Valuating the Impact of Multiple Small Hydropower Plants on Biodiversity in River Networks

Philipp Meier, Daniel Viviroli, Carlos J. Melian

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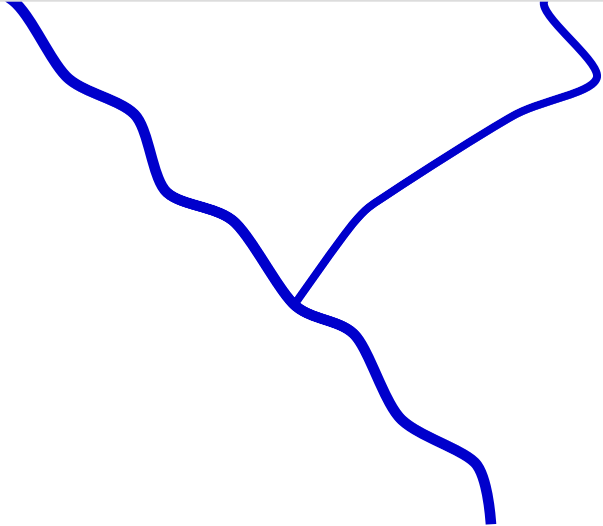
Trade-off between hydropower and ecosystem services

Where should we build small hydropower plants?



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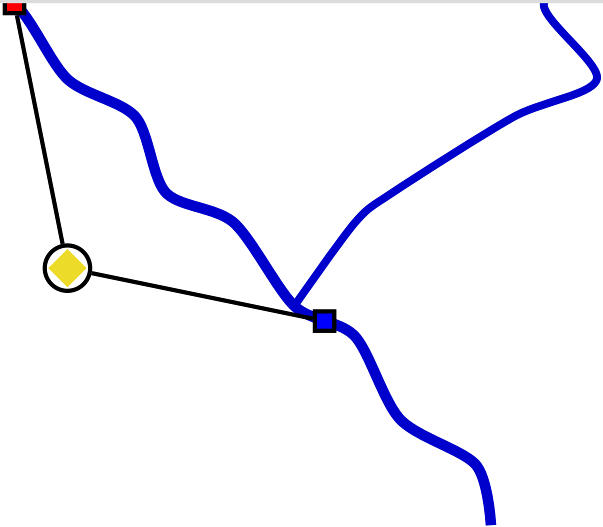

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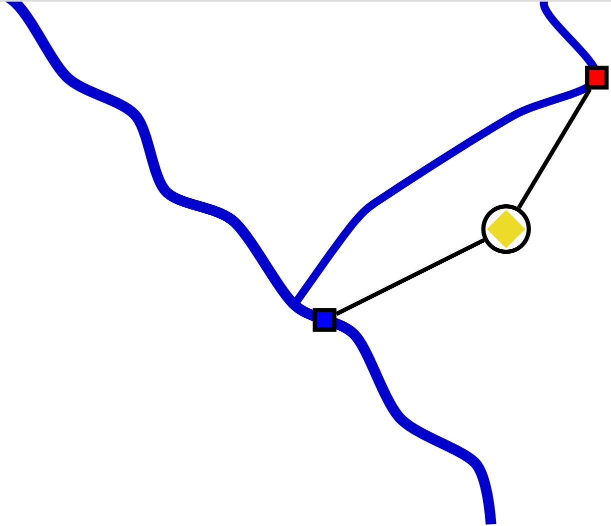

