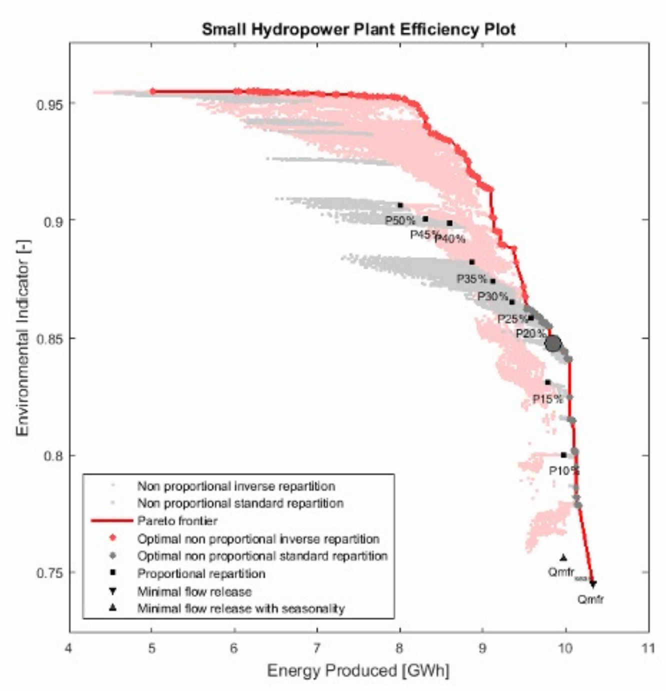
Water Resources Engineering and Management

(CIVIL-466, A.Y. 2024-2025)

5 ETCS, Master course

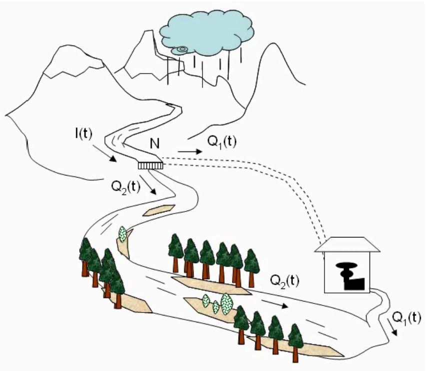


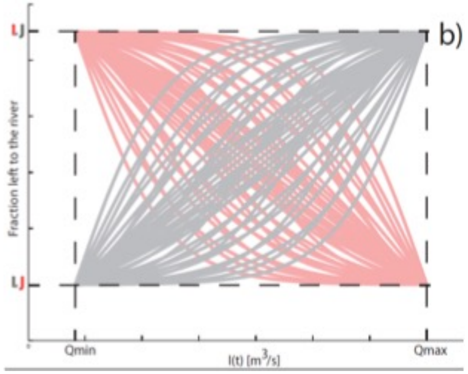
Lecture 10-3: Simulation and Pareto optimal allocation, GUI non-proportional rules

