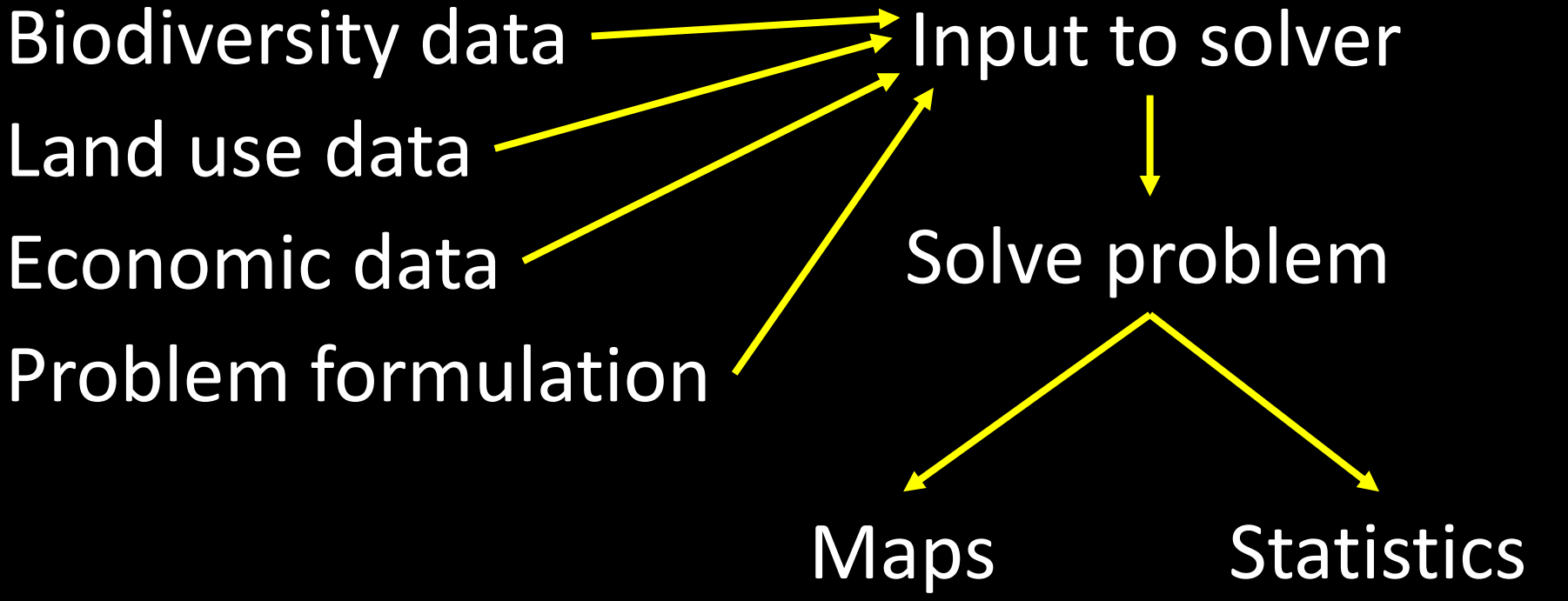
prioritizr.net

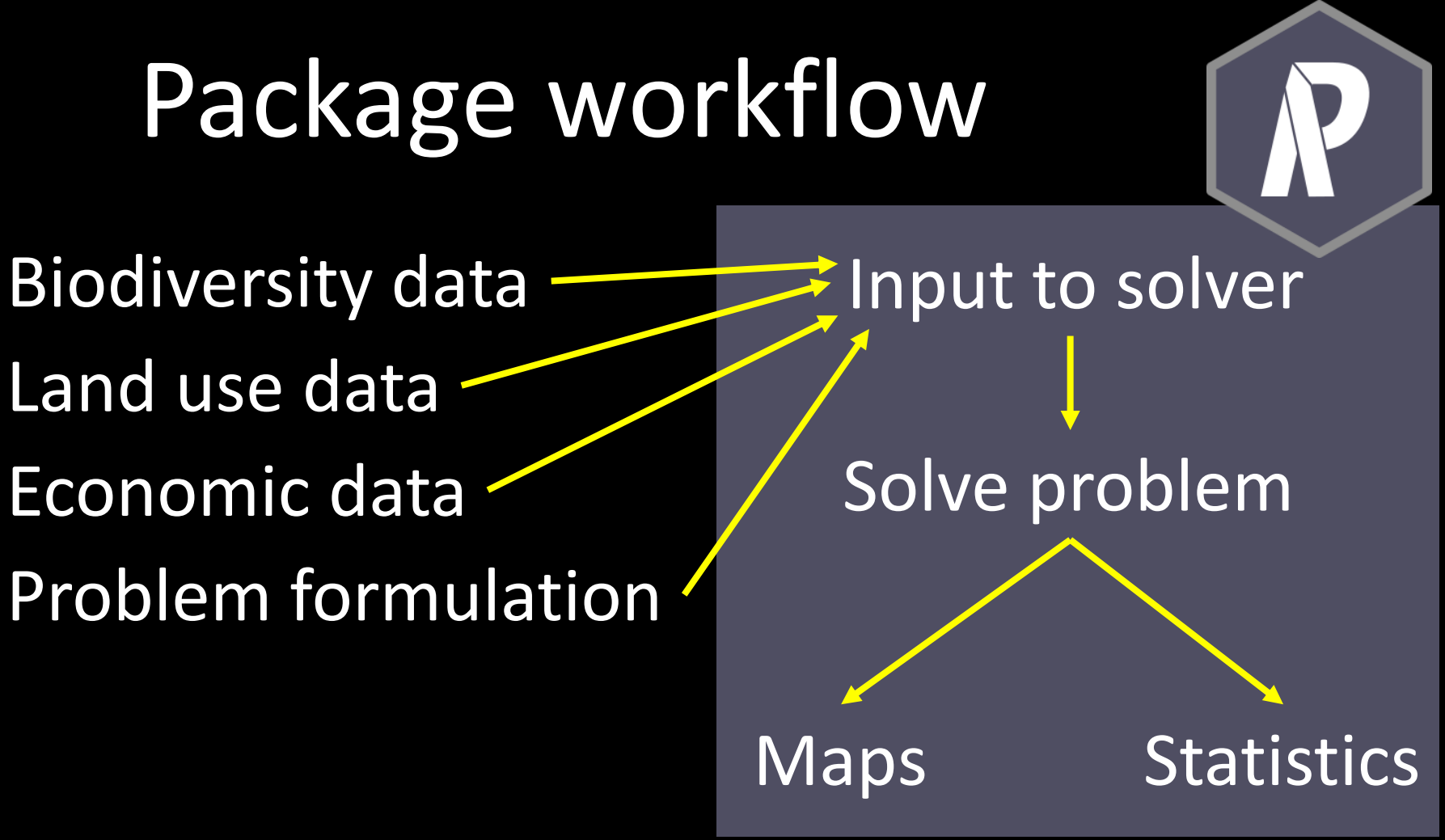
prioritizr

- Human readable code
- Design your problem
- Solve it fast!

