Sustainable water resources and agricultural management using environmental life cycle assessment

Outline

- Introduction
- Environmental Life Cycle Assessment (LCA)
- Mathematical optimization
- Ongoing research

Introduction (1): Why impact assessment?

- Sustainable development:

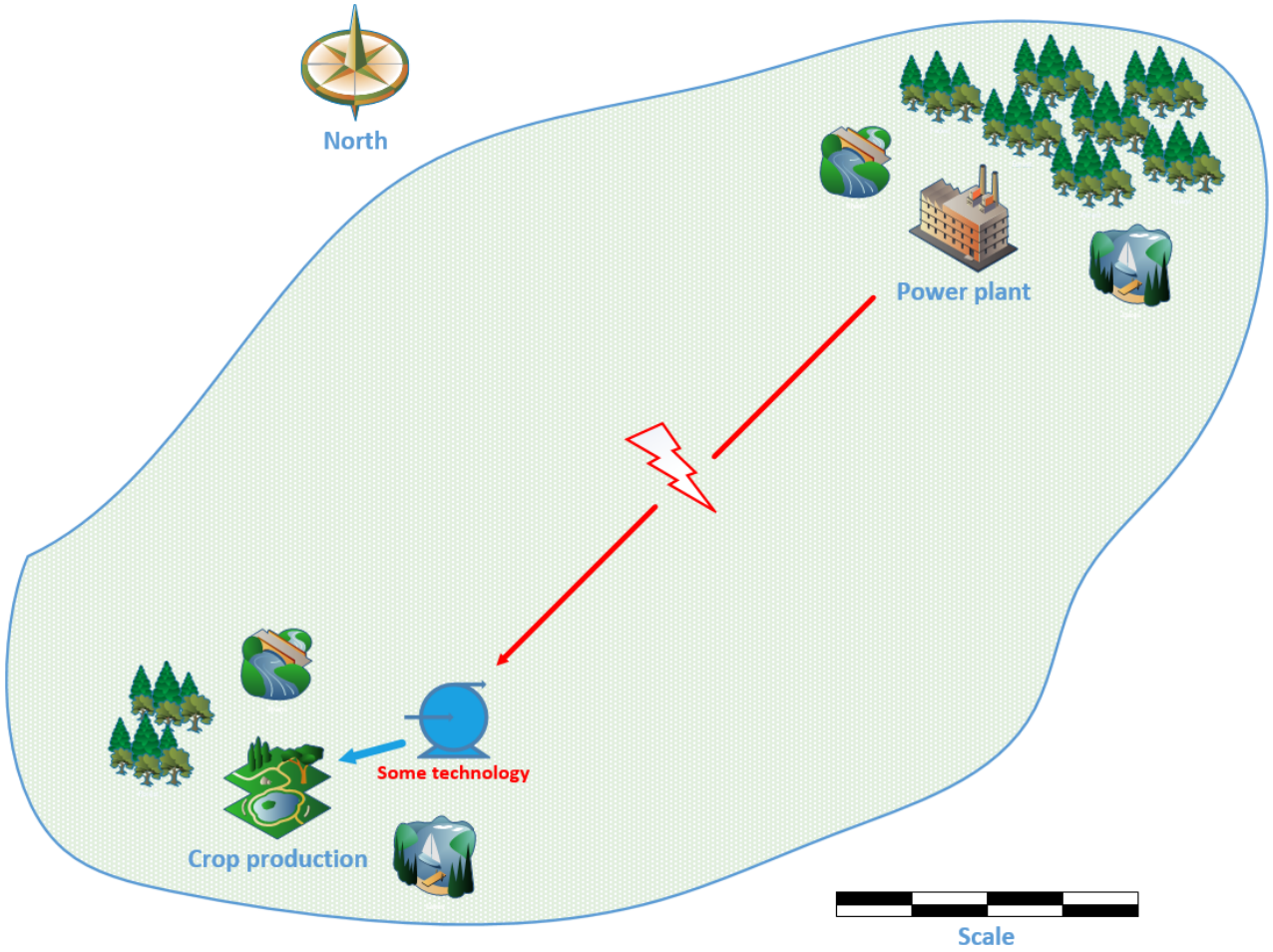
  "Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs"

  [Bruntland Commission's report "Our common future" WCED, 1987]

- Then, what is the sustainable amount or level?
- Nonetheless, we can make **"more sustainable"**

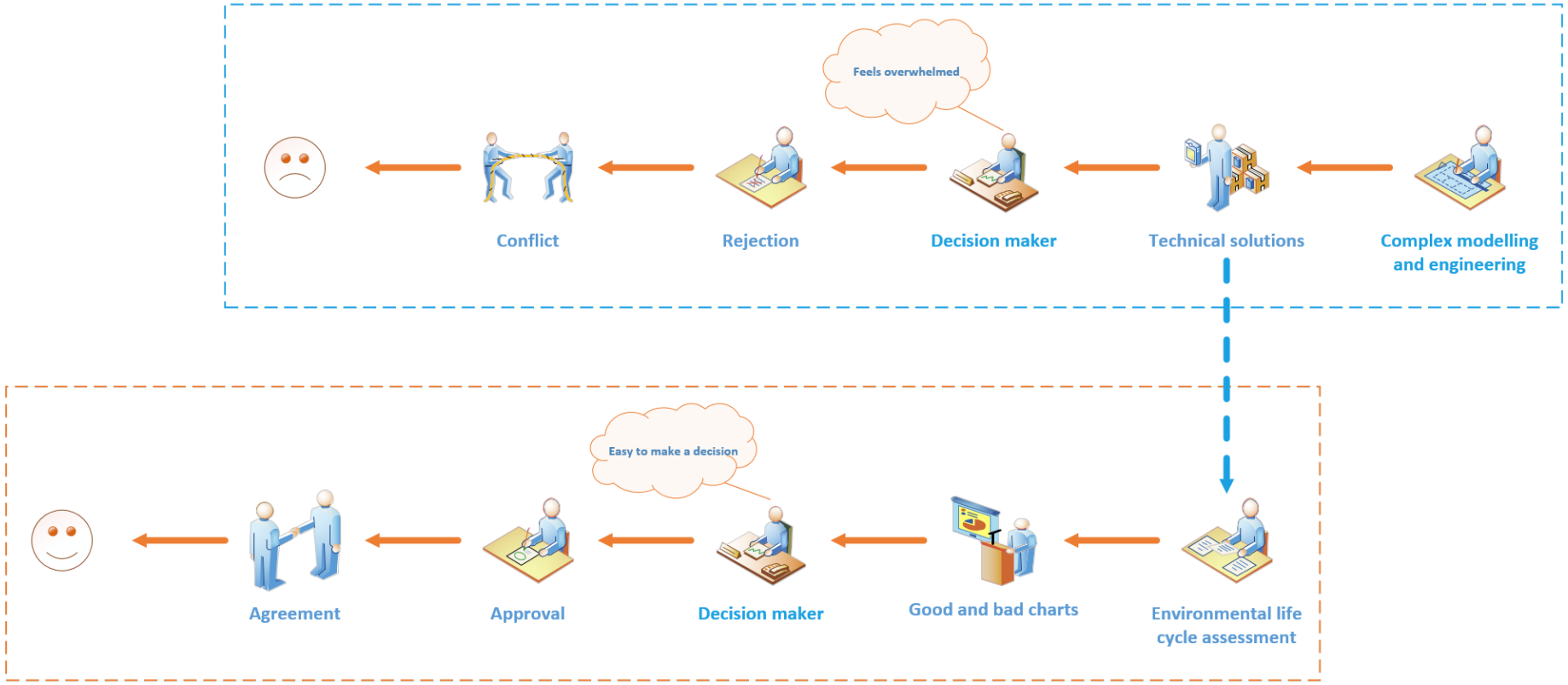
Introduction (2): Why impact assessment?

"Problem shifting":
Solving water issues by the cost of air pollution where electricity produced



Introduction (3): Why impact assessment?

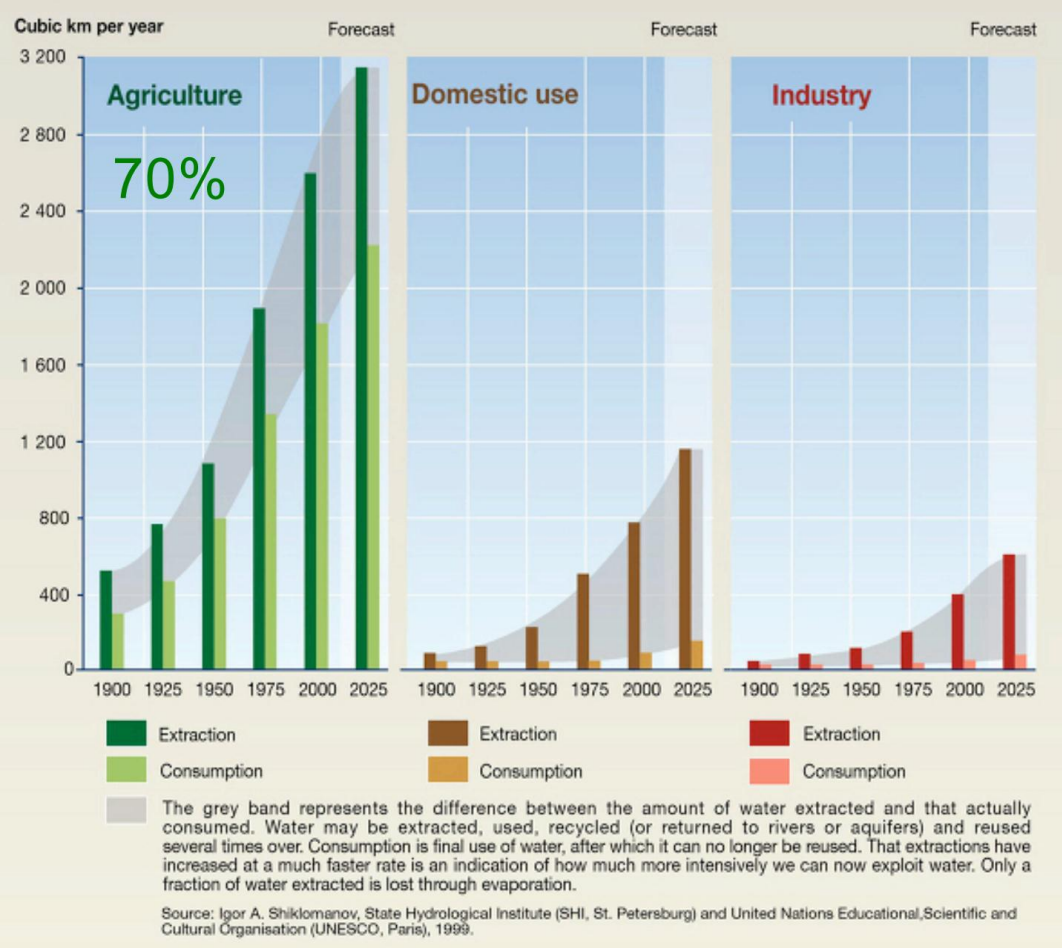
Comprehensive decision making and raising awareness:



Introduction (2): Why agriculture?