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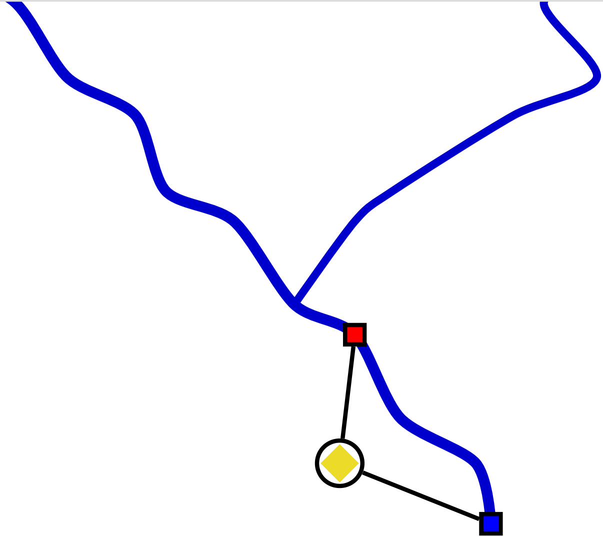

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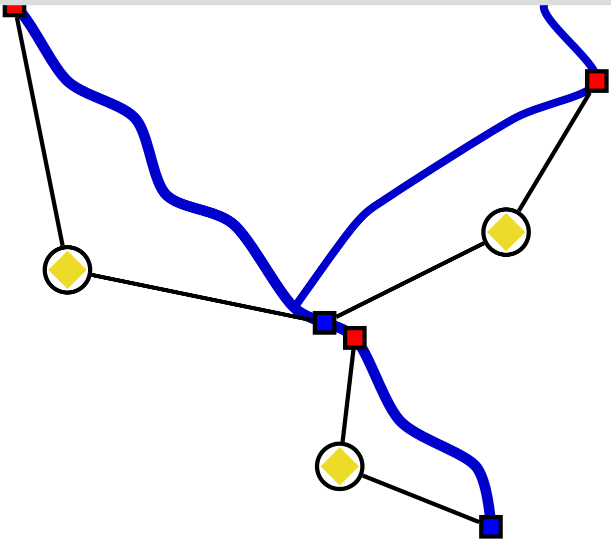


Trade-off between hydropower and ecosystem services

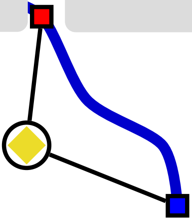
Where should we build small hydropower plants?

Economic criteria

- Expected power production
- Investment cost
- ...

Ecological criteria

- Mostly local criteria expressed as indicators
  - Hydrologic alteration
  - Morphology
  - Ecological state



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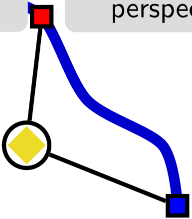
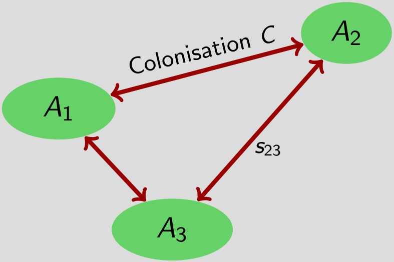
➜ Need to include network perspective



Metapopulation capacity λ_M

Landscape as network of habitats



- Equilibrium between extinction $E_i = \frac{e_o}{A_i}$ and colonisation $C_i = c_o \sum_j e^{-\alpha s_{ij}} A_j p_j$

s_{ij}	Distance between patch i and j
A_i	Area of patch i
p_i	Probability that patch i is occupied
$\frac{1}{\alpha}$	Mean migration distance

Metapopulation capacity λ_M

- Defined as the leading eigenvalue of matrix **M**, with $m_{ij} = e^{-\alpha s_{ij}} A_i A_j$.
- Rank different landscapes by their ability to support a viable population

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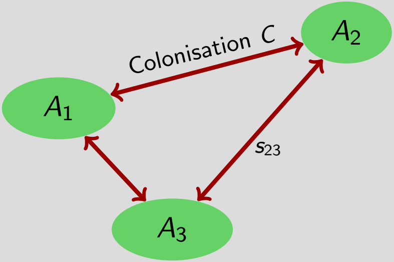