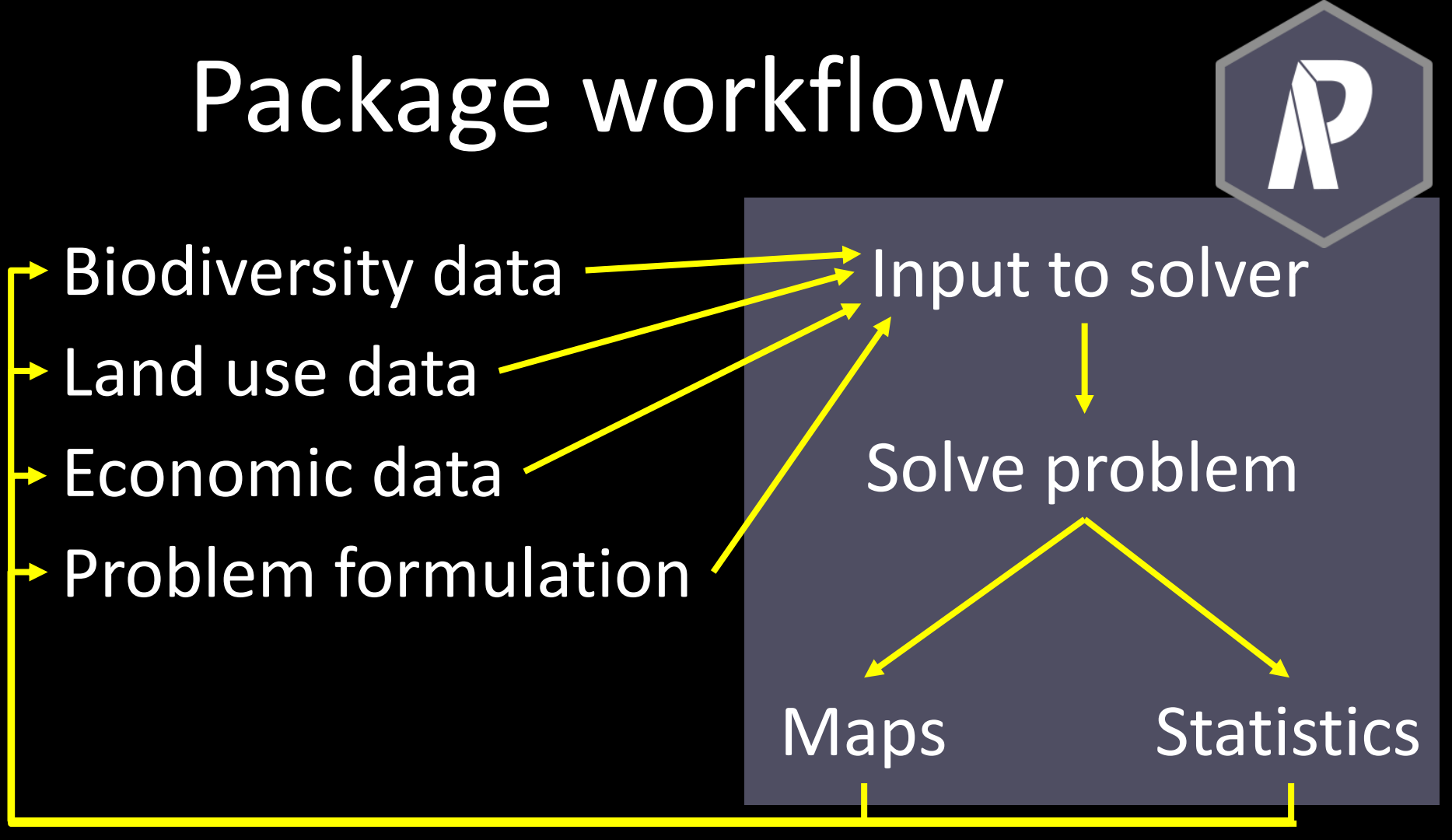
Package workflow



Package workflow



Package workflow



Human-readable code

Mental model

```
problem <-
  data +
  objective +
  constraints +
  penalties +
  decision type +
  solver


solution <- solve(problem)
```

Code

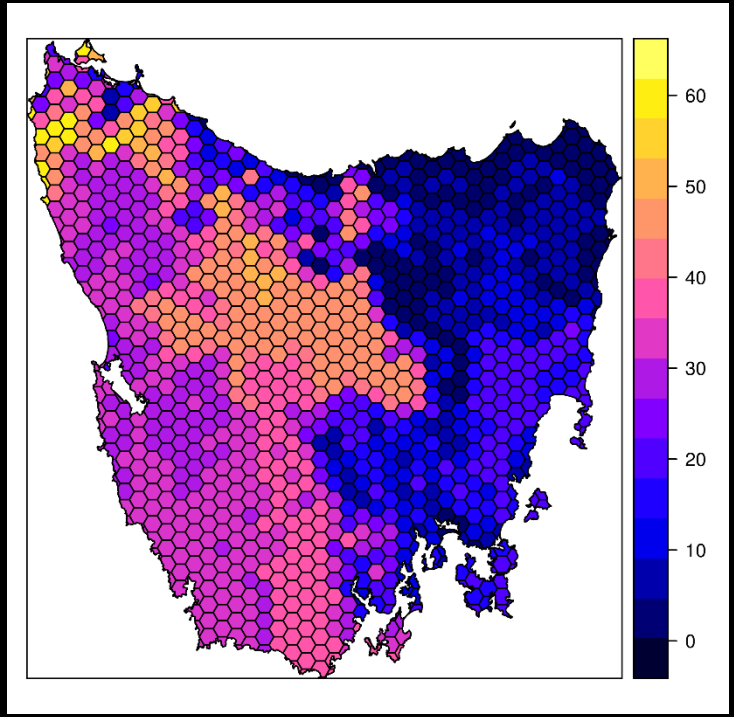
```
p <-
  problem(areas, feats) %>%
  add_min_set_objective() %>%
  add_relative_targets(0.1) %>%
  add_boundary_penalties(5) %>%
  add_binary_decisions() %>%
  add_rsymphony_solver()


solution <- solve(p)
```

Design your problem

Study area: Tasmania, Australia

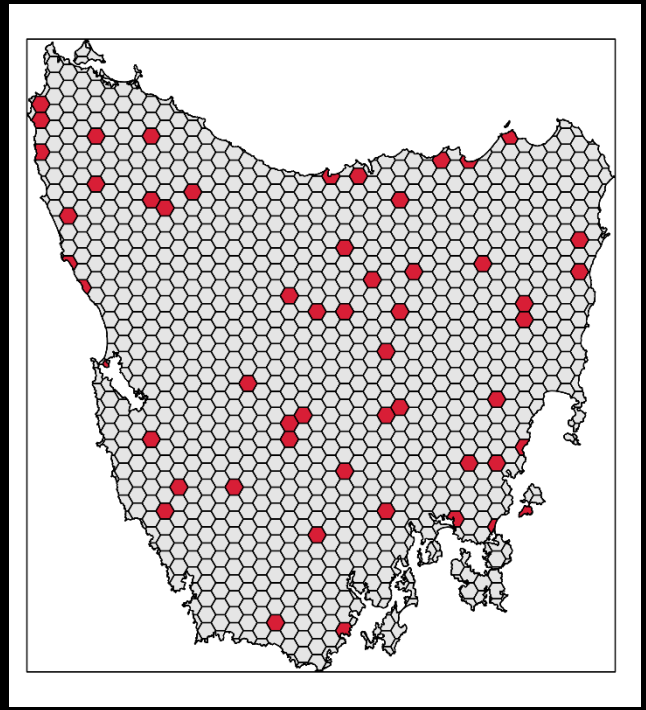
Planning units: 1130 hexagons

Features: 63 vegetation types



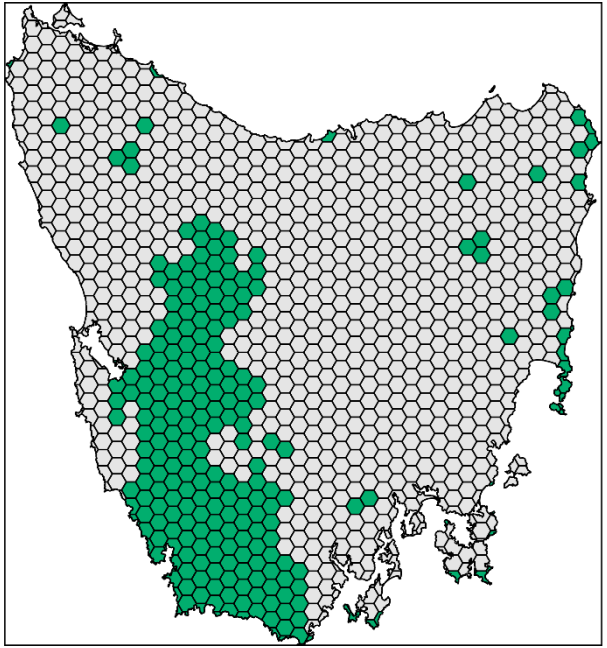
Design your problem

```
problem(tas_pu, tas_features,
        "cost") %>%
add_min_set_objective() %>%
add_relative_targets(0.1) %>%
add_binary_decisions() %>%
add_gurobi_solver(gap = 0) %>%
solve()
```