Prof. P. Perona

Platform of hydraulic constructions

Small hydropower: optimal allocation policies



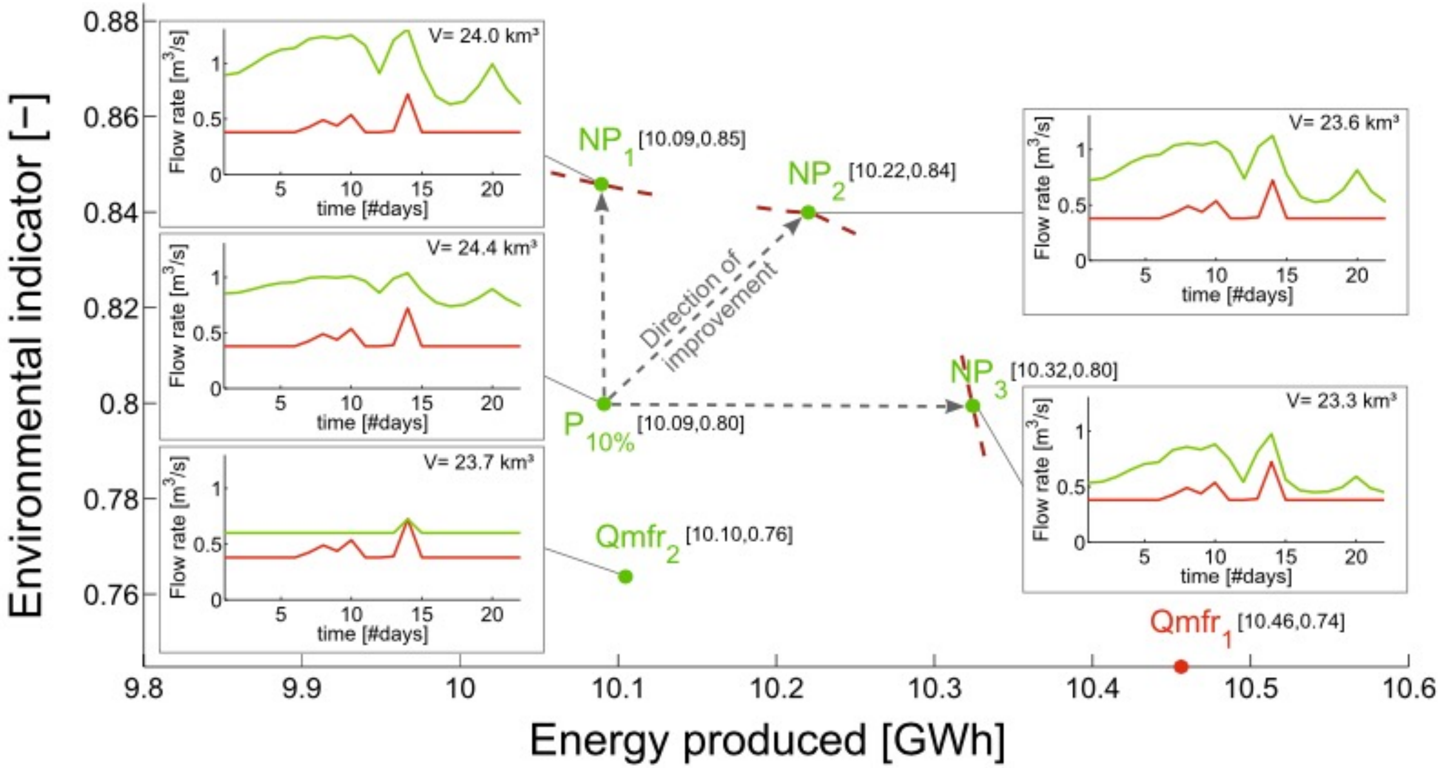


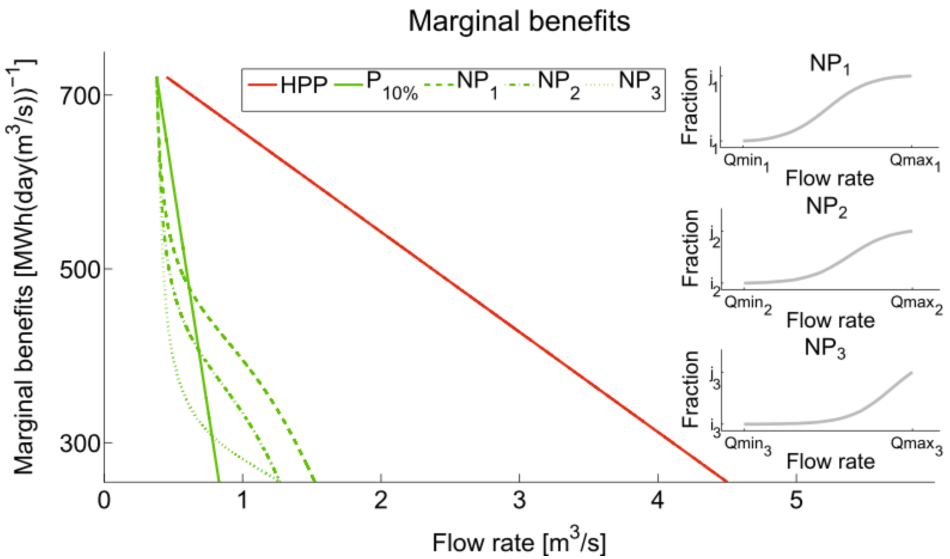
Razurel et al., WRM, 2015; ADW 2018

Perona et al., Frontiers Env Sci. (2021)

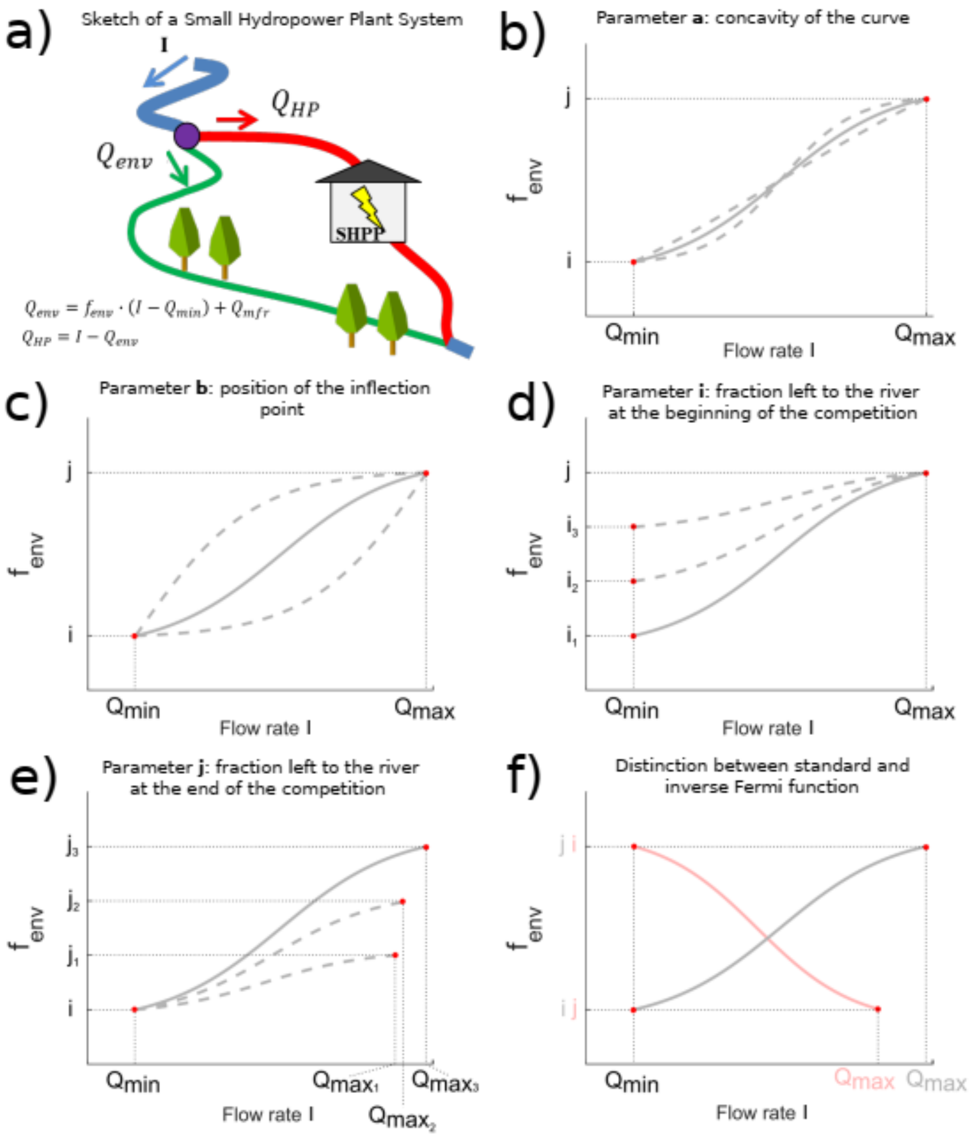
What did we learn?