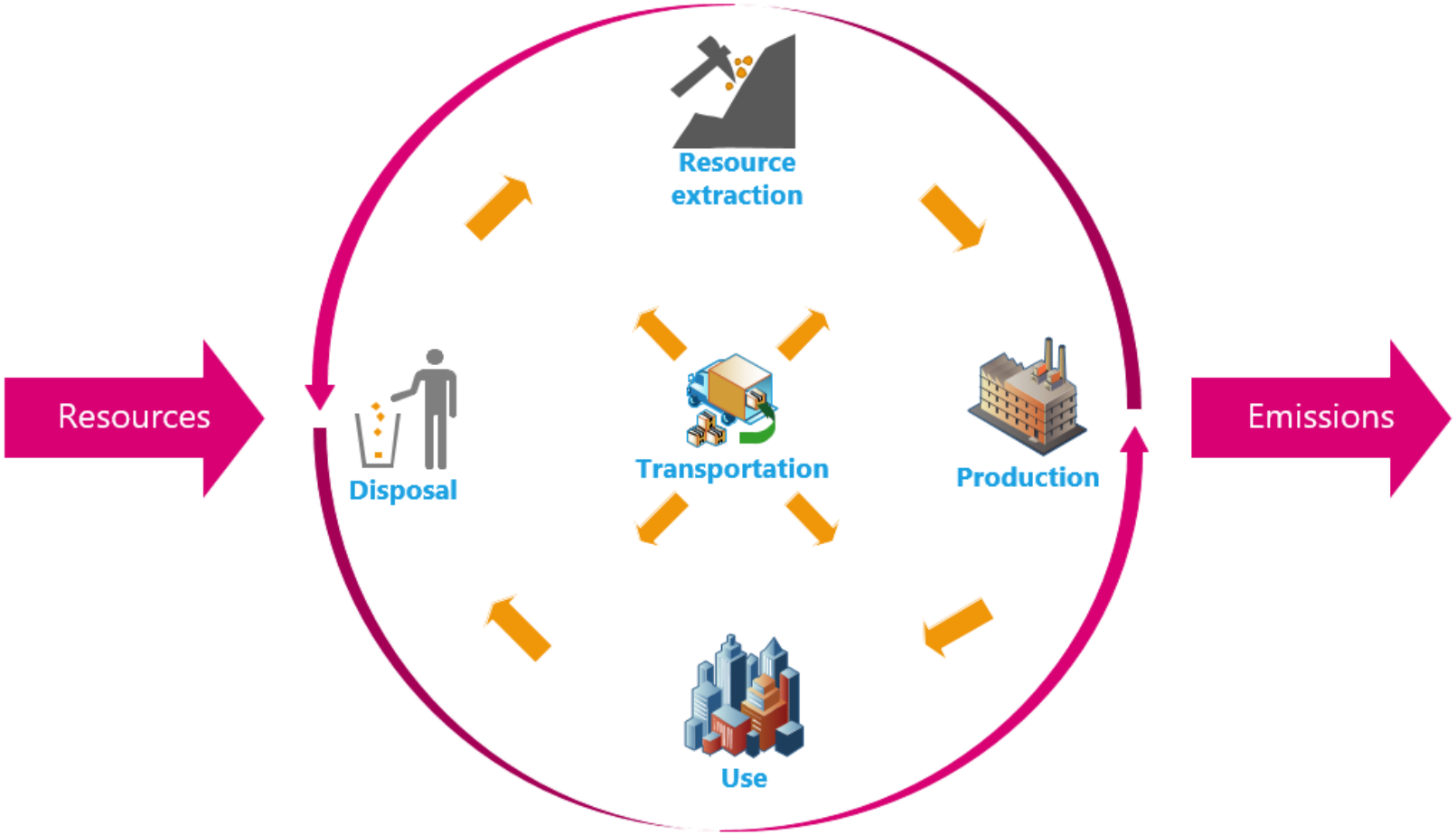
Source: *World Resources 2000-2001, People and Ecosystems: The Fraying Web of Life*, World Resources Institute (WRI), Washington DC, 2000.