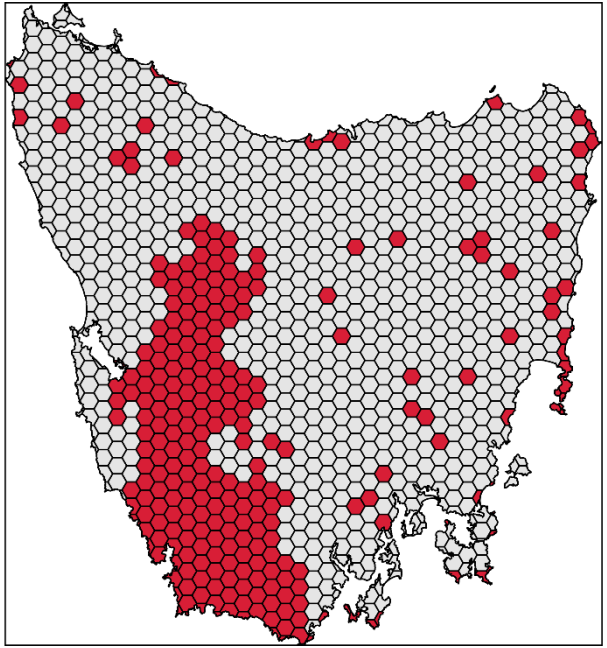
Design your problem

```
problem(tas_pu, tas_features,
        "cost") %>%
add_min_set_objective() %>%
add_relative_targets(0.1) %>%
add_locked_in_constraints("in") %>%
add_binary_decisions() %>%
add_gurobi_solver(gap = 0) %>%
solve()
```



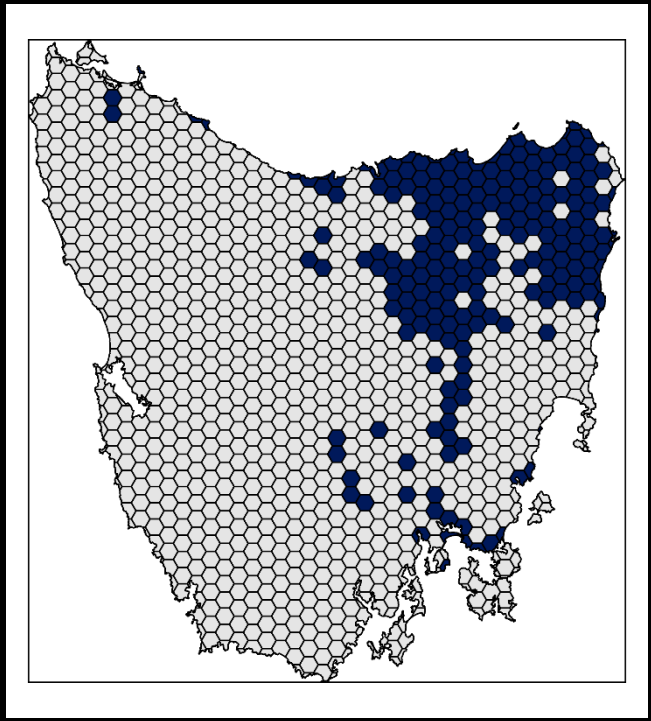
Design your problem

```
problem(tas_pu, tas_features,
        "cost") %>%
add_min_set_objective() %>%
add_relative_targets(0.1) %>%
add_locked_in_constraints("in") %>%
add_binary_decisions() %>%
add_gurobi_solver(gap = 0) %>%
solve()
```



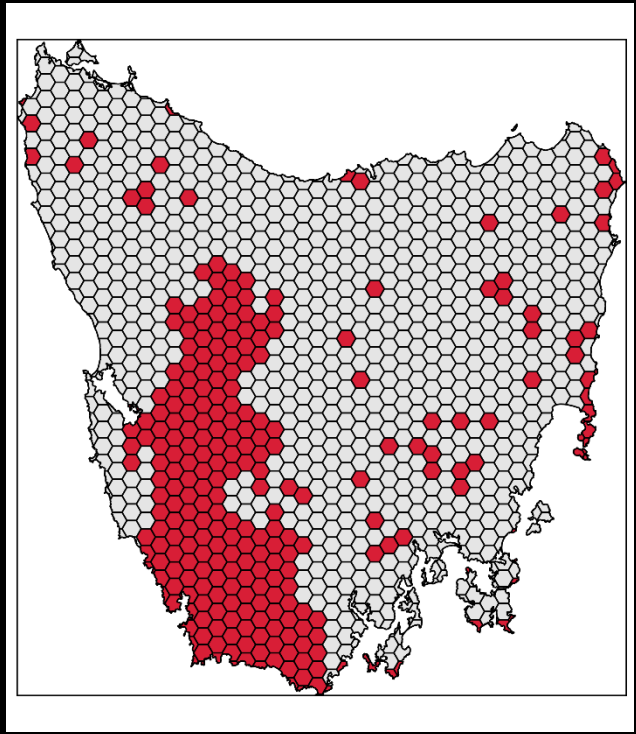
Design your problem

```
problem(tas_pu, tas_features,
        "cost") %>%
add_min_set_objective() %>%
add_relative_targets(0.1) %>%
add_locked_in_constraints("in") %>%
add_locked_out_constraints("out") %>%
add_binary_decisions() %>%
add_gurobi_solver(gap = 0) %>%
solve()
```



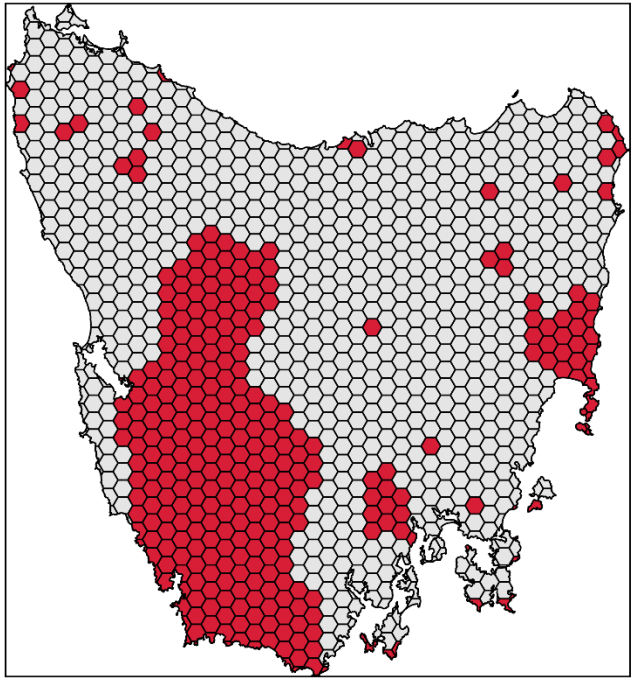
Design your problem

```
problem(tas_pu, tas_features,
        "cost") %>%
add_min_set_objective() %>%
add_relative_targets(0.1) %>%
add_locked_in_constraints("in") %>%
add_locked_out_constraints("out") %>%
add_binary_decisions() %>%
add_gurobi_solver(gap = 0) %>%
solve()
```