We learned that dynamic allocation policies non necessarily imply loosing water, but they are generally better to maintain more natural flow like variability in the regulated river reach

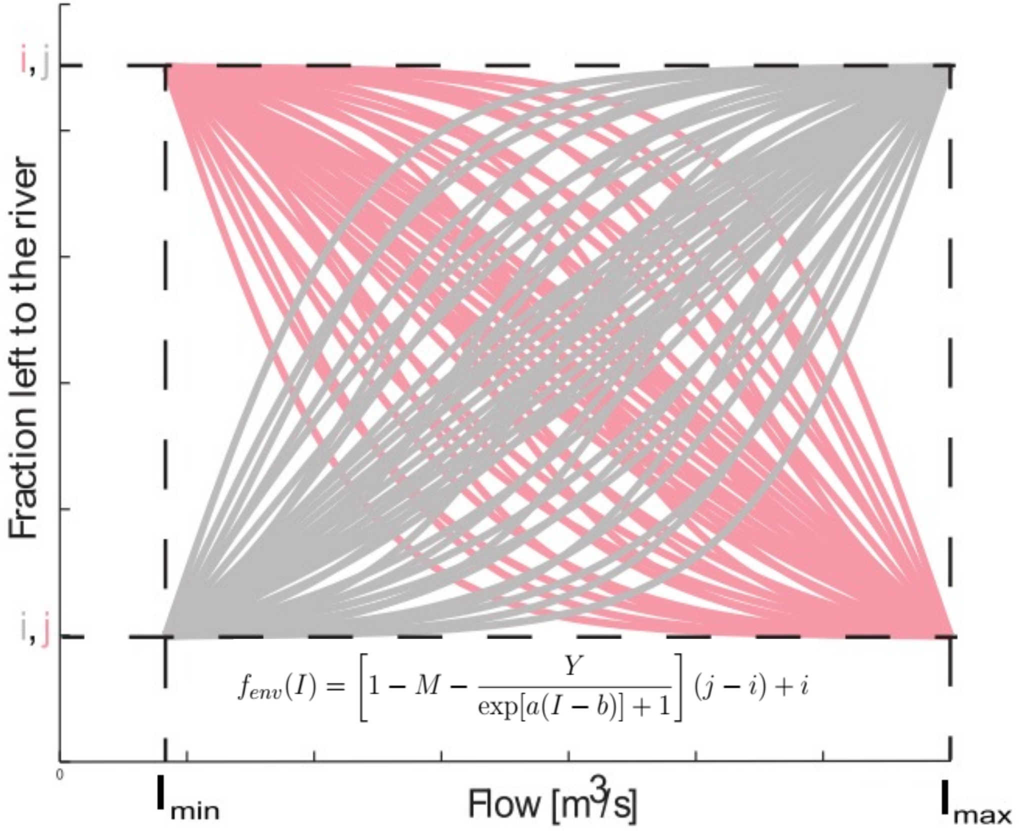




Non-proportional flow release: proof of concept



We tested hundreds of thousand redistribution policies in order to identify the most efficient (in Pareto sense) one