Introduction (2): Competition for water

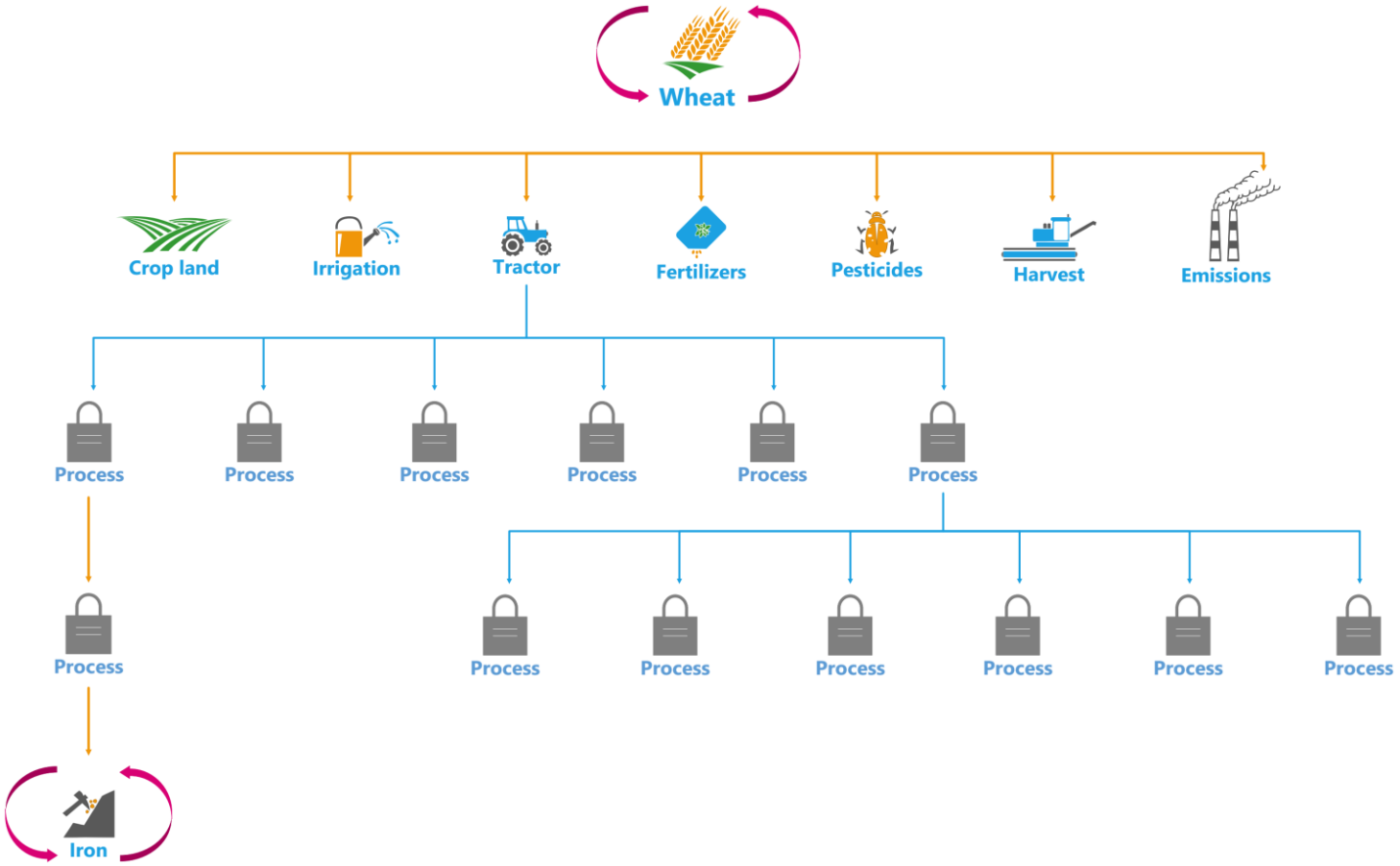


- Main consumer
- Competition among agriculture and the other economic sectors

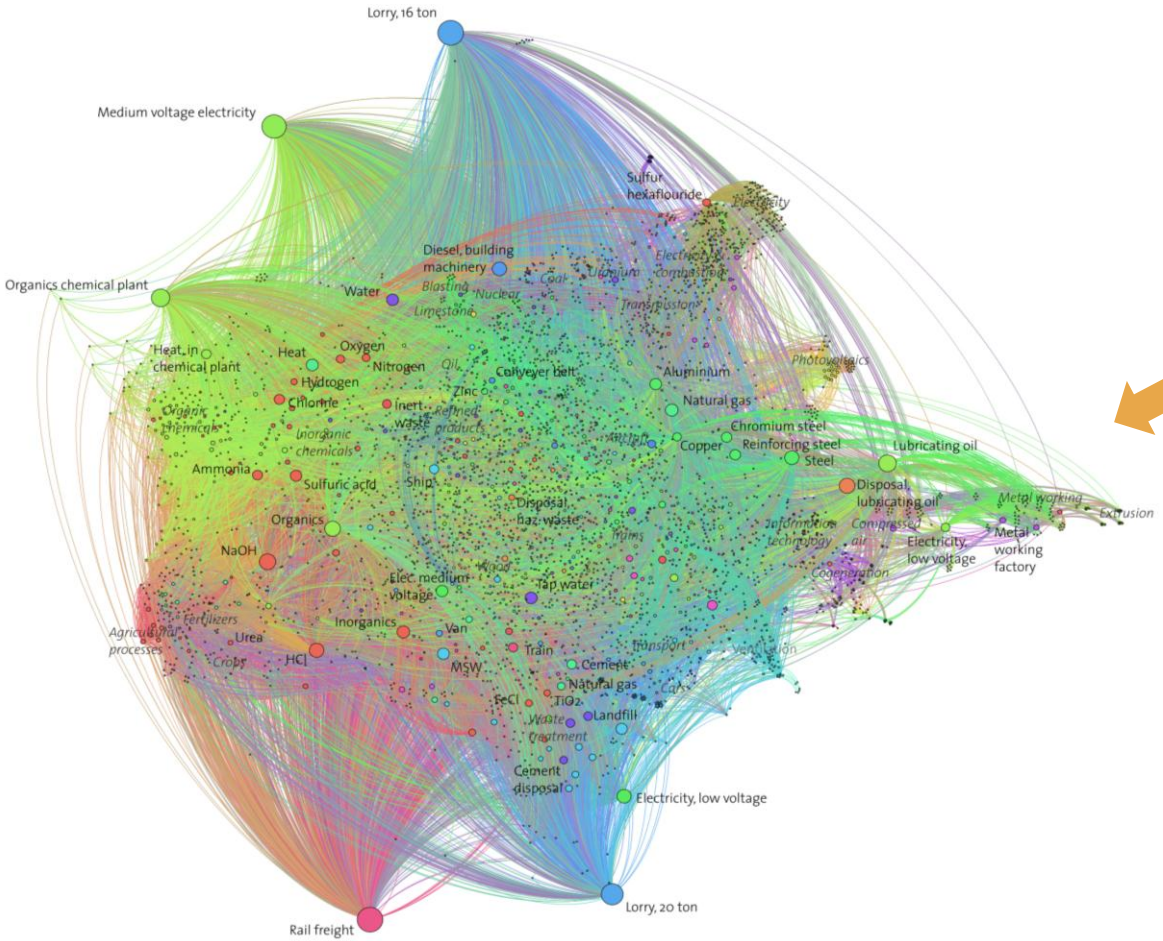
Life Cycle Assessment (1): Overview

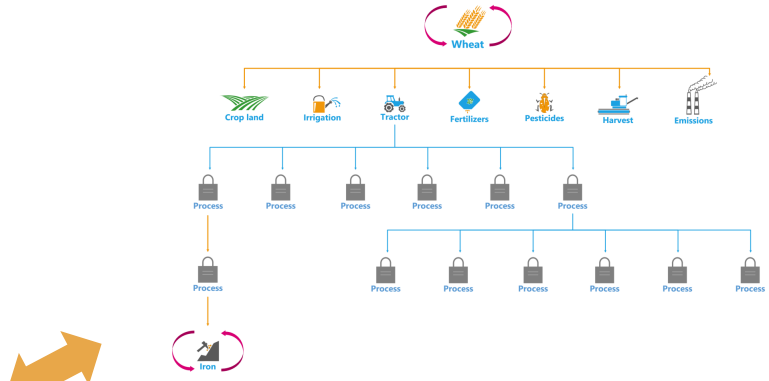


Life Cycle Assessment (2): Wheat production



Life Cycle Assessment (2): LCA Database

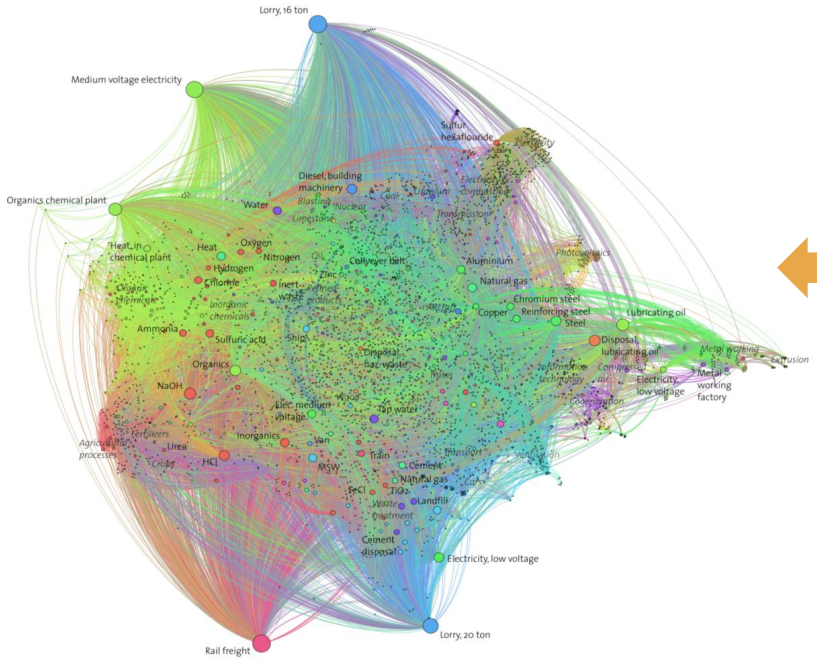


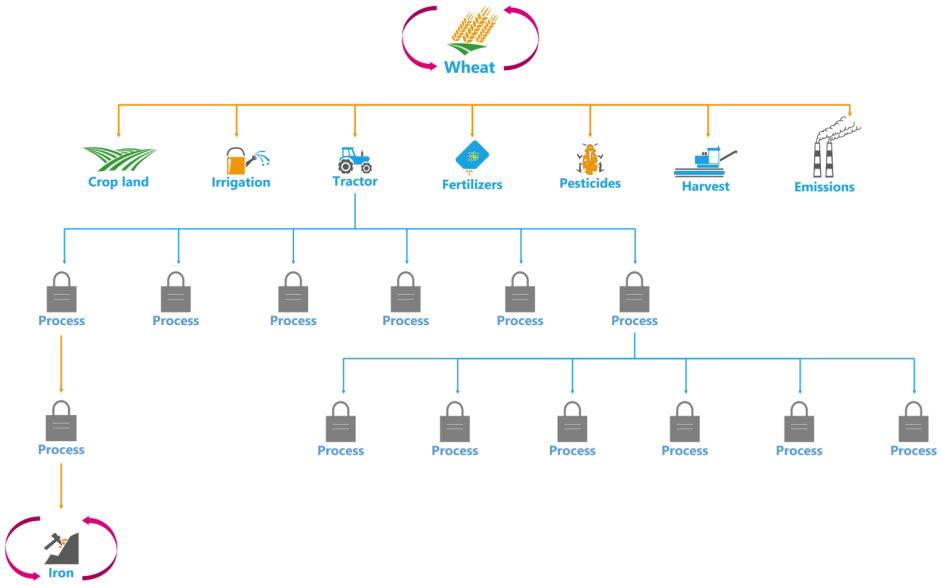


“Spiral Spider Web”
LCA database

Example cloud is Ecoinvent LCA database by Dr. Chris Mutel

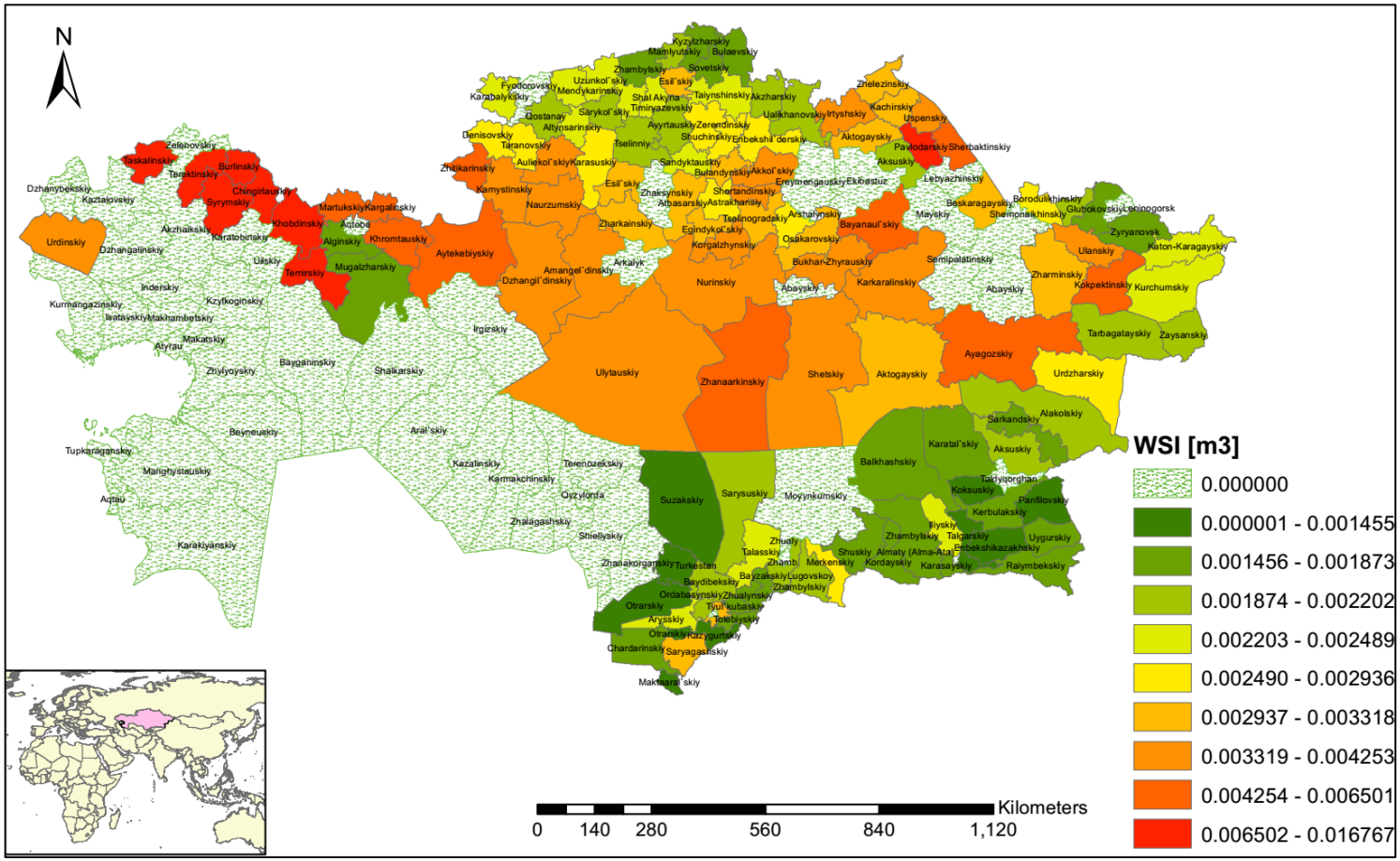
Life Cycle Assessment (2): Why database?





- Comprehensive analysis of impacts throughout the whole system!
- No “Problem shifting”!
- Nothing is skipped!

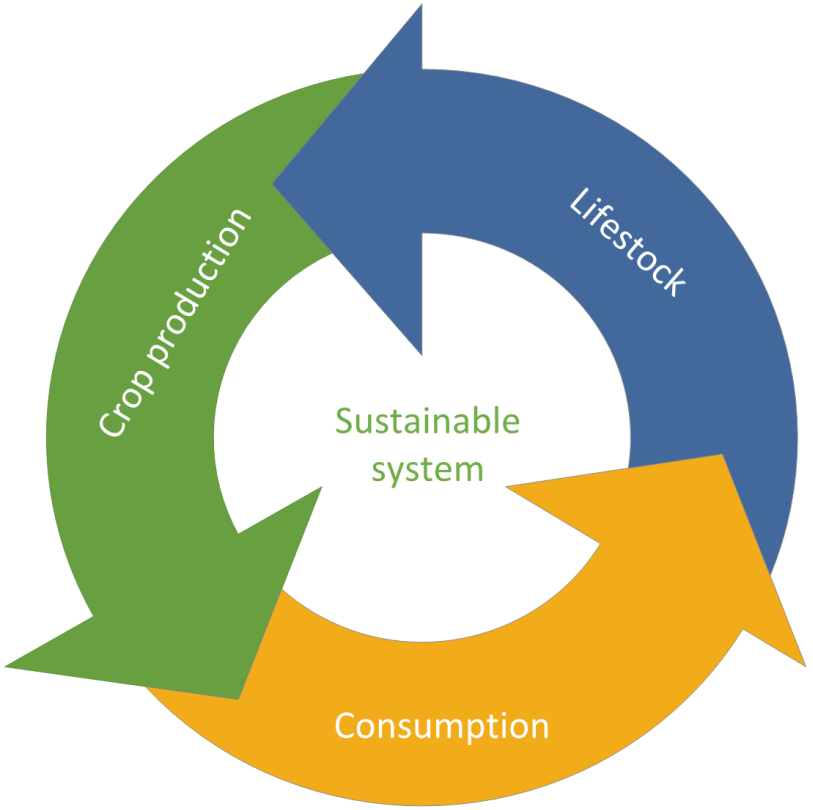
Master thesis: Impact maps



Sustainability assessment toolbox

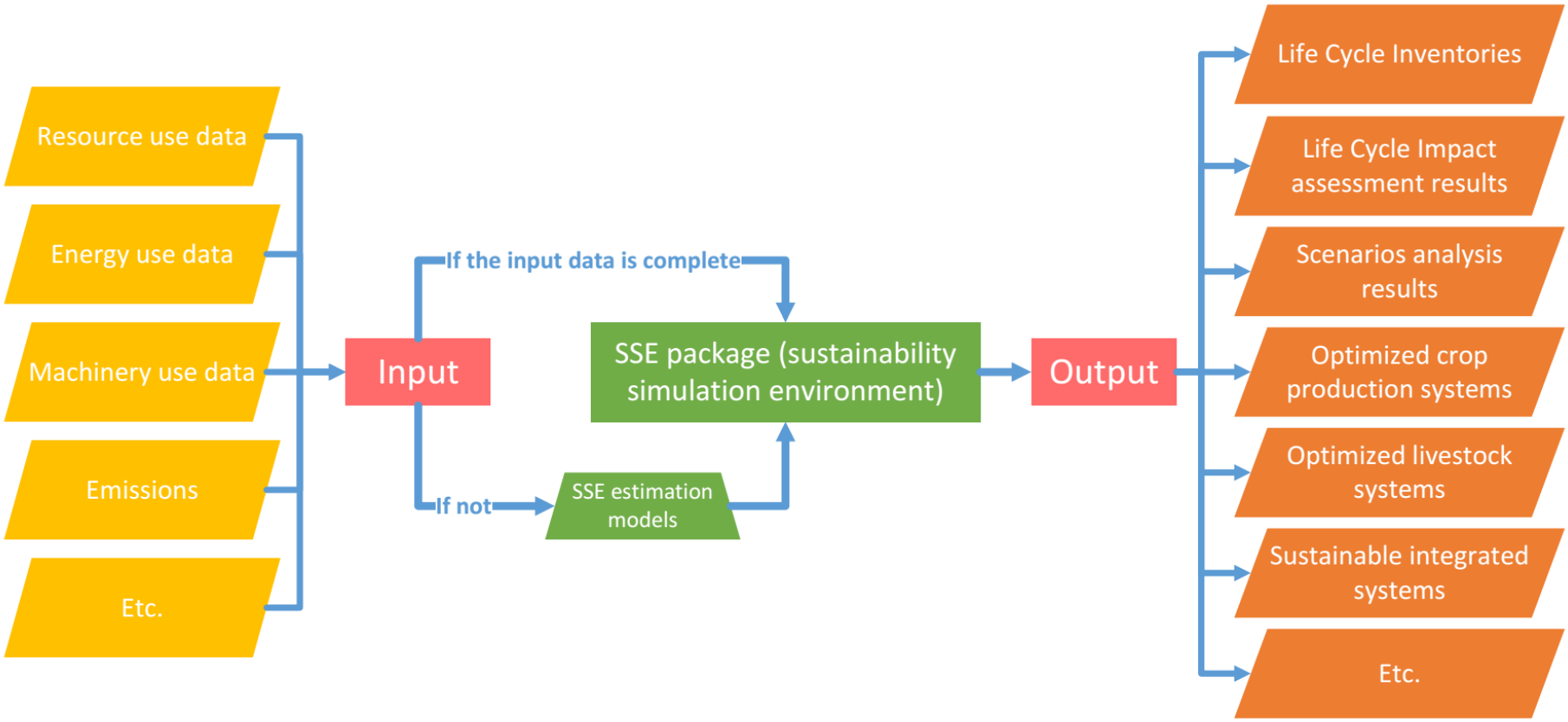
SSE: purpose

- Environmental Impact Assessment:
  - Inventory modelling environment for life cycle assessment purposes
- Modeling:
  - Parsimonious modelling in water resources, agriculture etc.
- Mathematical optimization:
  - Technical
  - Economical
  - Social
  - Sustainability
- PISA framework