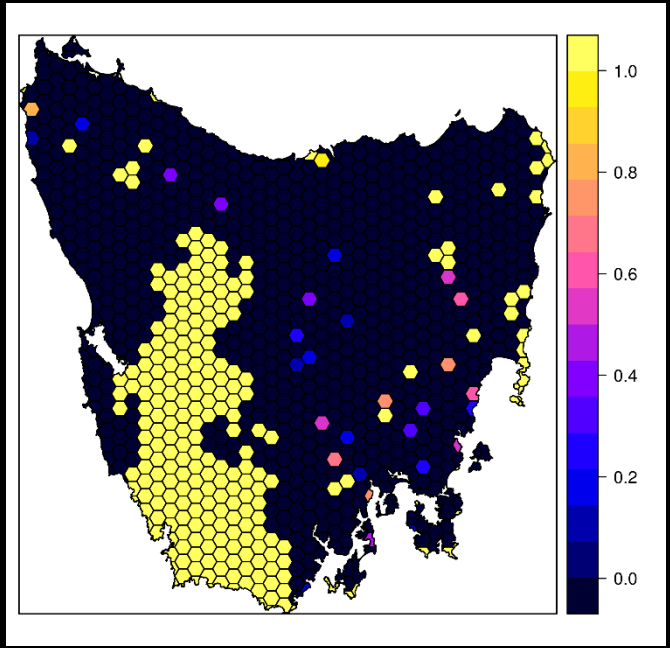
Design your problem

```
problem(tas_pu, tas_features,
        "cost") %>%
add_min_set_objective() %>%
add_relative_targets(0.1) %>%
add_locked_in_constraints("in") %>%
add_locked_out_constraints("out") %>%
add_boundary_penalties(0.01, 0.5) %>%
add_binary_decisions() %>%
add_gurobi_solver(gap = 0) %>%
solve()
```



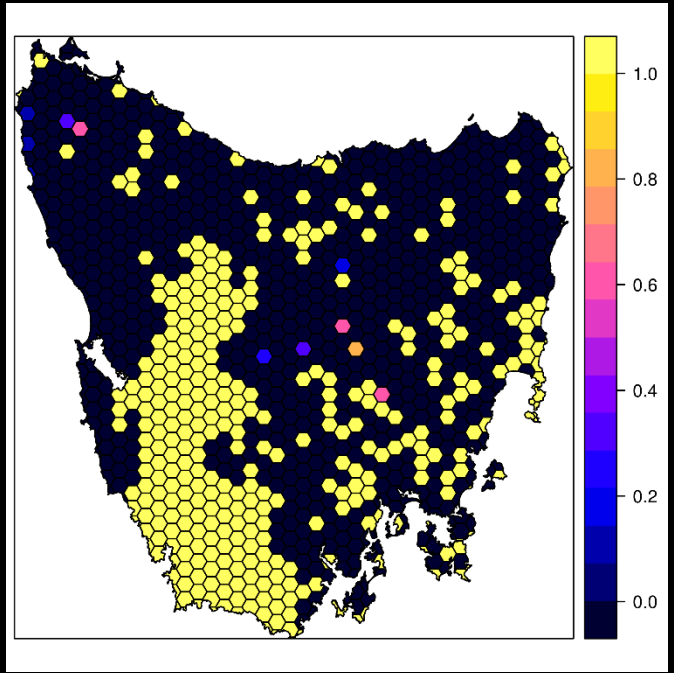
Design your problem

```
problem(tas_pu, tas_features,
        "cost") %>%
add_min_set_objective() %>%
add_relative_targets(0.1) %>%
add_locked_in_constraints("in") %>%
add_locked_out_constraints("out") %>%
add_proportion_decisions() %>%
add_gurobi_solver(gap = 0) %>%
solve()
```

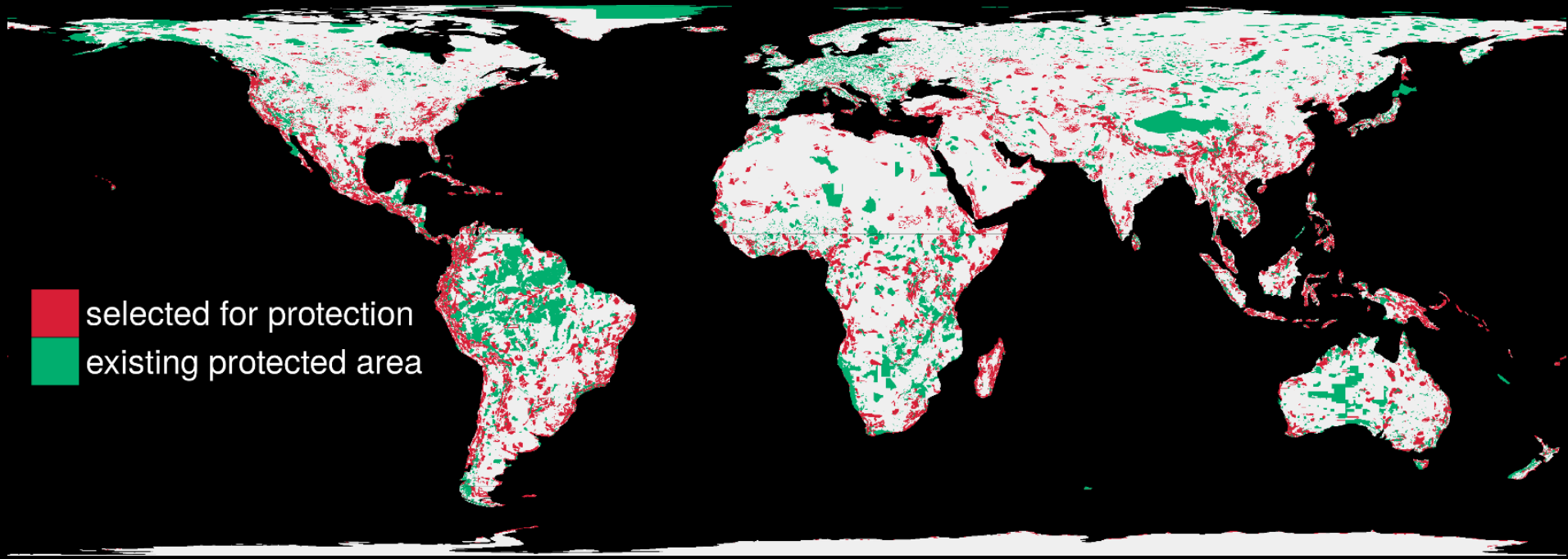


Design your problem

```
problem(tas_pu, tas_features,
        "cost") %>%
add_max_features_objective(budget)%>%
add_relative_targets(0.1) %>%
add_locked_in_constraints("in") %>%
add_locked_out_constraints("out") %>%
add_proportion_decisions() %>%
add_gurobi_solver(gap = 0) %>%
solve()
```



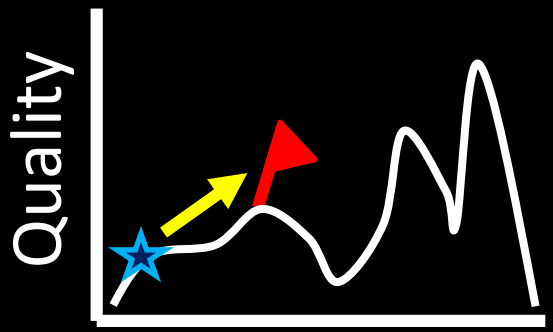
Solve it fast!