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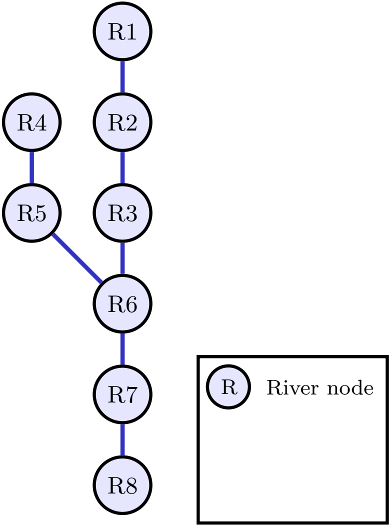
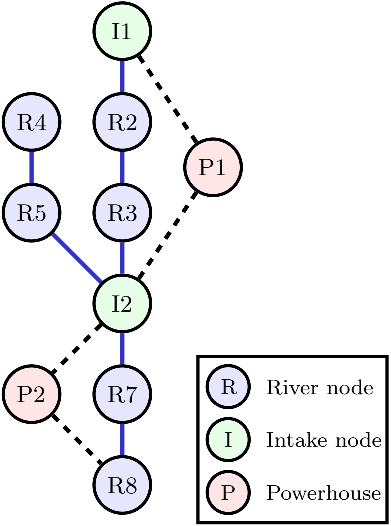
Optimisation model



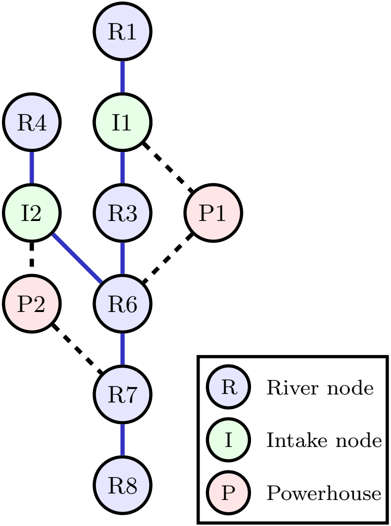
1. River network divided into nodes and links
   - $\frac{\Delta Q}{\Delta x}$ at each node

Optimisation model



1. River network divided into nodes and links
   - $\frac{\Delta Q}{\Delta x}$ at each node
2. Position of power plants
   - Determined by optimisation algorithm
3. Simulation
   - Flow routing
   - Evaluation of objectives

Optimisation model



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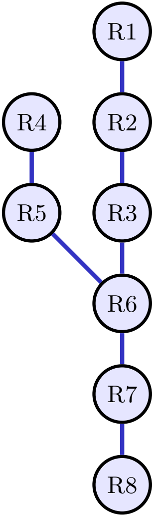
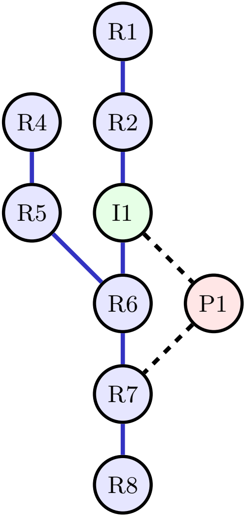


Metapopulation capacity

- Habitat area dependent on mean discharge and segment length
- Dispersal not biased by flow direction

Optimisation model



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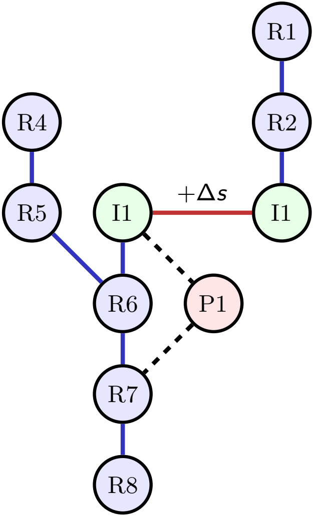