SSE: general structure diagram

SSE: how it works



GUI

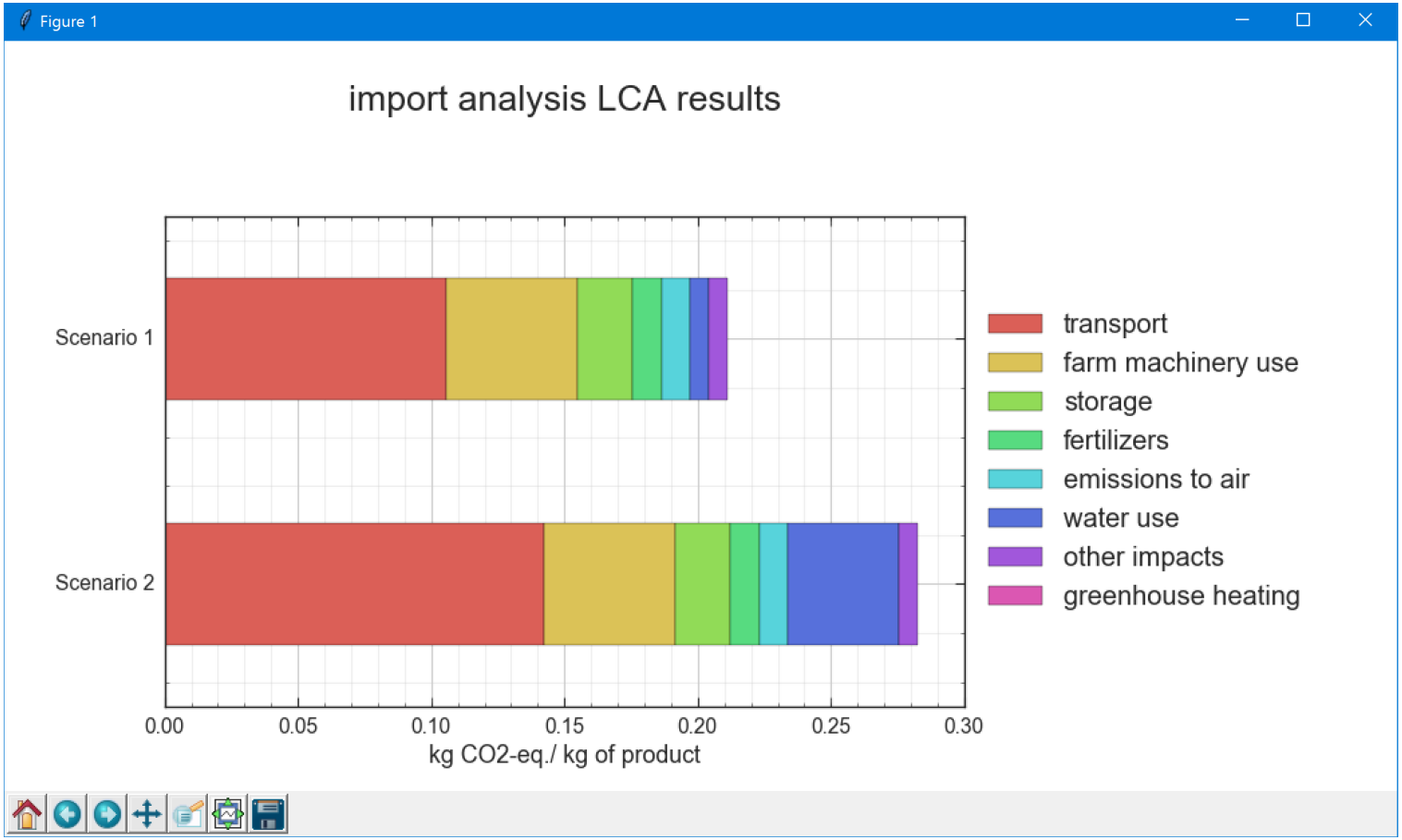
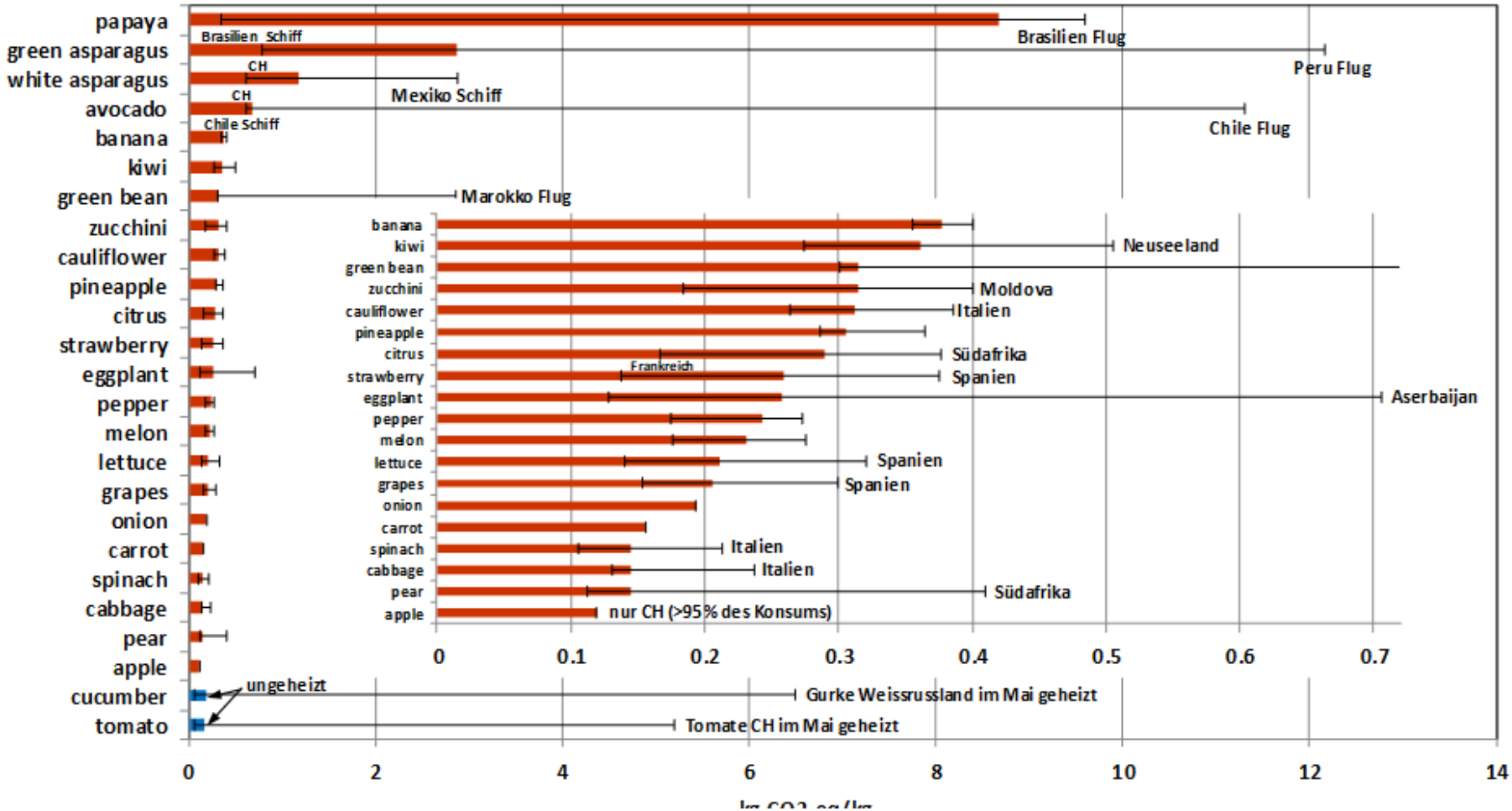
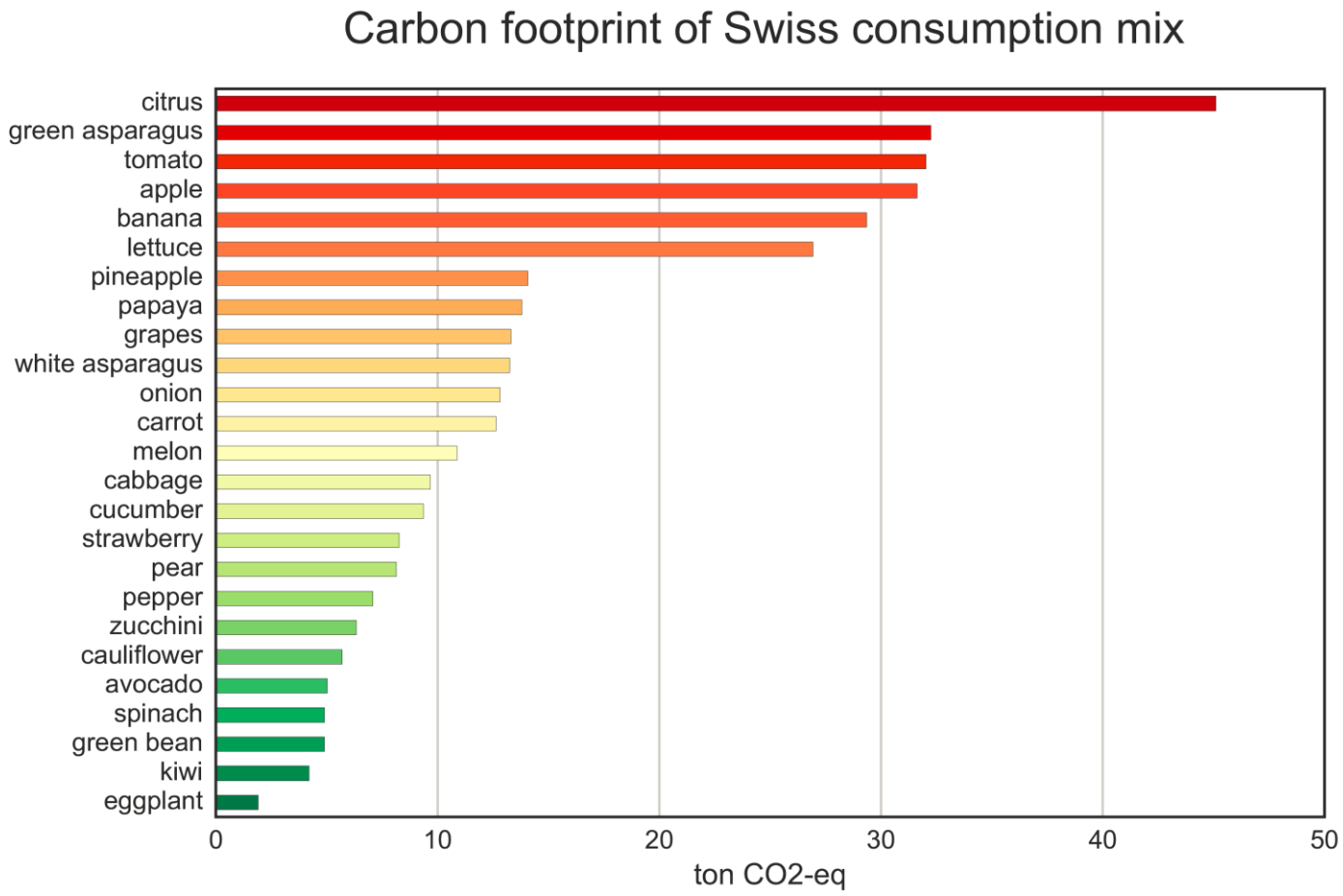


Figure 1
import analysis LCA results
Scenario 1
Scenario 2
0.00
0.05
0.10
0.15
0.20
0.25
0.30
kg CO2-eq./ kg of product
transport
farm machinery use
storage
fertilizers
emissions to air
water use
other impacts
greenhouse heating

Case study: Switzerland (1)



Case study: Swiss import results for total consumption (2)



Mathematical optimization (1): Why?