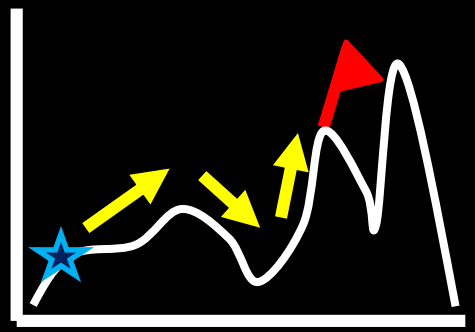
1.5 million planning units & 22,644 species: 76 minutes

Guaranteed quality

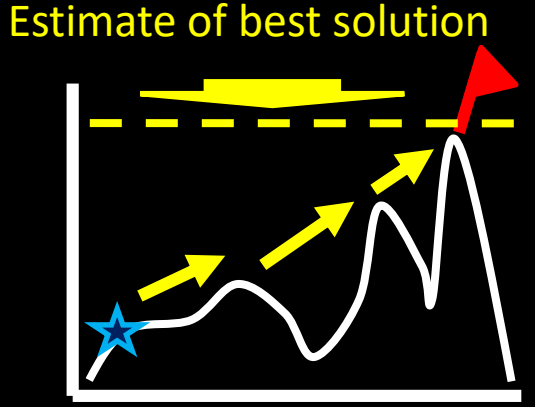
Heuristic algorithms



Meta-heuristic algorithms

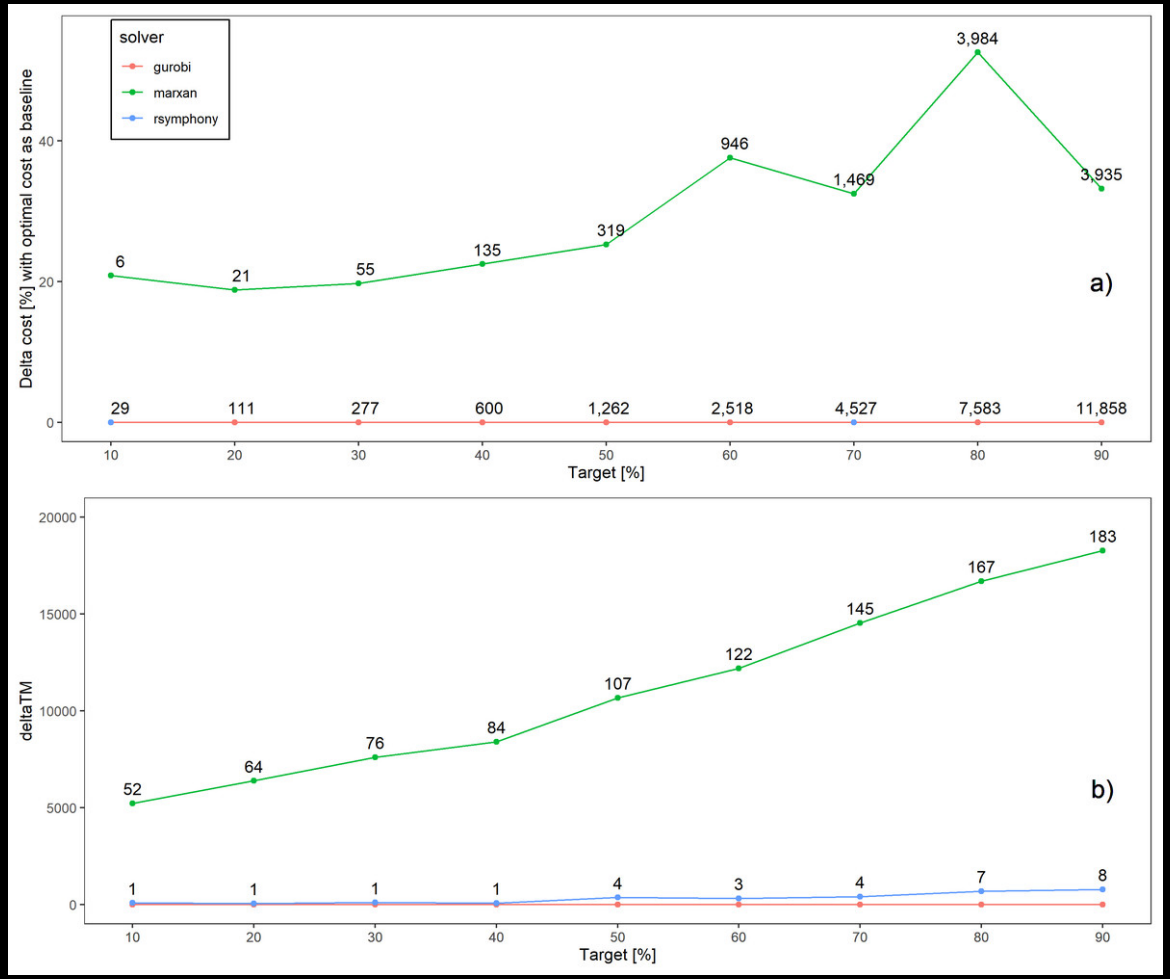


Exact algorithms



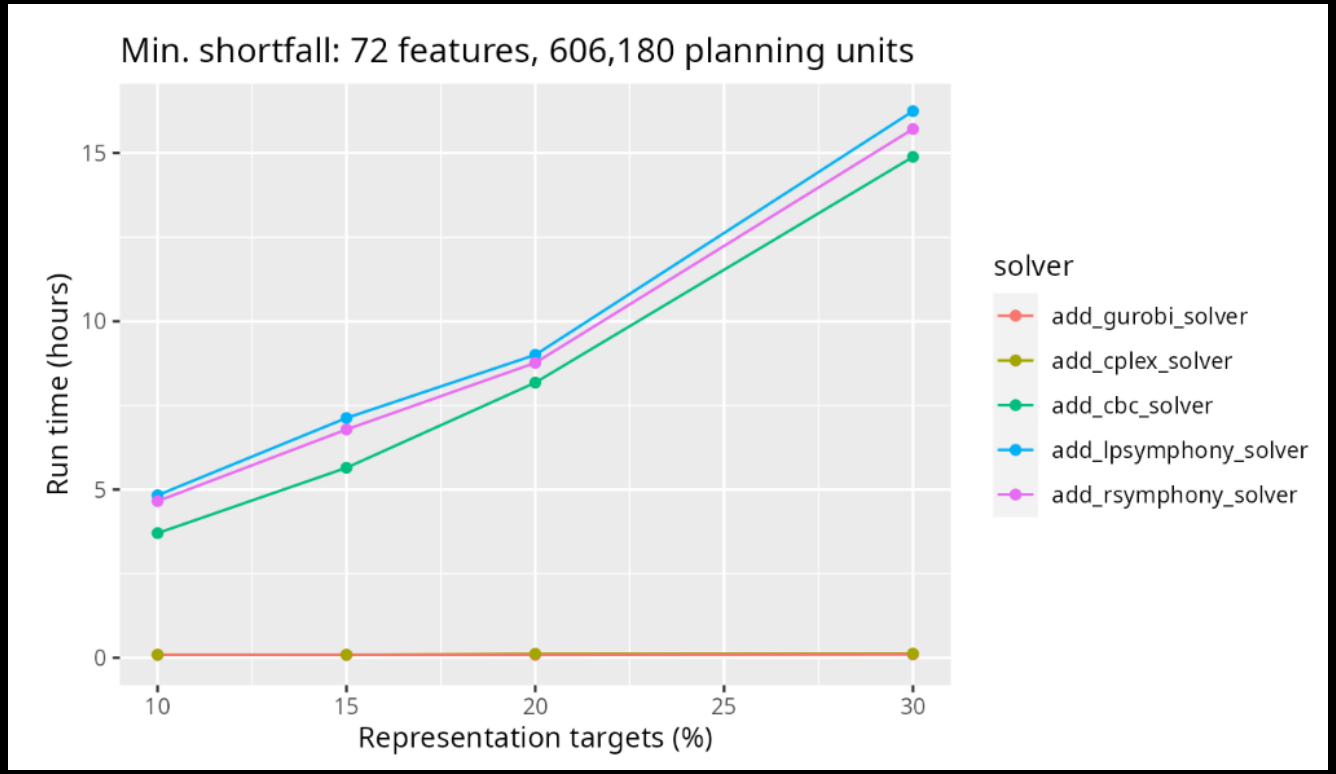
MARXAN
conservation solutions

GUROBI OPTIMIZATION
IBM CPLEX
COIN|OR



Solve efficiently + fast

Schuster et al. (2020) PeerJ, DOI:10.7717/peerj.9258



The catch: for complex problems, open-source solvers are a lot slower than Gurobi and IBM CPLEX