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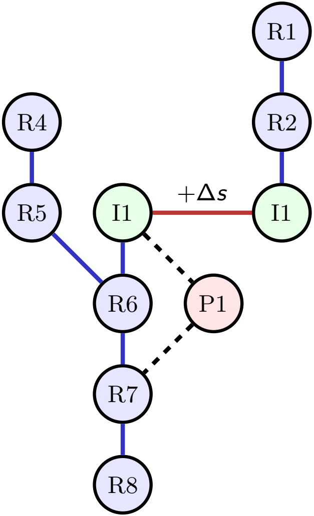

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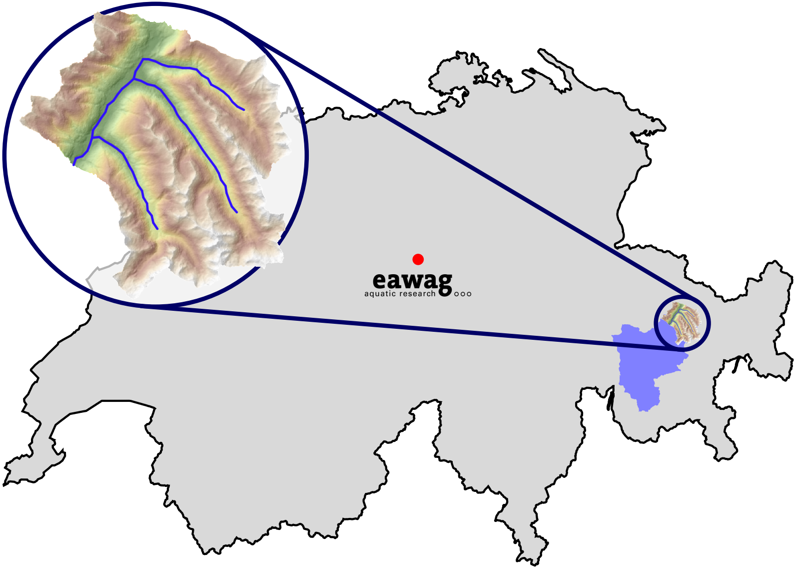
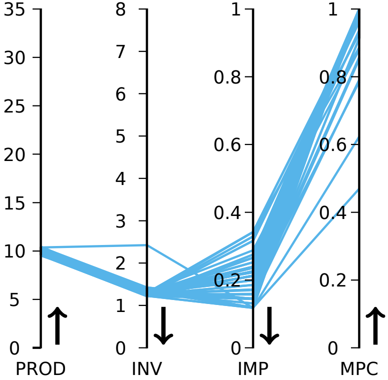
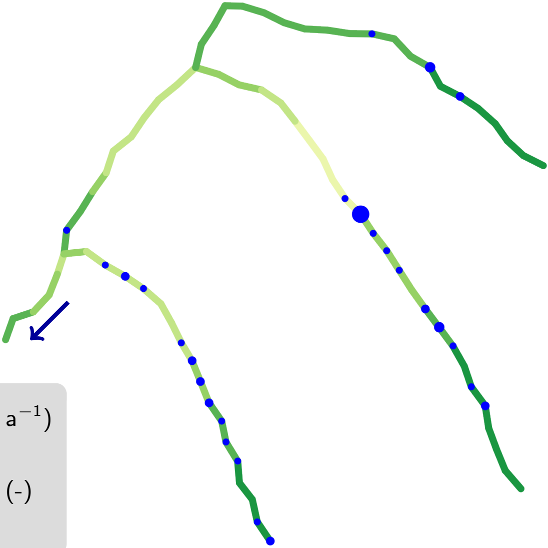
- River network derived from DEM
- $\frac{\Delta Q}{\Delta x}$ at each node from hydrological model (PREVAH)
- Simulation model implemented using Pynsim
- Multi-objective evolutionary algorithm: BorgMOEA

Study area



Results





PROD	Electricity production (GWh a^{-1})
INV	Investment cost
IMP	Fraction of impacted length (-)
MPC	Metapopulation capacity