Conflicting interests:

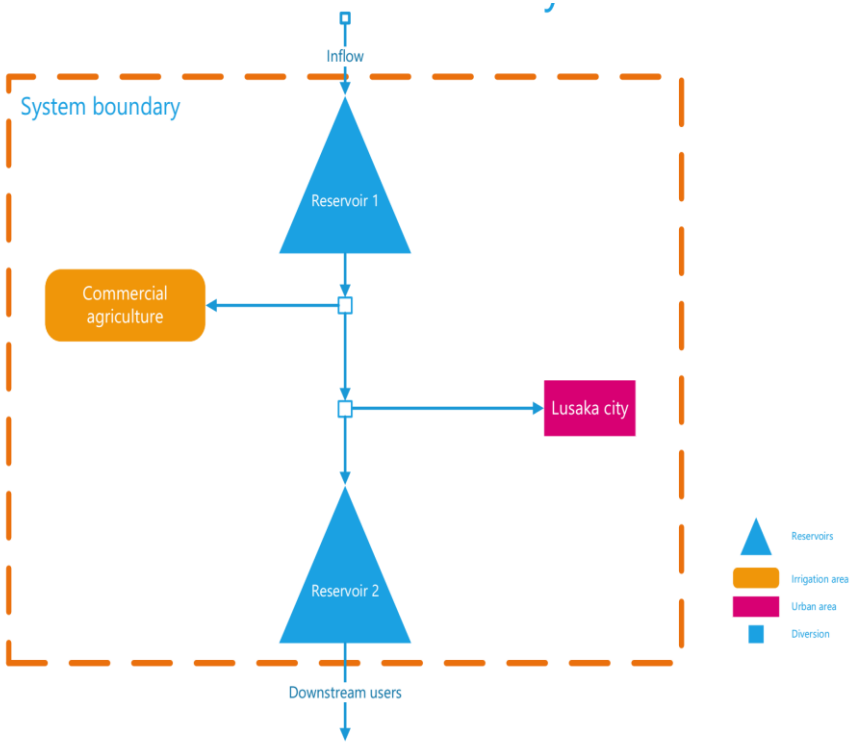
- Upstream vs. Downstream
- Reservoir vs Irrigation
- Reservoir vs City flooding

Constrains:

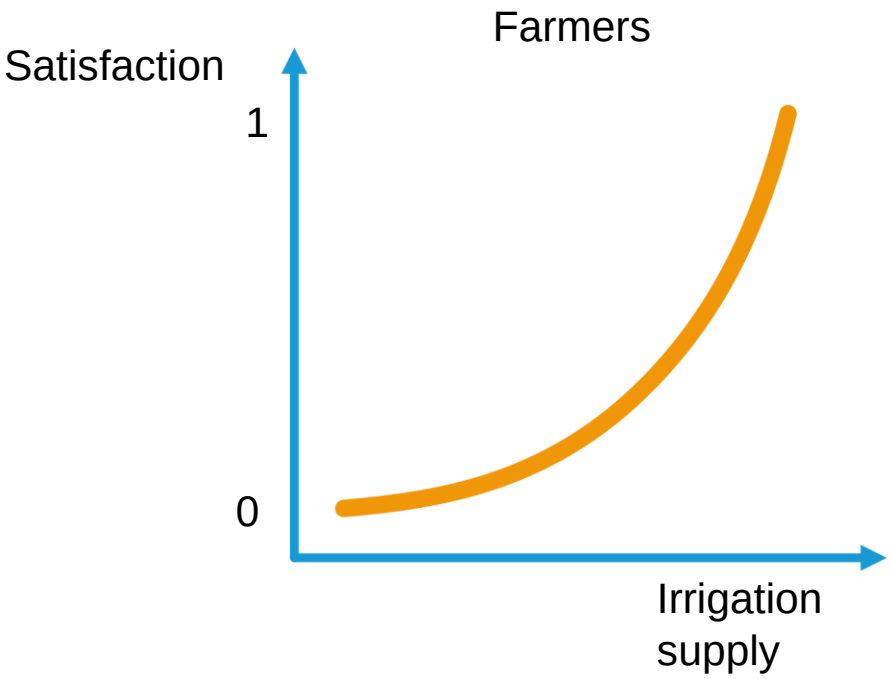
- Cost vs Water saving
- Cost vs Low impact

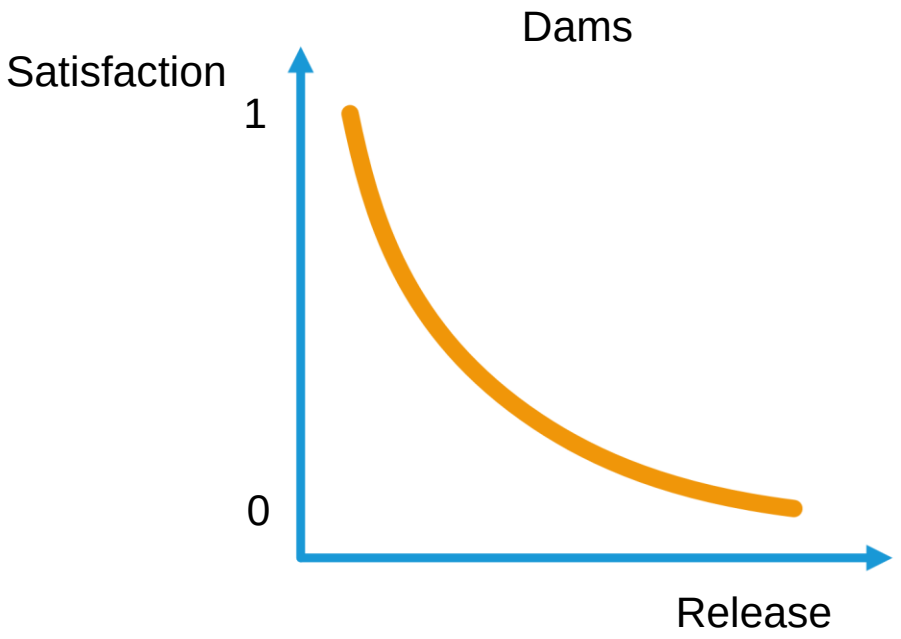
System optimization:

- Optimal design and planning



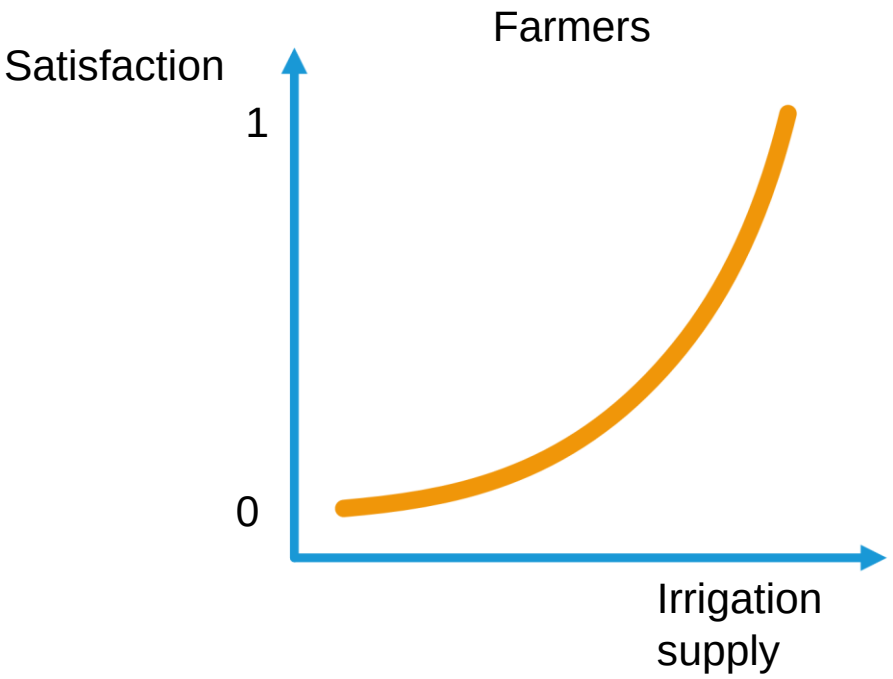
Mathematical optimization (1): Dam vs Irrigation

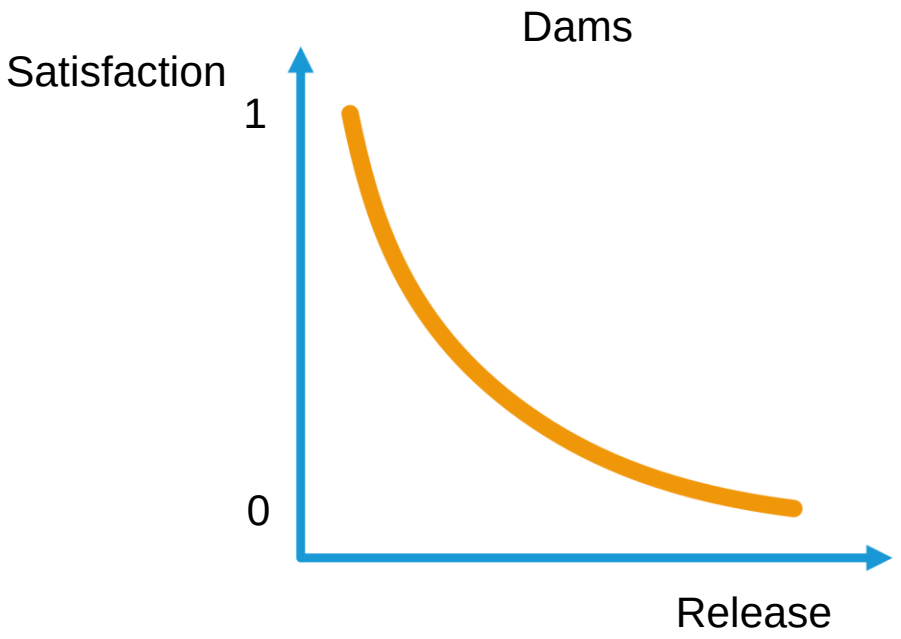




Social aspect!!!