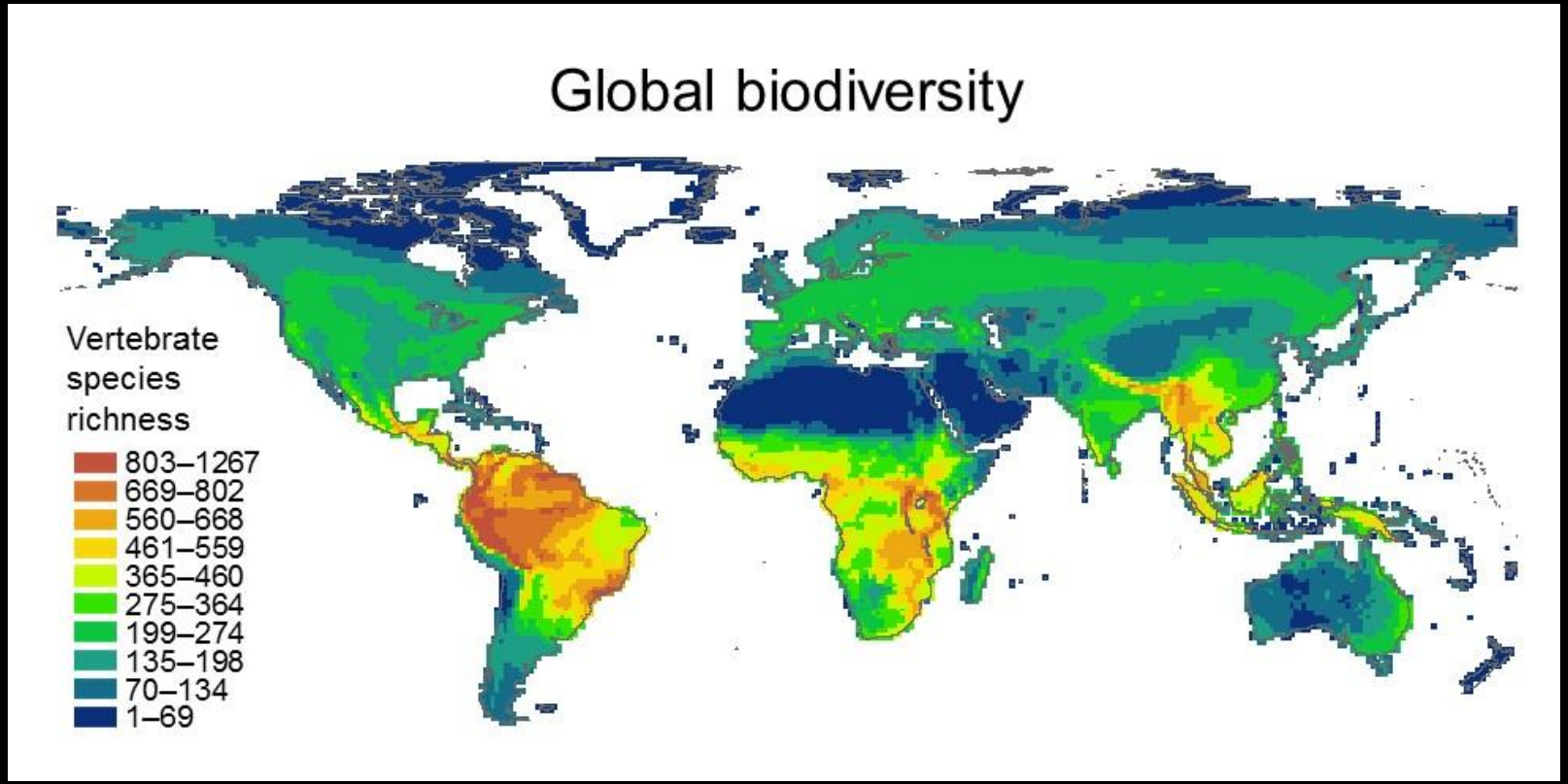
(https://prioritizr.net/articles/solver_benchmarks.html)

Asset maps vs. priority maps

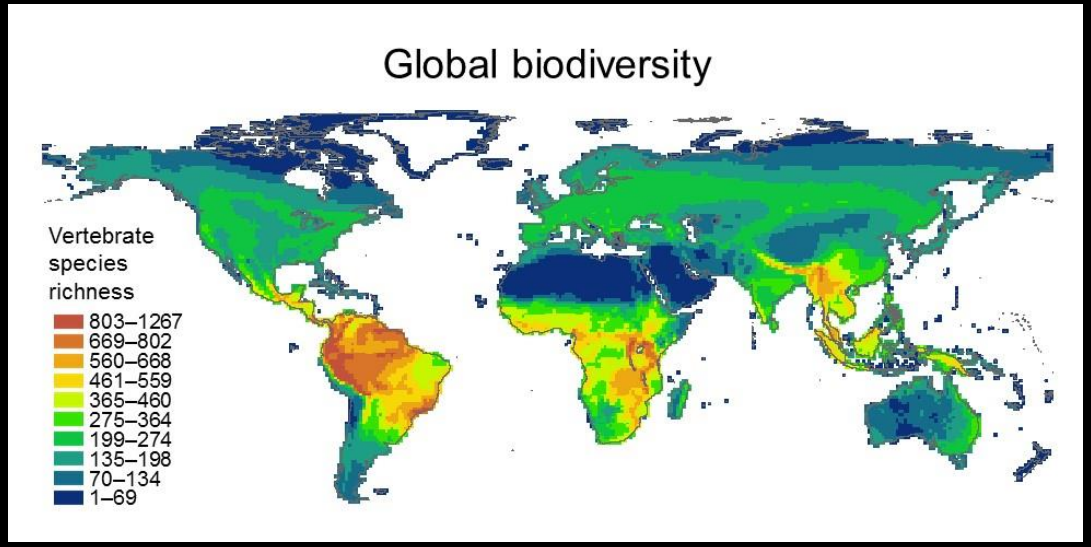
- Asset maps: where is biodiversity?
  - potential data for informing reserve selection

- Priority maps: where to conserve biodiversity?
  - have explicit actions (e.g. protect)
  - have explicit well-defined objectives
  - have explicit constraints (e.g. targets, budgets)

Asset map or priority map?



Asset map or priority map?