Assessment of ecological performances

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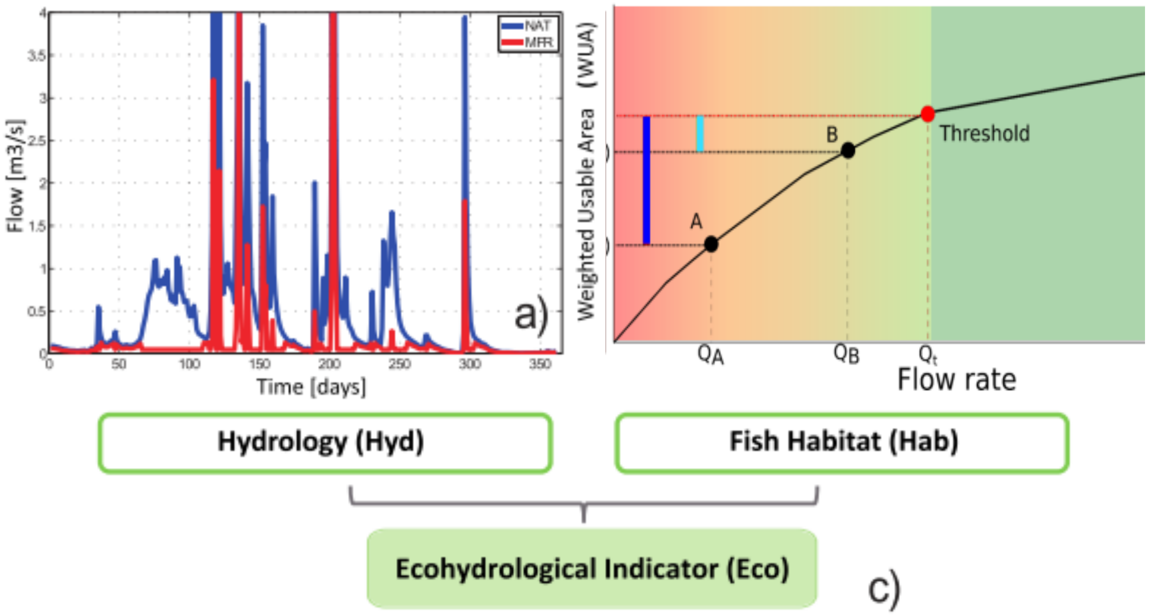
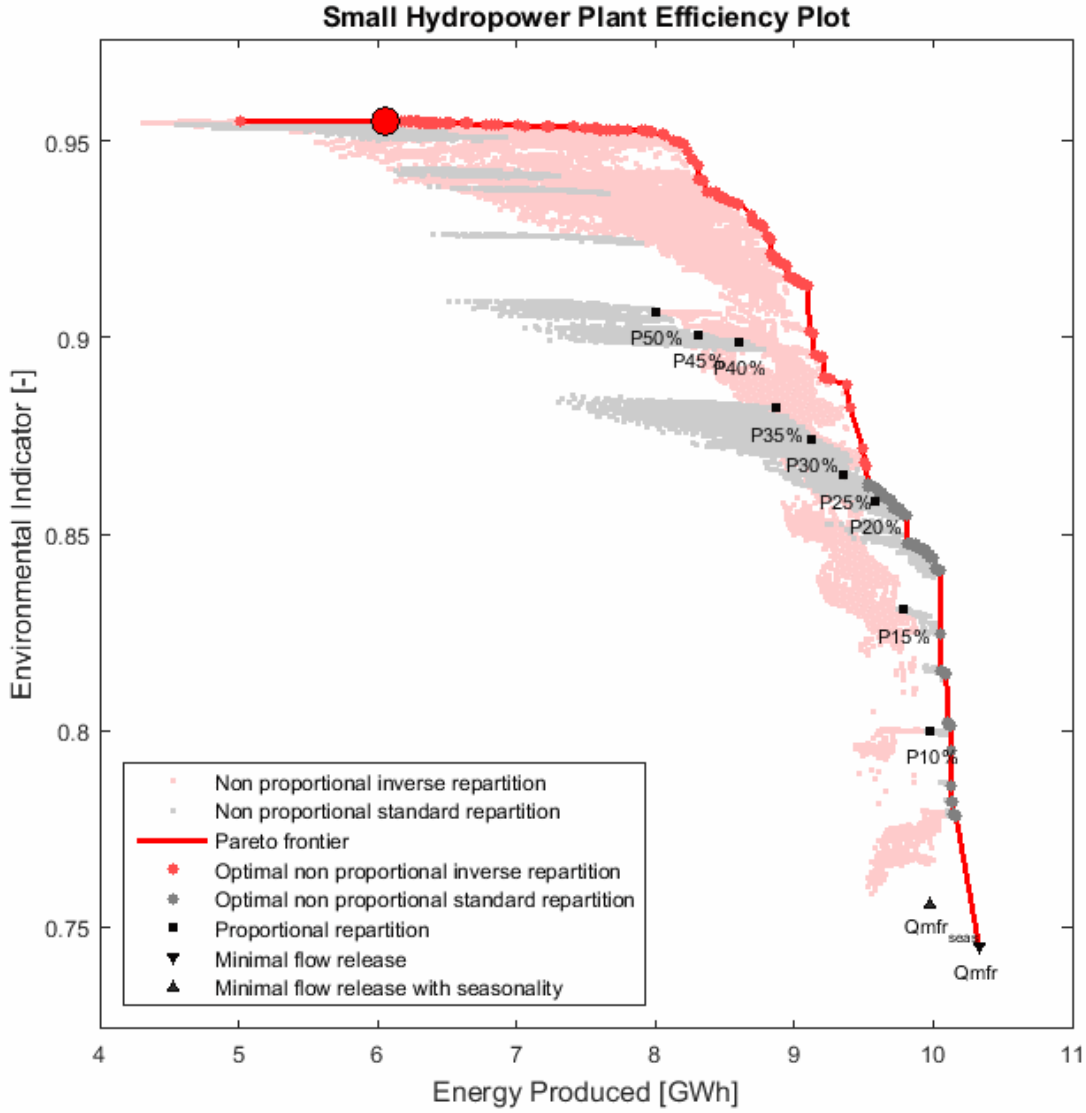
Global performances in respect of Q_{347} using Richter's hydrological indicators for flow variability

IHA statistics group	Regime characteristics	Hydrologic parameters
Group 1: Magnitudes of monthly water conditions	Magnitude Timing	Mean value for each calendar month
Group 2: Magnitudes and duration of annual extreme water conditions	Magnitude Duration	Annual minima 1-d mean Annual maxima 1-d mean Annual minima 3-d mean Annual maxima 3-d mean Annual minima 7-d mean Annual maxima 7-d mean Annual minima 30-d mean Annual maxima 30-d mean Annual minima 90-d mean Annual maxima 90-d mean
Group 3: Timing of annual extreme water conditions	Timing	Julian date of annual 1-d maxima Julian date of annual 1-d minima
Group 4: Frequency and duration of high and low pulses	Magnitude Frequency Duration	No. of high pulses each year No. of low pulses each year Mean duration of high pulses per year Mean duration of low pulses per year
Group 5: Rate and frequency of water condition changes	Frequency Rate of change	Means of all positive differences between consecutive daily means Means of all negative differences between consecutive daily values No. of rises No. of falls

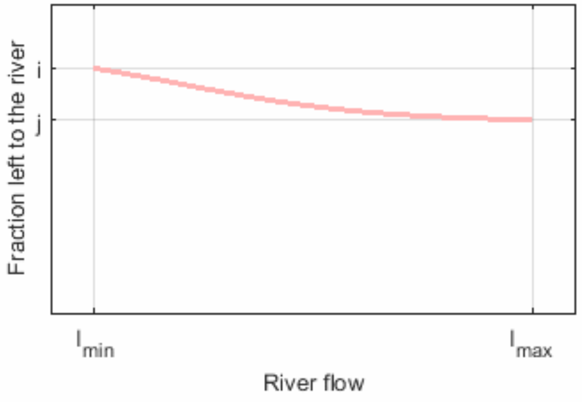


Alternative	Definition
Eco_{V1}	$max(\sum consecutive\ days\ under\ threshold)$
Eco_{V2}	$max(\sum_{i=1}^{d}(WUA(Q_i) - WUA(Q_t))^2$
Eco_{V3}	$Eco_{v1} \cdot \sum(total\ days\ under\ threshold)/(total\ number\ of\ days)$

Pareto frontier for hydropower and ecology



Use the arrows to select a point on the Pareto frontier (red line) and plot the correspondent Fermi repartition function in the graphic below.