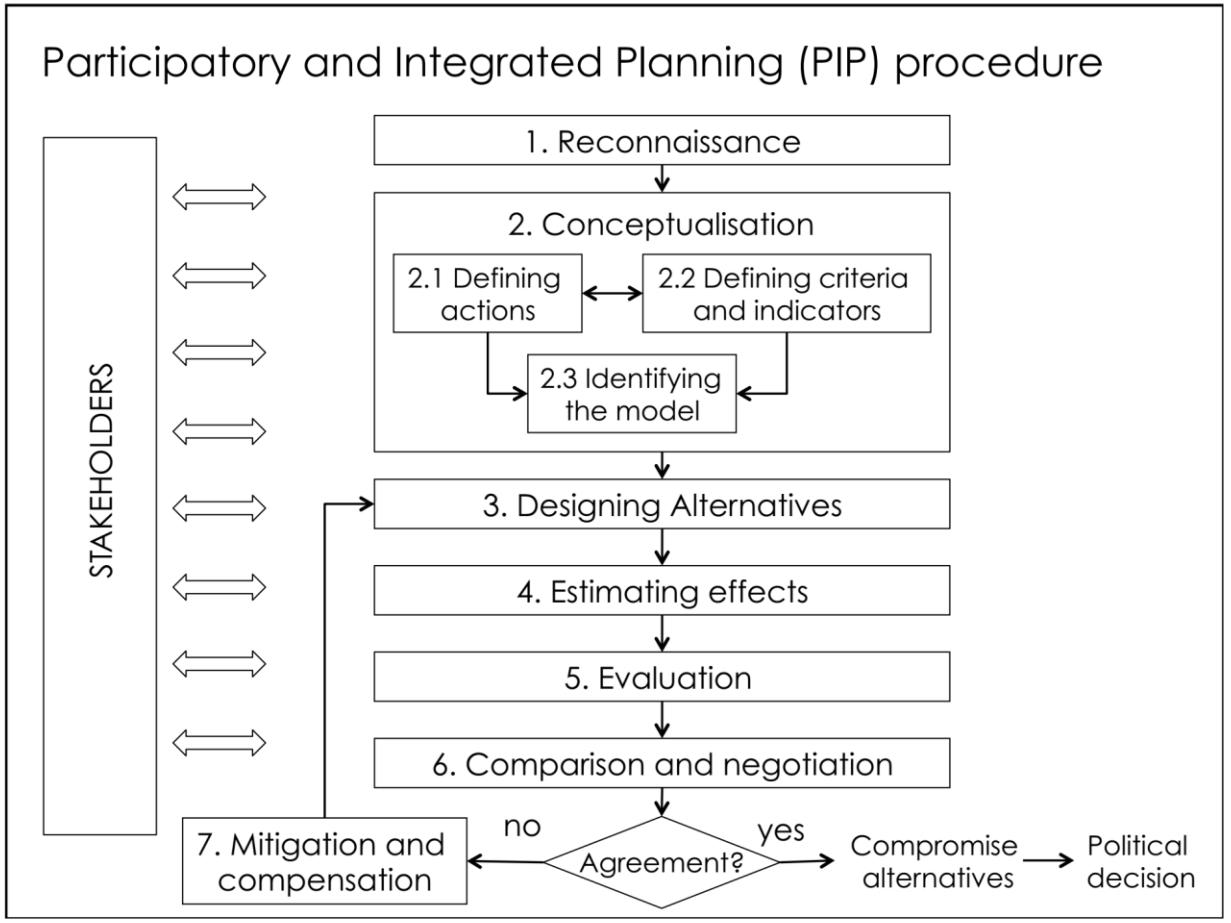
Mathematical optimization (1): Dam vs Irrigation



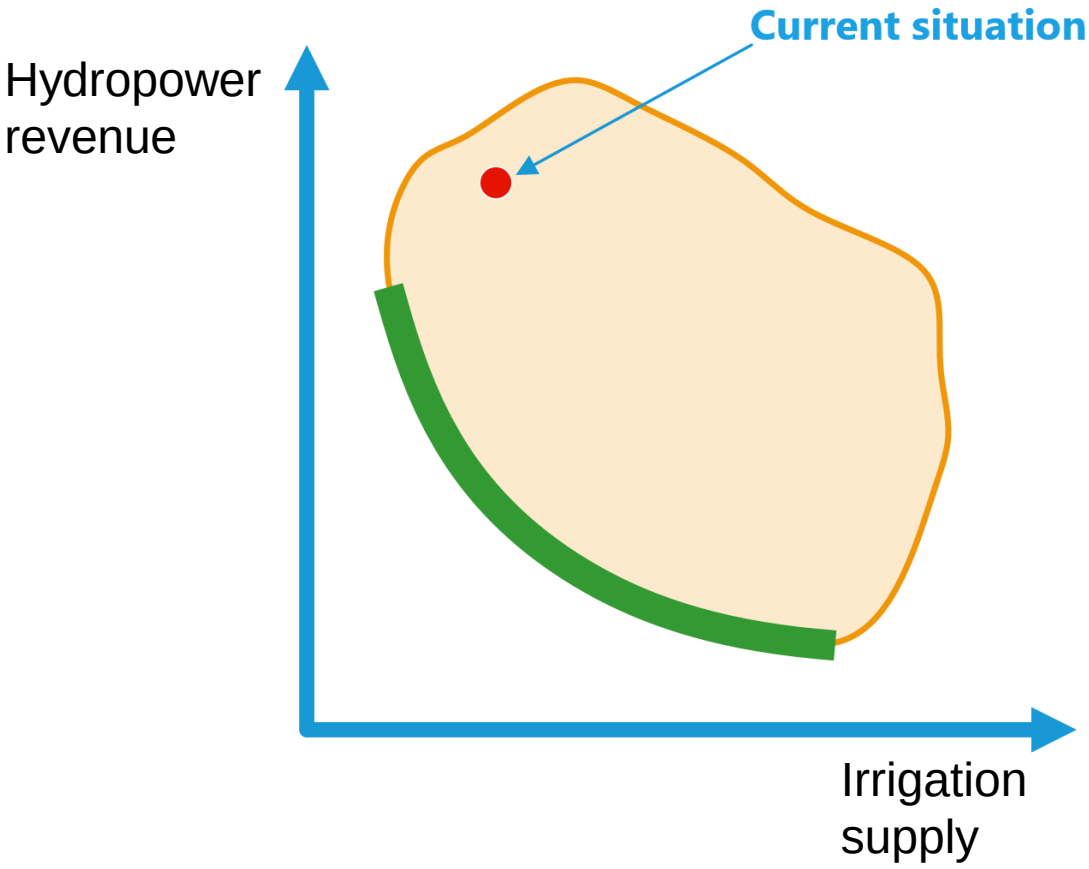


Social aspect!!!

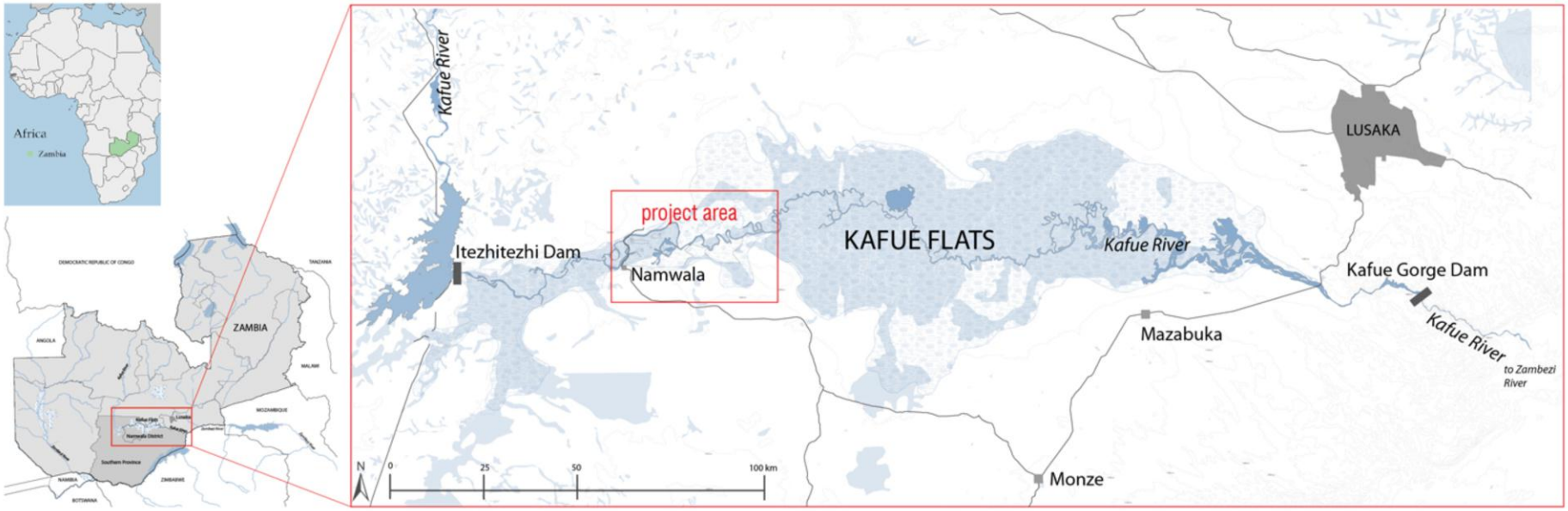
Mathematical optimization (1): Framework