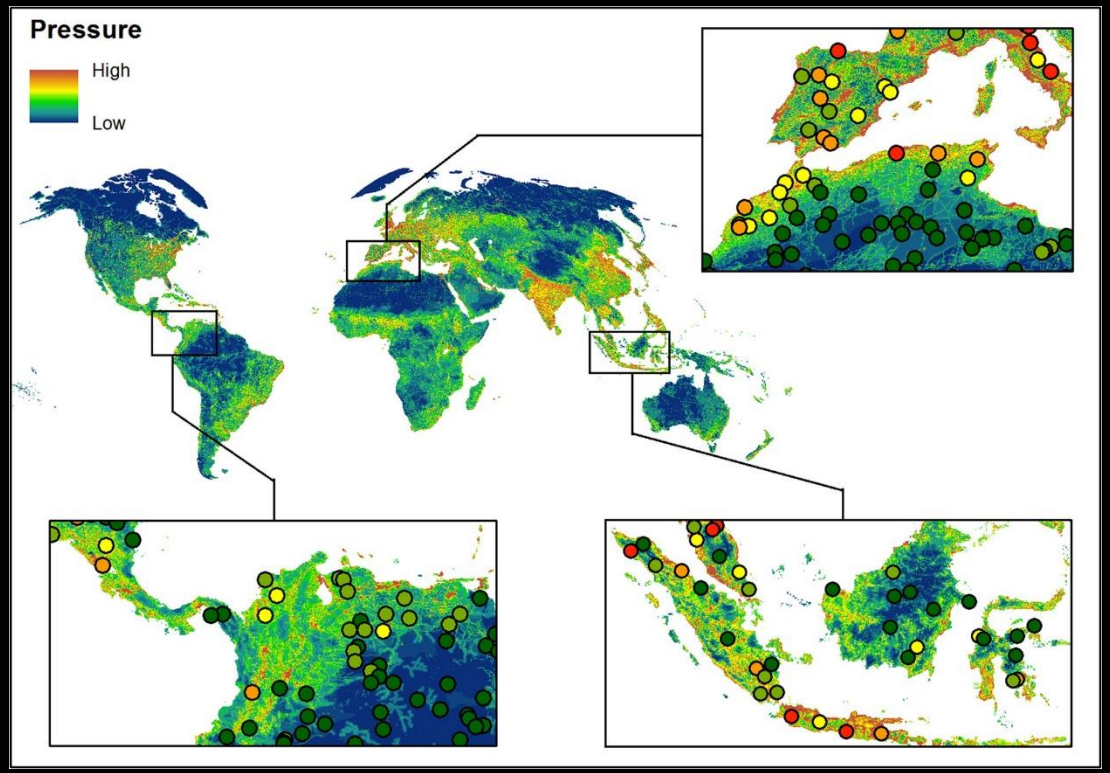


Totally useless!

The underlying data on each species distribution is needed

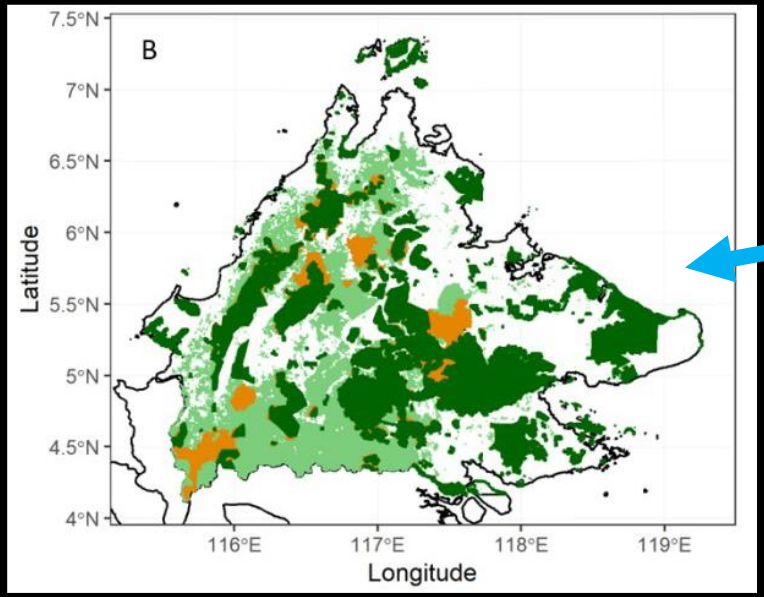
Asset map or priority map?

Human footprint index; higher = more anthropogenic alteration



Venter, et al. (2016), Scientific Data, doi:10.1038/sdata.2016.67

Asset map or priority map?

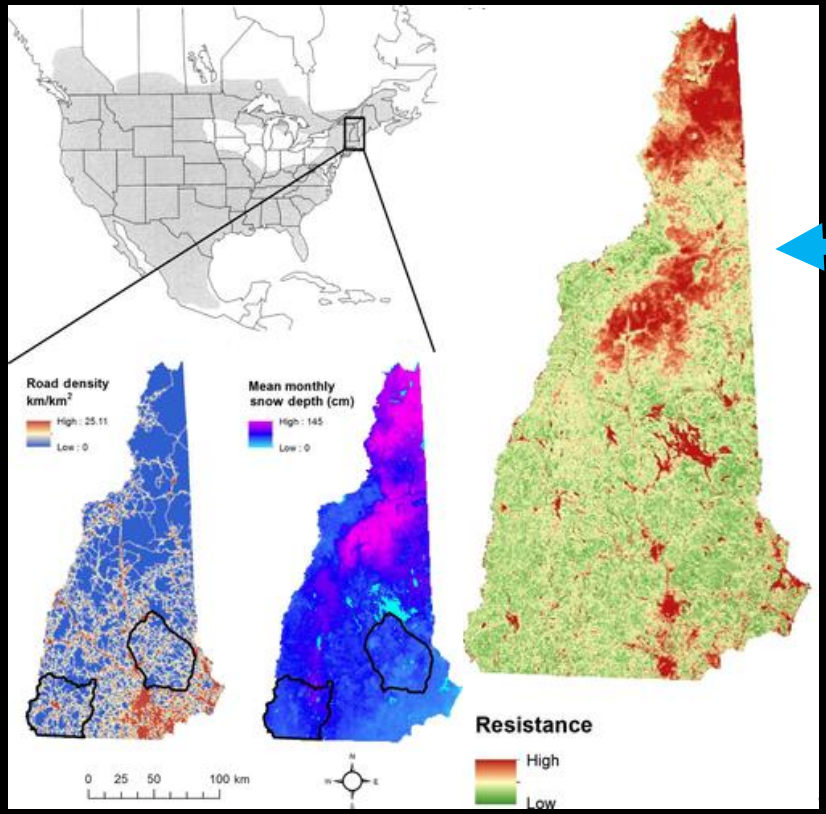


(orange) places for protected area establishment
(dark green) existing protected areas
(light green) remaining forested areas

Methods: “we prioritized the input features for each of seven categories (i.e., plants, butterflies, vertebrates, aboveground carbon, forest types, elevational connectivity, and dispersal corridors) […] with the objective of maximizing the number of features that meet a specified target without exceeding a land area budget.”

Williams, et al. (2020) Cons Biol, doi:10.1111/cobi.13450

Asset map or priority map?



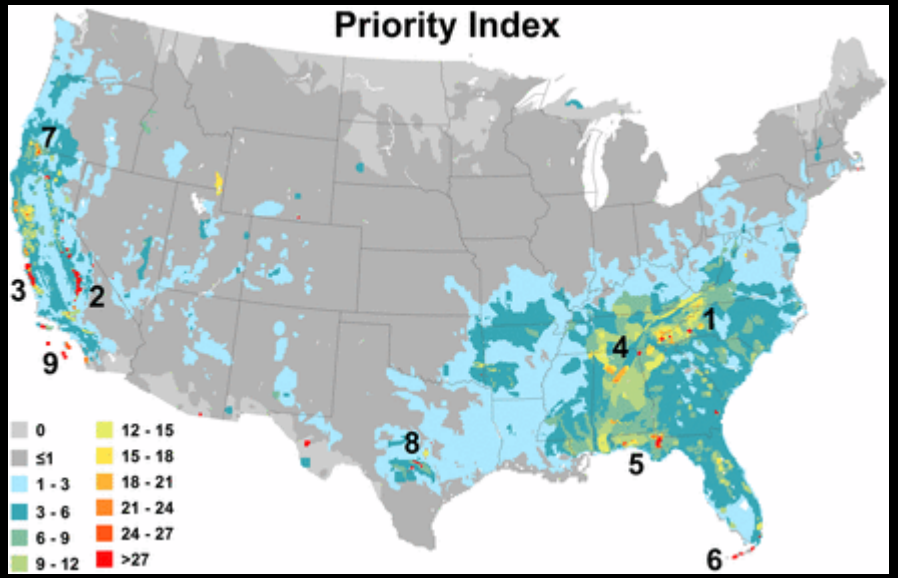
Landscape resistance to Bobcat connectivity

Red = High barrier to connectivity

Green = Low barrier to connectivity

Reed, et al. (2017) Anim Conserv, doi:10.1111/acv.12325

Asset map or priority map?