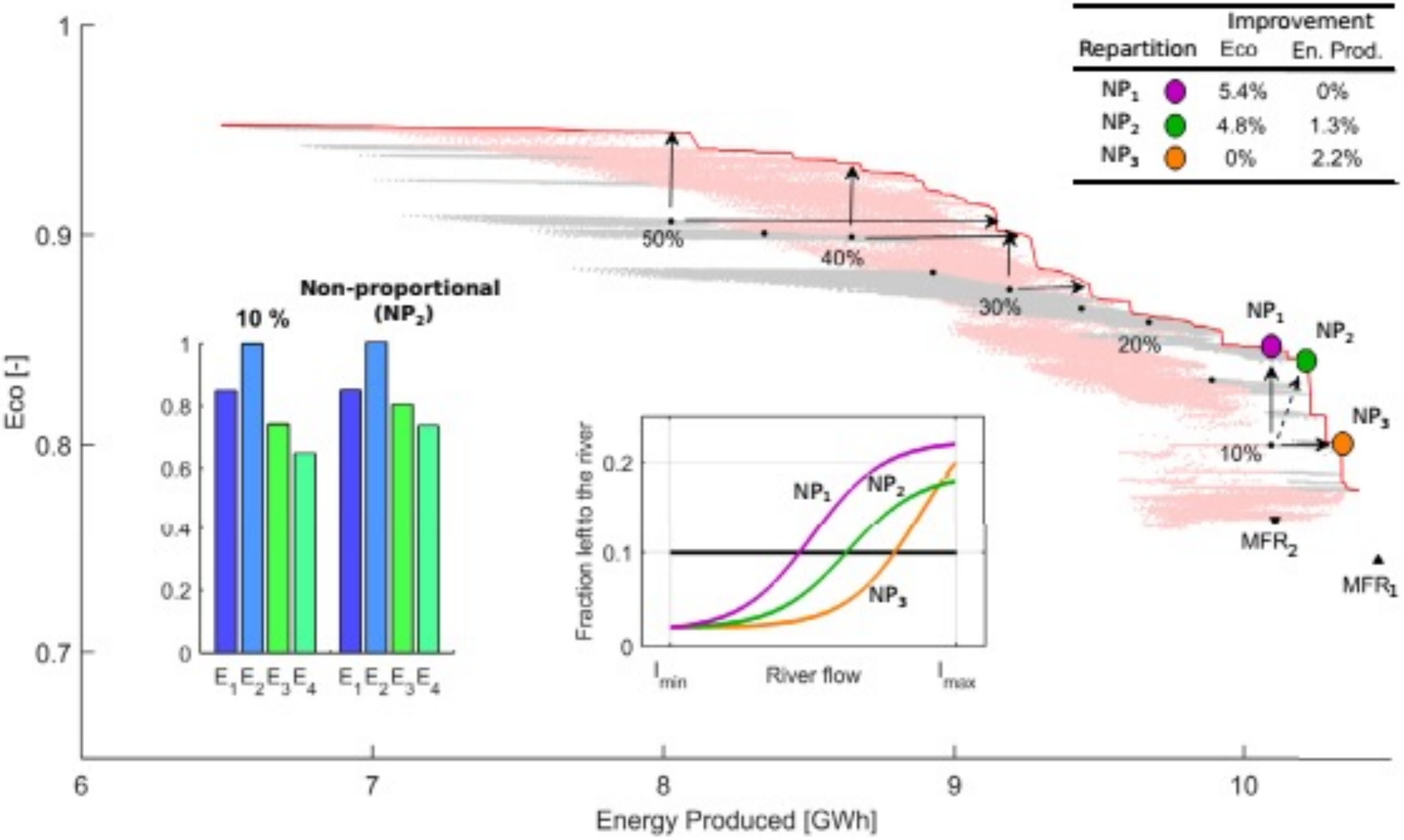
River flow range for repartition
I_min = 0.83 m3/s
I_max = 14.97 m3/s

Parameter values of the Fermi function
i = 0.85
j = 0.65
a = 4.50
b = 0.20

Save the screen as a pdf

The Pareto Frontier is almost entirely composed by non-proportional policies!

Typically used policies worldwide lie all below the Pareto frontier



Although this proves that better alternatives exist with respect to the MFR and proportional distribution, they are far from being implemented yet

Graphical User Interface for hydropower

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SMALL HYDROPOWER PLANT (Run-of-River)

Goal: Find the optimal water allocation policies that maximize energy production and preserve riverine ecosystem

Method: This model simulate different water repartition rules applied at the water intake, in the case of a small hydropower plant.
Results are presented as an efficiency plot showing, for each scenario, the Environmental Indicator vs the Energy Produced

I(t): Natural flow discharge
Q1(t): Worked flow, diverted to the powerhouse
Q2(t): Residual flow, left to the river

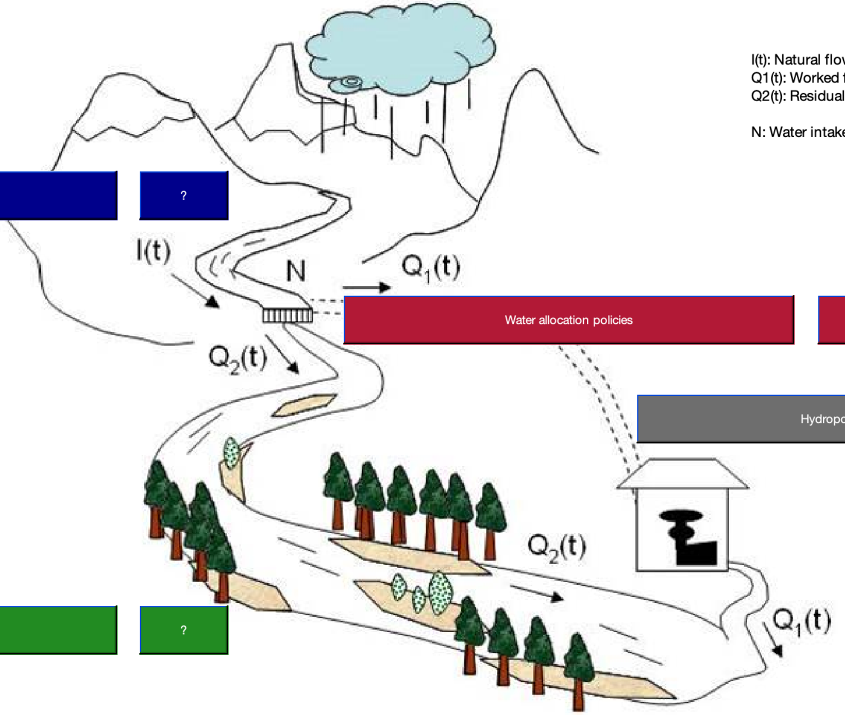
N: Water intake

River natural hydrograph | ?