Mathematical optimization (1): Pareto frontier



Mathematical optimization (2): Case study



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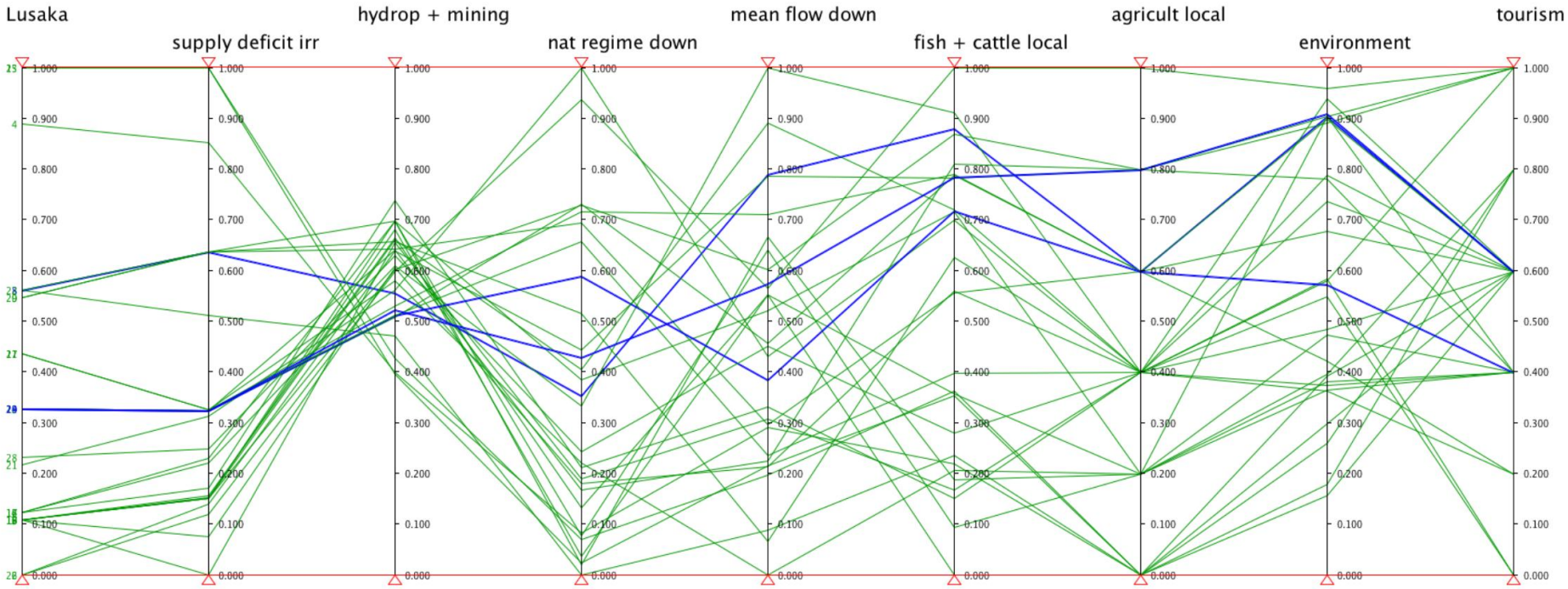
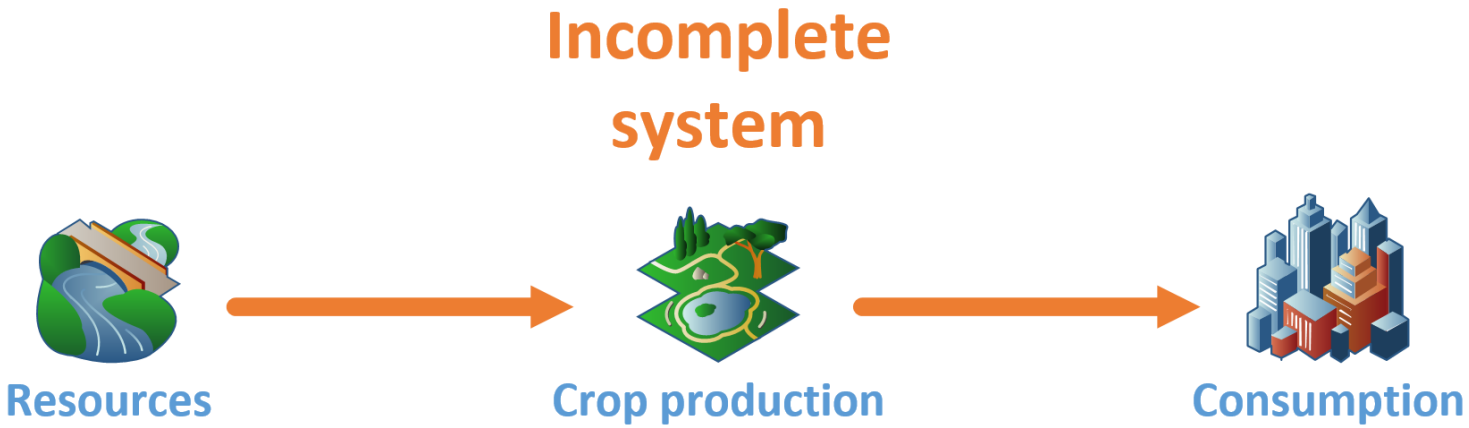
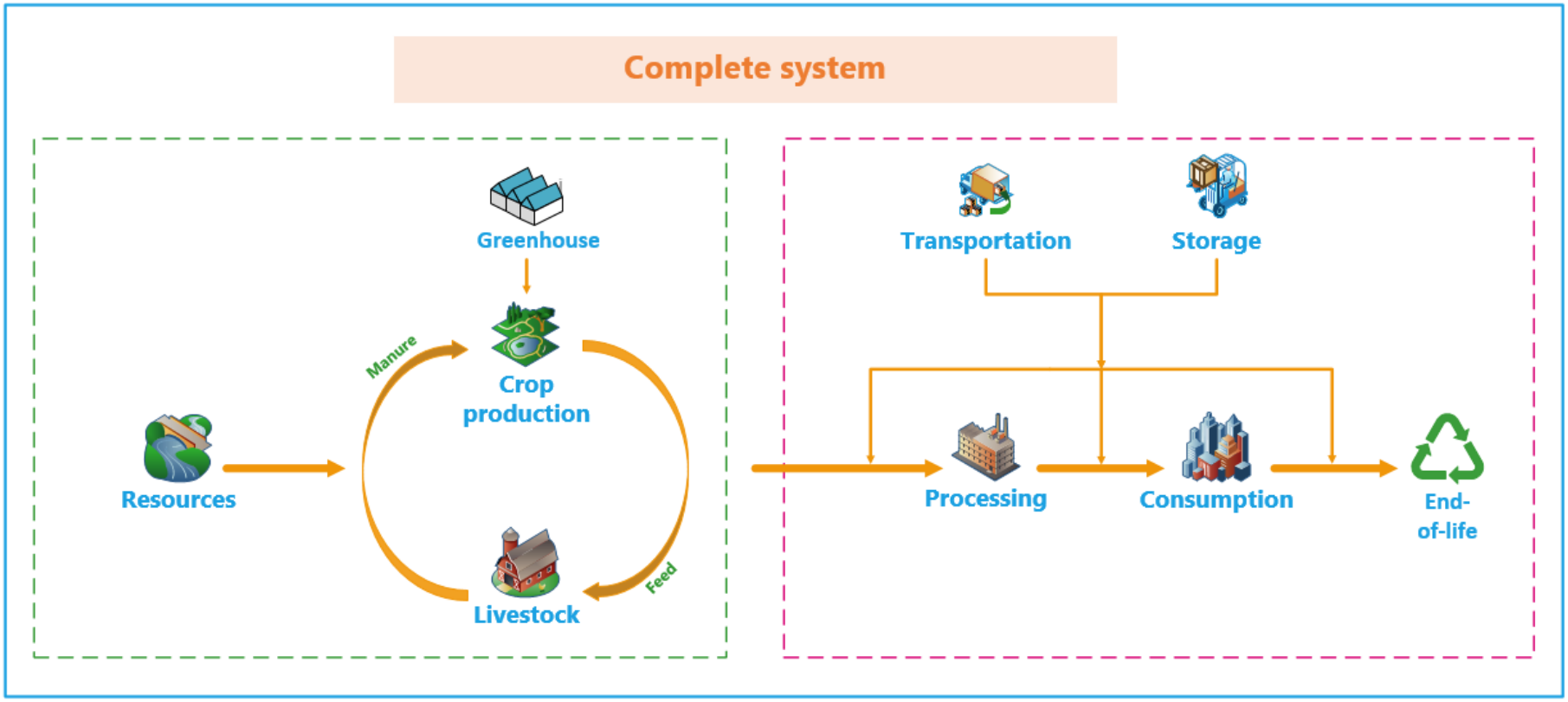


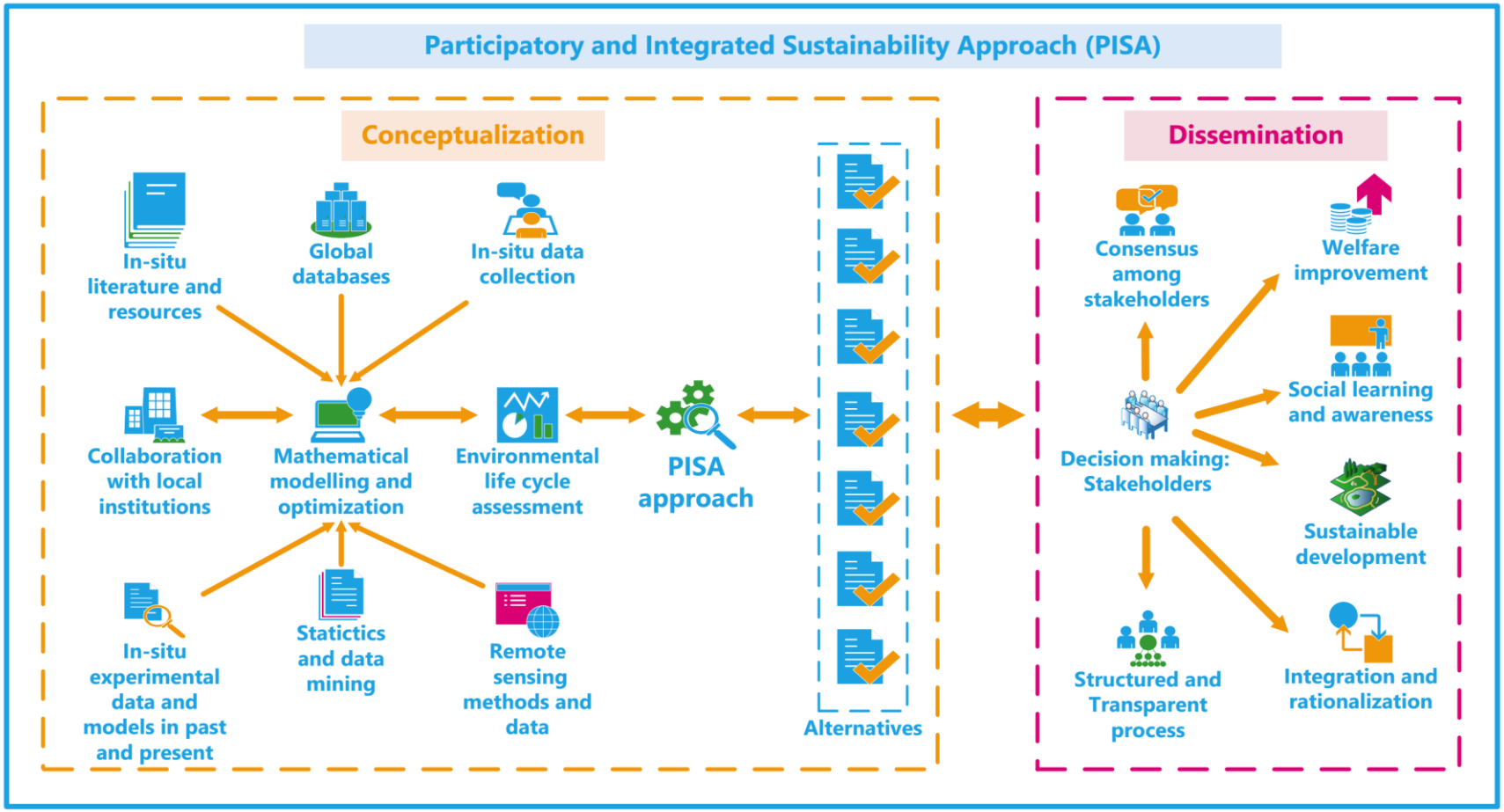
Ongoing research: What is done often



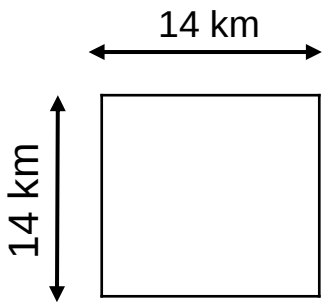
Ongoing research: Zooming out

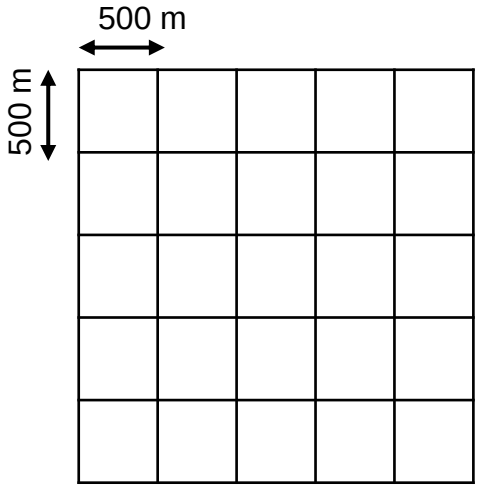


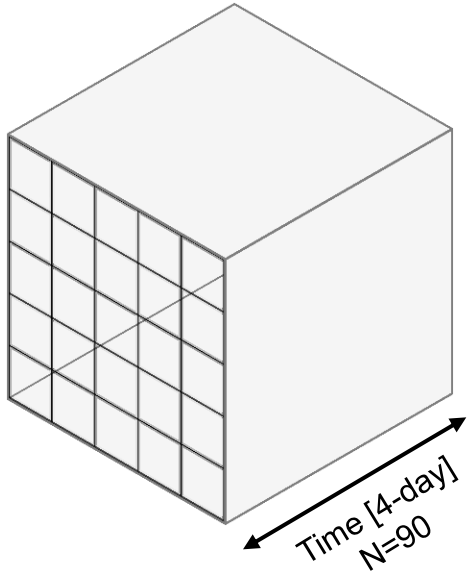
Ongoing research: PISA framework



Ongoing research: Spatially distributed version







- Temperature
- Precipitation
- Solar radiation
- Wind
- Sunshine hours
- Pressure
- Dew point temperature

- Soil data (1 km2)
- Leaf area index (LAI)
- Photosynthetic active ration (PAR)
- Land cover
- Crop type classification