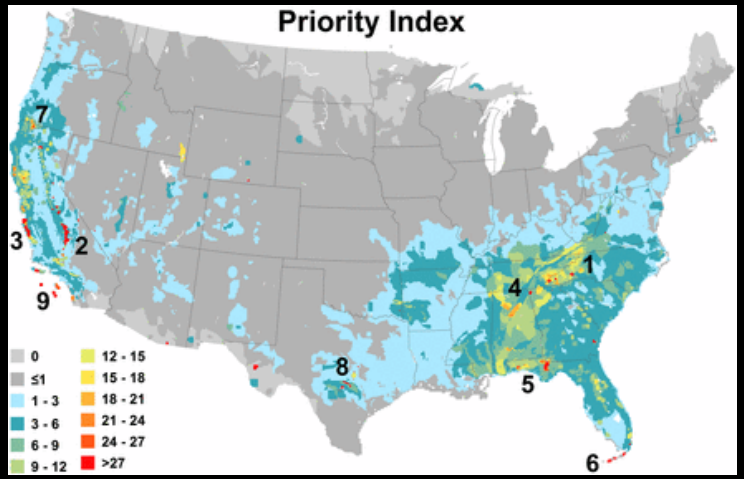
"[..] analysis indicates that remaining habitat in these areas, and potential for restoring habitat, is a top priority for biodiversity conservation."

Methods: "To prioritize lands for future conservation, we focused on the >1,200 endemic species […]. For each species, we calculated a priority score equal to the proportion of the species' range that is unprotected (i.e., not in IUCN I to VI protected areas) divided by the area of the species' range. This score increases as range size decreases, in accordance with the well-established relationship between range area and extinction risk (**20⇓–22**) Priority maps sum scores […] all taxonomic groups (**Fig. 4**)."

Jenkins, et al. (2015) PNAS, doi:10.1073/pnas.1418034112

Asset map or priority map?

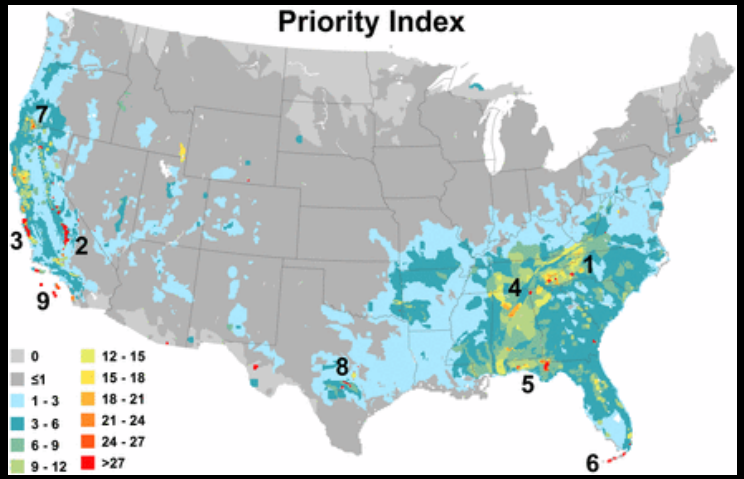
"In their recent article, Jenkins et al. (1) identify "priorities for future conservation investment" in the continental United States..."



"Such scoring systems defy contemporary planning approaches, and have repeatedly been shown to identify priorities that are biologically ineffective and economically inefficient (2)."

Brown, et al. (2015) PNAS, doi:10.1073/pnas.1509189112

Asset map or priority map?



"First, priority setting requires explicit and defensible objectives (2) […] The locations highlighted by Jenkins et al. (1) simply contain the largest number of relatively unprotected and restricted-range species, and it is unclear whether protecting these locations would achieve any particular objective."

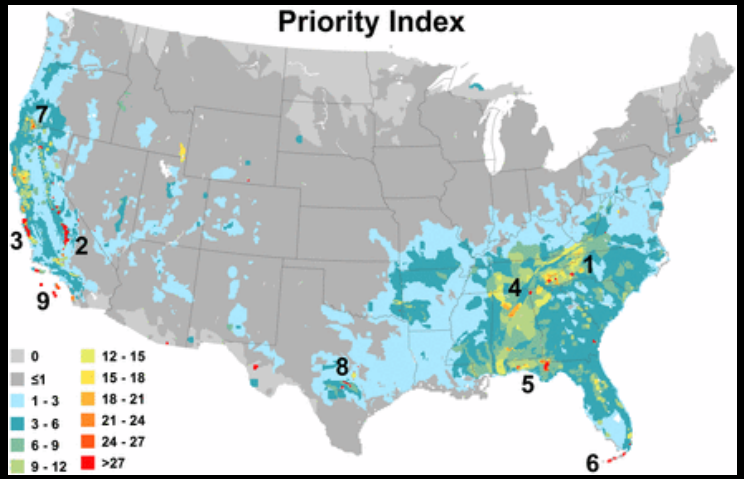
Brown, et al. (2015) PNAS, doi:10.1073/pnas.1509189112

Asset map or priority map?

“Second, conservation plans should prioritize actions, not species or places (2). Prioritizing species does not clarify what actions should be taken to avert species’ declines. Jenkins et al. (1) refer to protected areas, yet they also mention restoration and easements. Each of these actions has different costs and probabilities of success. Ignoring the costs and feasibilities of these different actions results in inefficient plans (2).”

Brown, et al. (2015) PNAS, doi:10.1073/pnas.1509189112

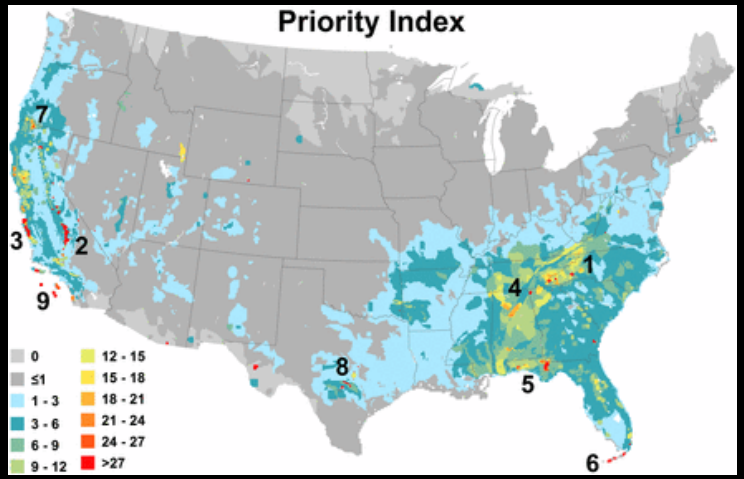
Asset map or priority map?



"Third, conservation plans should consider at least some of the economic, political, and social constraints on actions."

Brown, et al. (2015) PNAS, doi:10.1073/pnas.1509189112

Asset map or priority map?



"Finally, a central principle of conservation planning is that decisions account for the composition of species assemblages across sites ("complementarity"; see ref. 4). Considering complementarity ensures that protection is directed at all species, not simply those colocated in species-richness hotspots."

Brown, et al. (2015) PNAS, doi:10.1073/pnas.1509189112

What you will do today

- Workshop manual section 5.
  - Generate prioritisations!
  - Answer questions in the manual

https://prioritizr.github.io/workshop

Getting help

- prioritizr website
  - https://prioritizr.net
- RDocumentation
  - https://www.rdocumentation.org
- Geocompr
  - https://geocompr.robinlovelace.net/

jeffrey.hanson@uqconnect.edu.au

github.com/prioritizr/prioritizr

prioritizr.net