Water allocation policies | ?

Hydropower plant data | ?

Habitat suitability thresholds | ?



EVALUATION OF THE DIFFERENT FLOW REDISTRIBUTION POLICIES - DISPLAY THE EFFICIENCY PLOT

Complete all the fields before you can launch the simulations

Developed by the group AHEAD

This GUI runs in Matlab and produces a phase space plot of energy generation vs ecological efficiency for a mixed small hydropower system without storage reservoir. The efficiency plot also highlights the Pareto frontiers of efficient solutions for comparing redistribution policies

User steps: 1. River natural hydrograph

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River natural hydrograph

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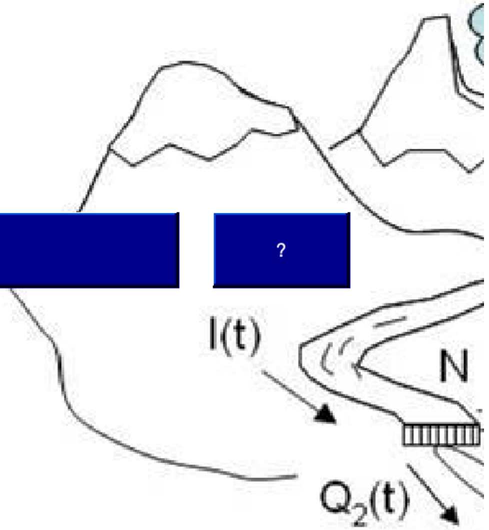
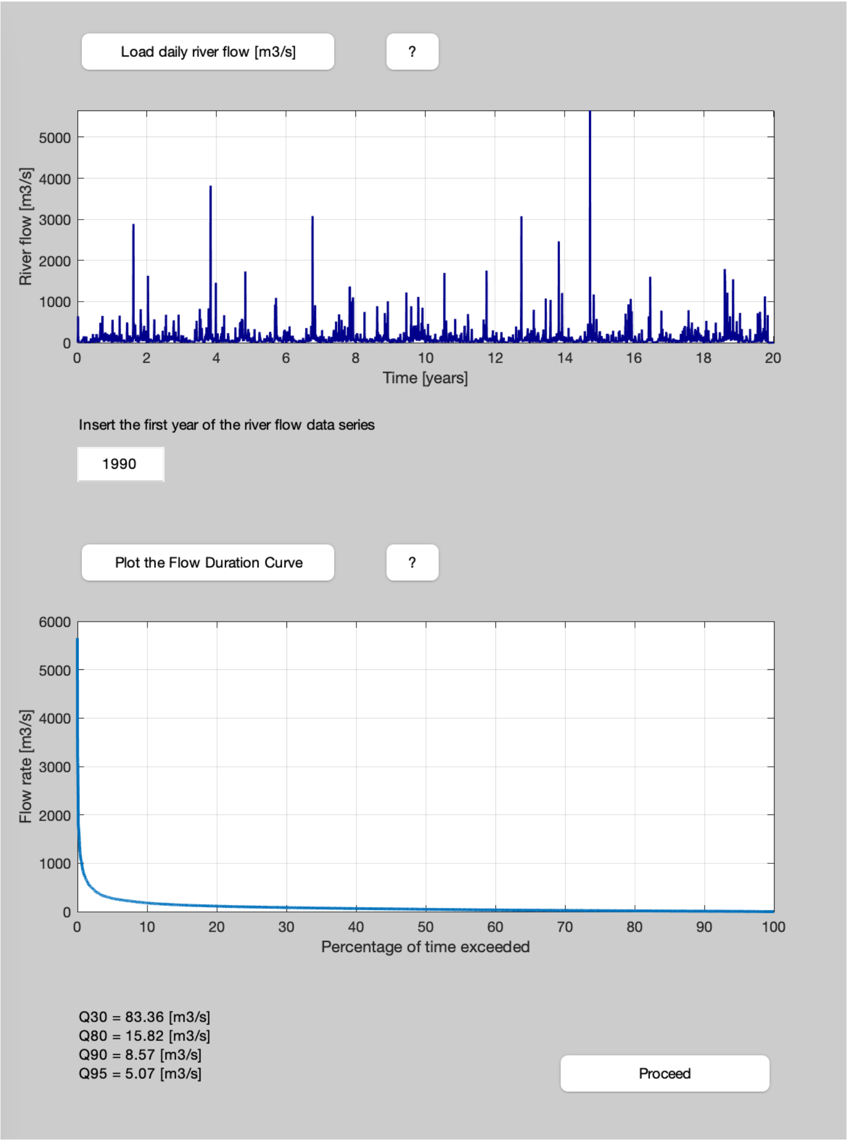
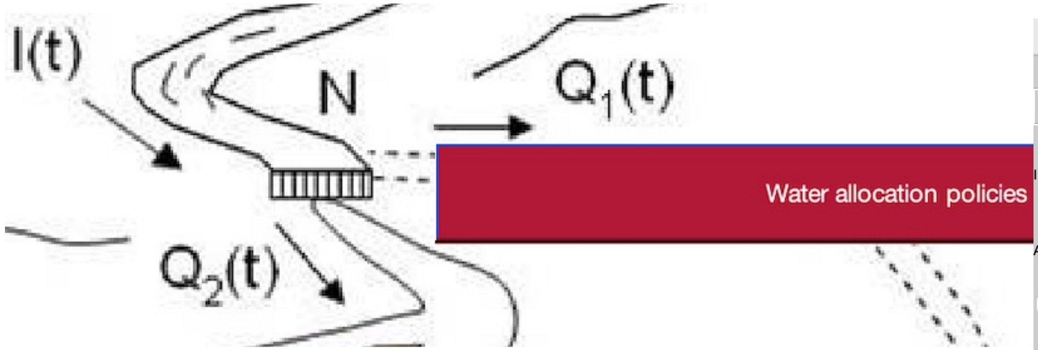
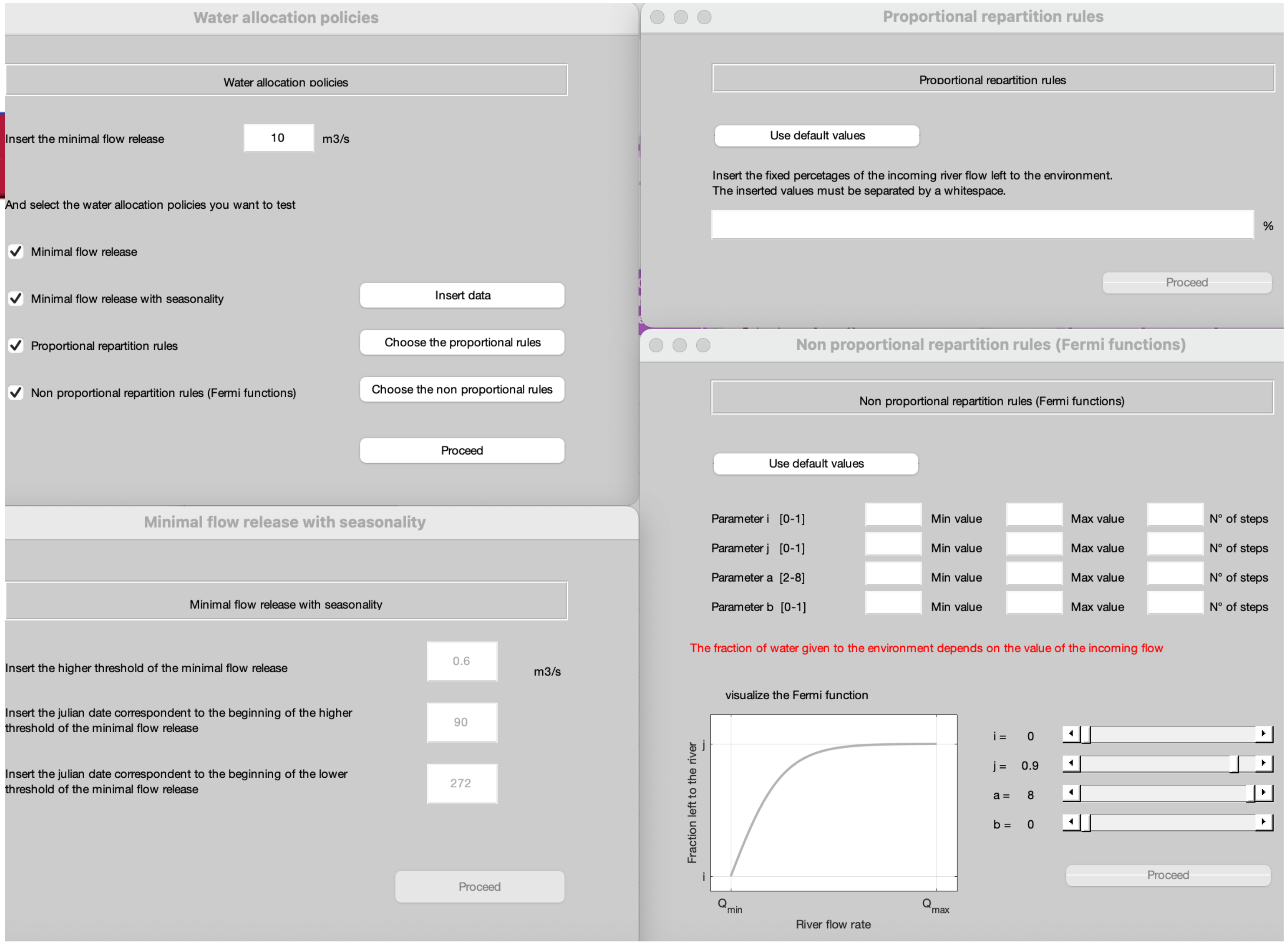