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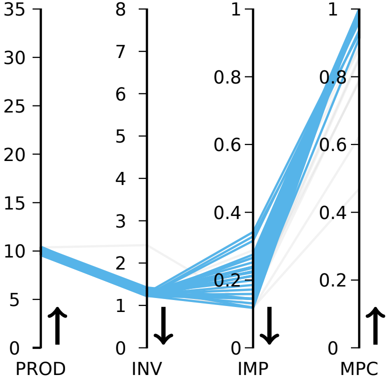

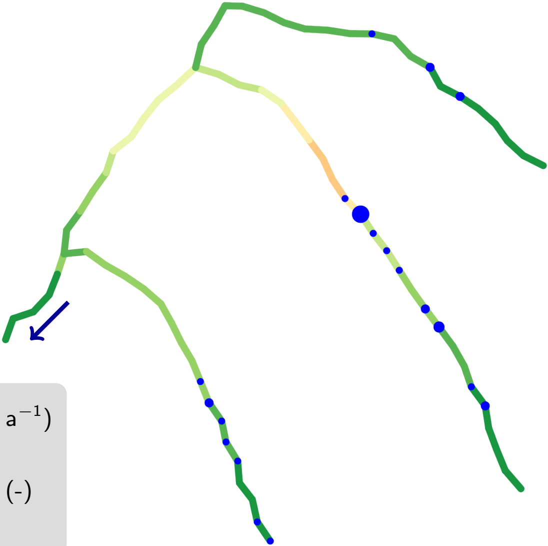

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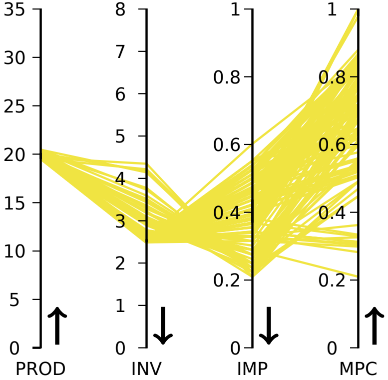

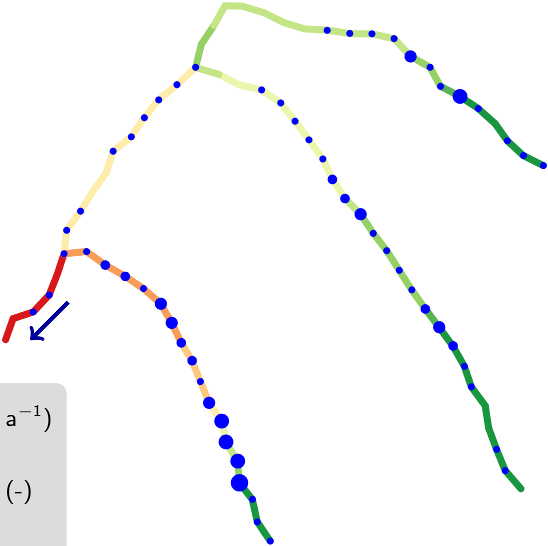

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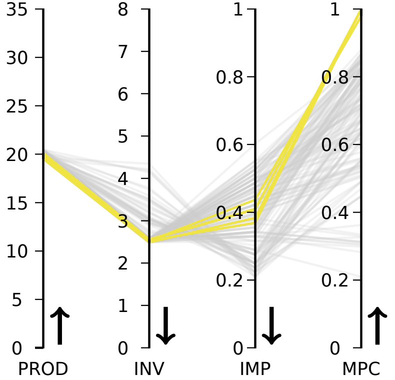