Here you enter the river data series as a sequence of daily data. The program calculates the main statistics

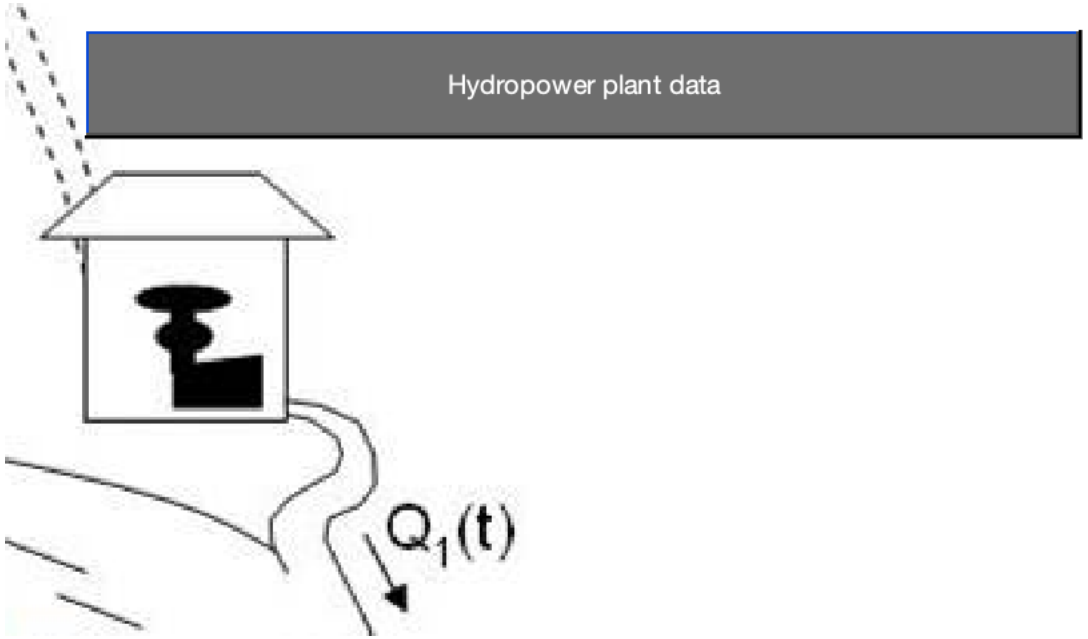
User steps: 2. Water allocation policies



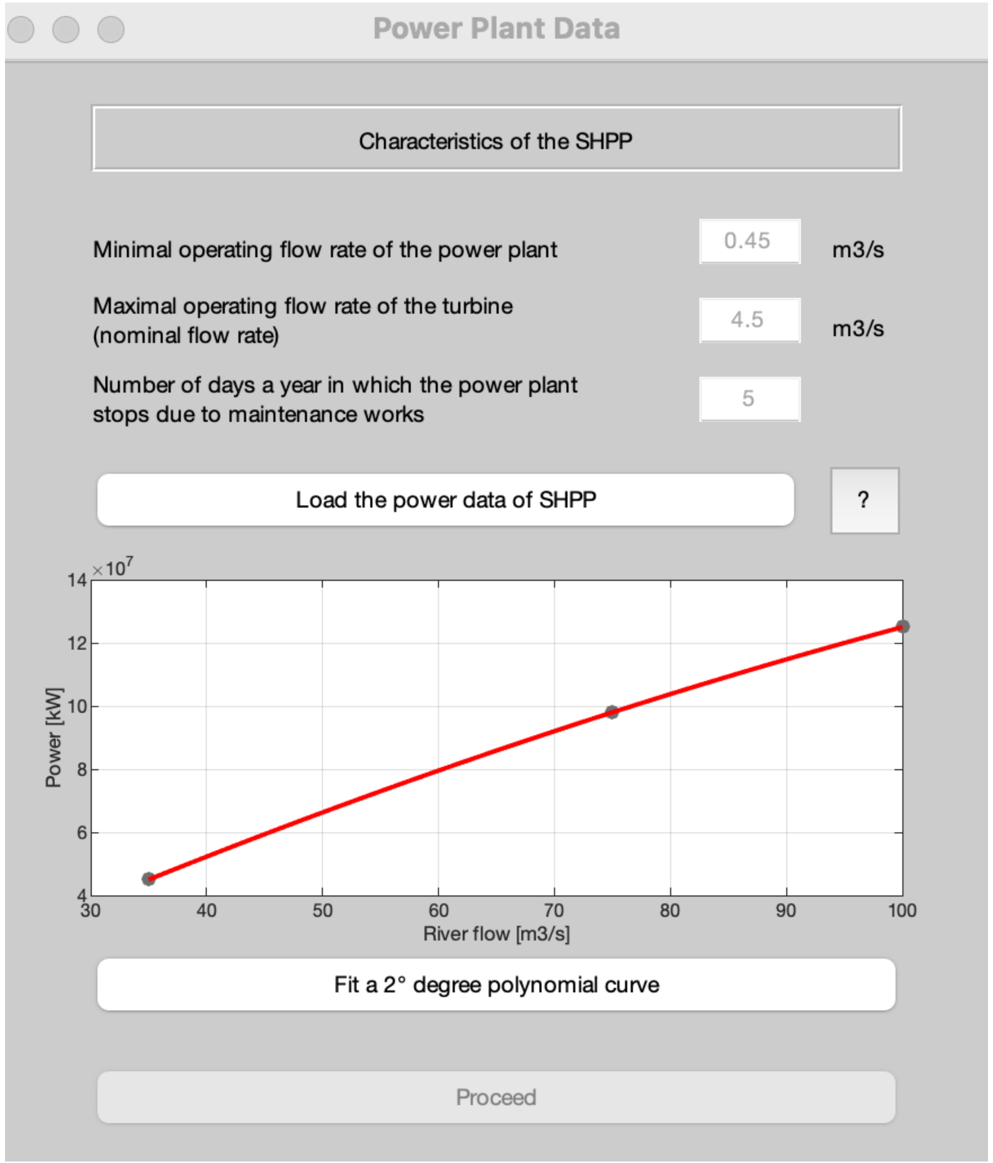


Here you enter the water allocation policies that you want to test. These include minimal flow with and without seasonal variation, proportional policies and non-proportional ones beonging to the Fermi function family

User steps: 3. Power plant data



Here you enter the technical data of the power plant that you want to test, including minimal and maximum operating flow as well as the number of consecutive days per year of maintenance work. These are then fixed randonmly along the year. The power data defines the operating range of the power plant and the power generated; whether at the alternator or by the turbine depends on which efficiency is used to generate the data points.



User steps: 4. Habitat suitability thresholds

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Habitat suitability thresholds

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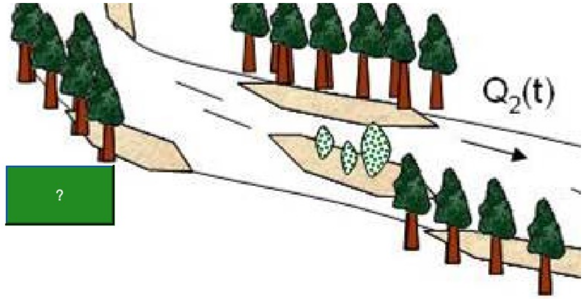

Here you enter the thresholds for young and adult reference fish species below which fish are in stress and a penalty function is calculated.