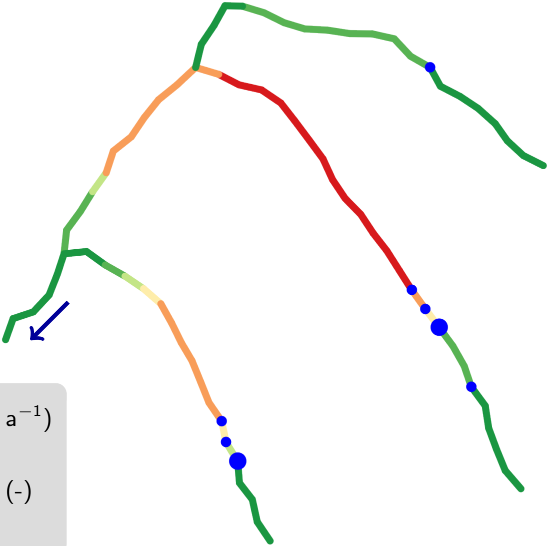

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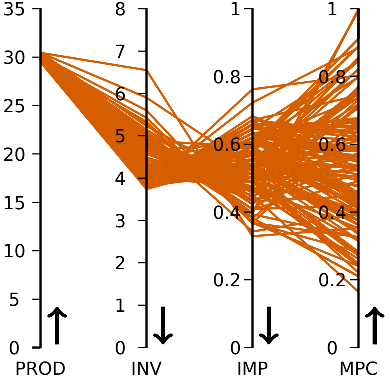

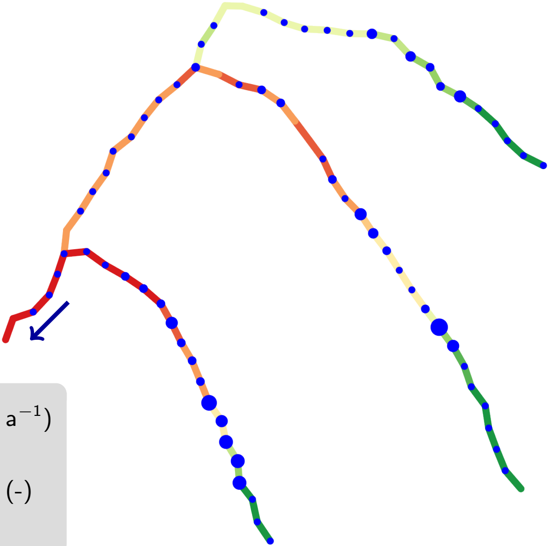

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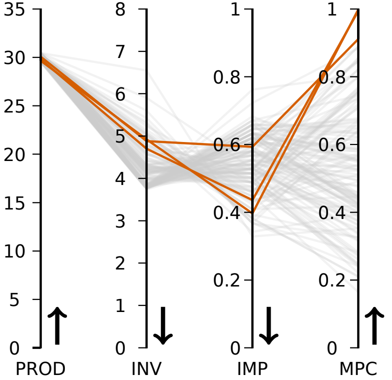

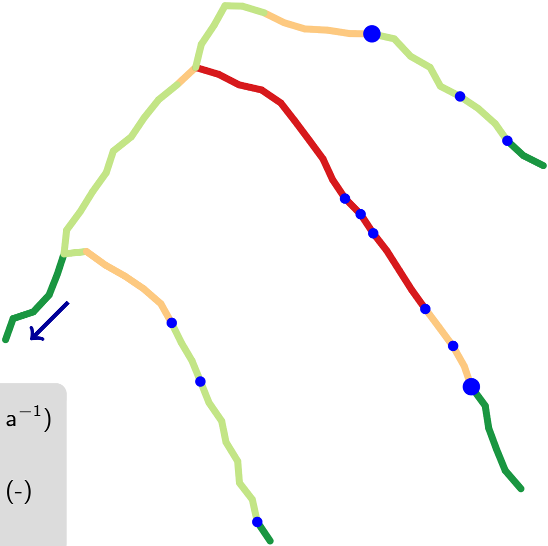

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Conclusions

- Need to address the value of a river network as a system
- Metapopulation capacity can be a useful tool for determining more suitable locations of run-of-river power plants
- Considering network effects does not necessarily increase costs
- The loss of habitat area dominates over the disruption of migration paths