- ❑ Crop yield
- ❑ Irrigation demand
- ❑ Soil nutrient balance

Ongoing research: Field classification

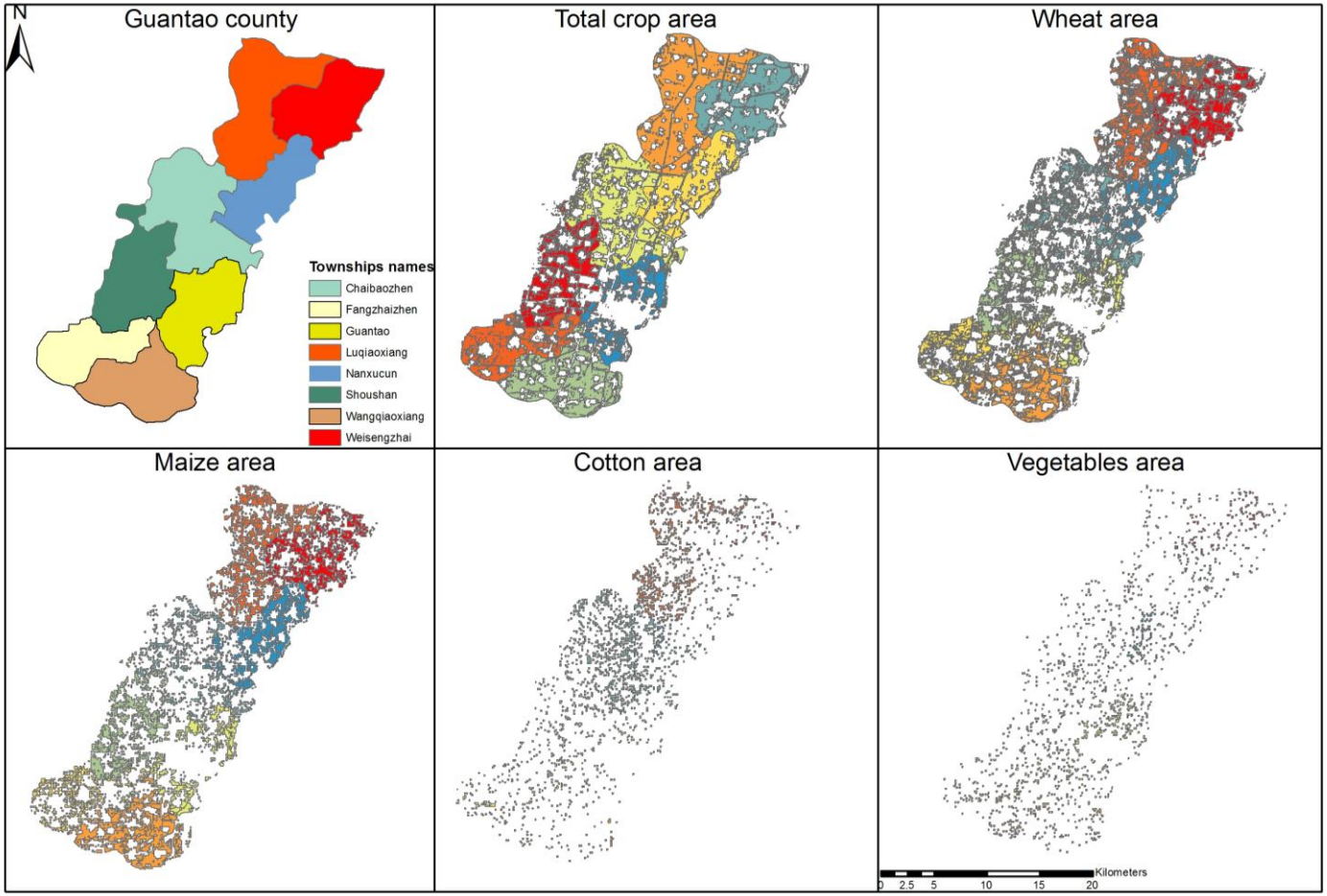
Crop field

Greenhouse

Results can be used for:

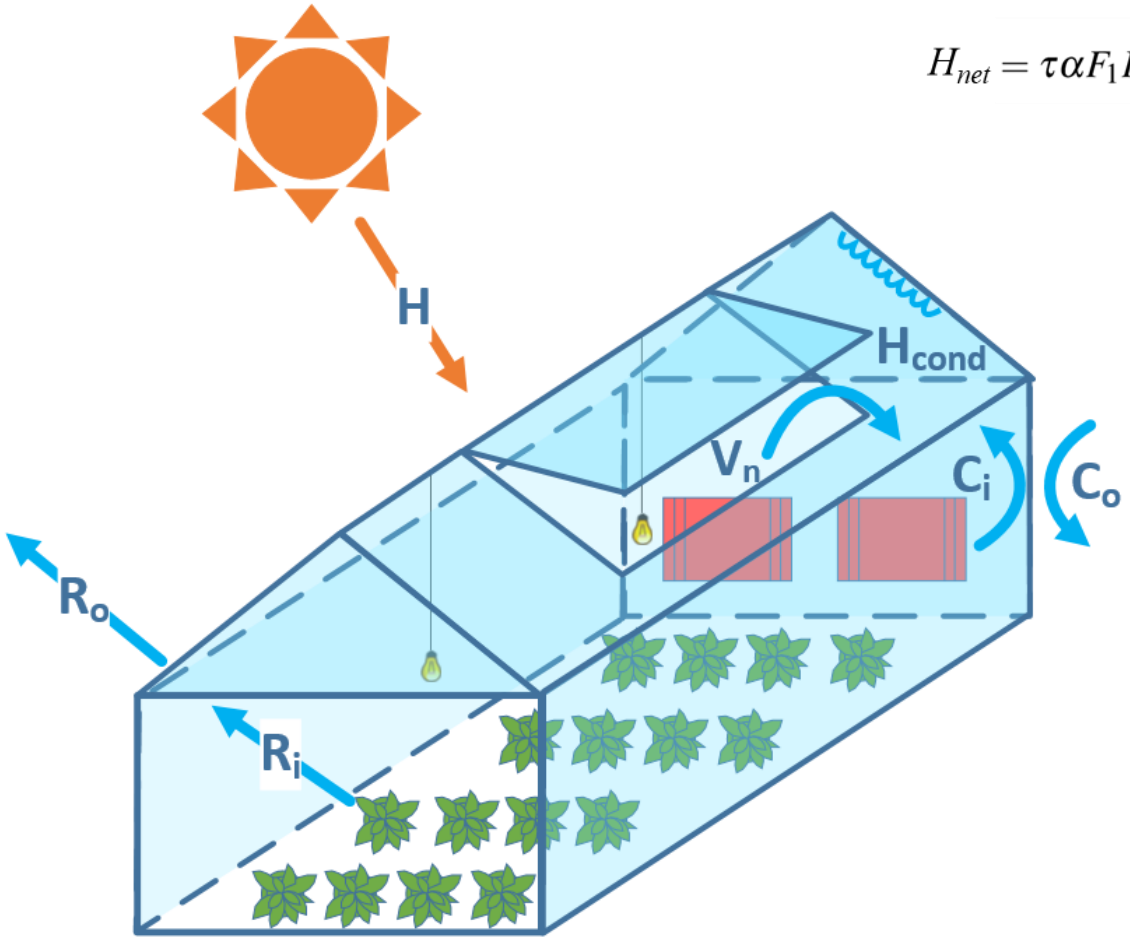
- Hot spots
- Spatial analysis
- More precise crop and greenhouse areas
- More accurate regionalized impact assessment

Ongoing research: Crop type classification

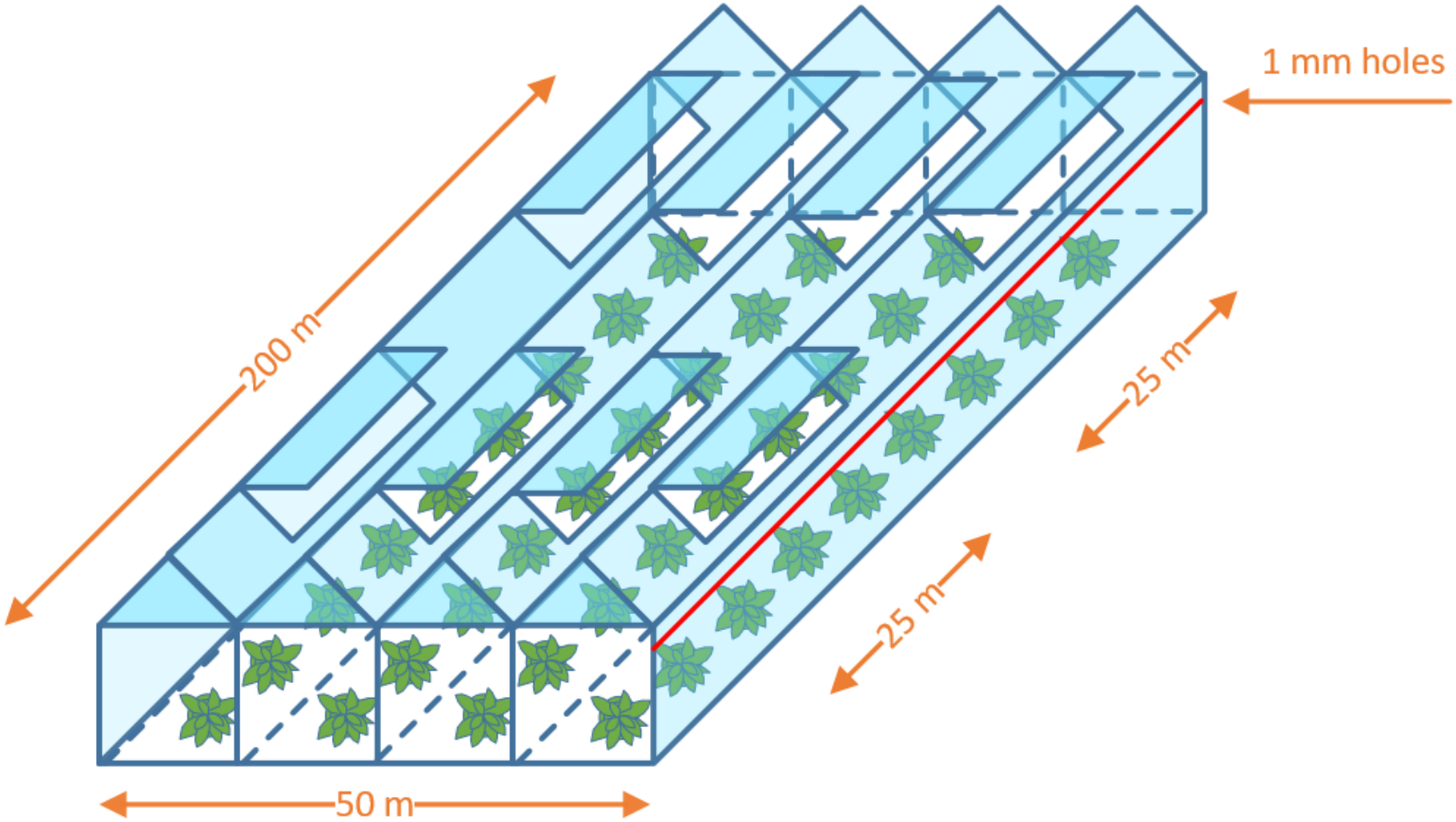


Ongoing research: New greenhouse model

$$H_{net} = \tau\alpha F_1 F_2 A_f H(t) - U(t) A_c (T_{ai}(t) - T_{a_o}(t))$$

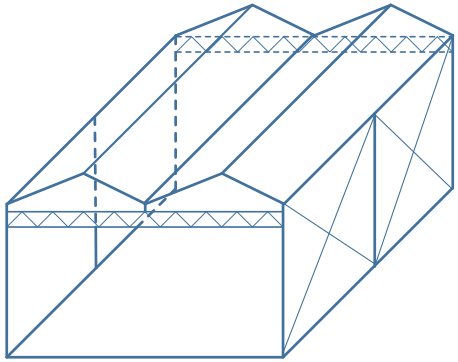


Ongoing research: Modelling assumptions

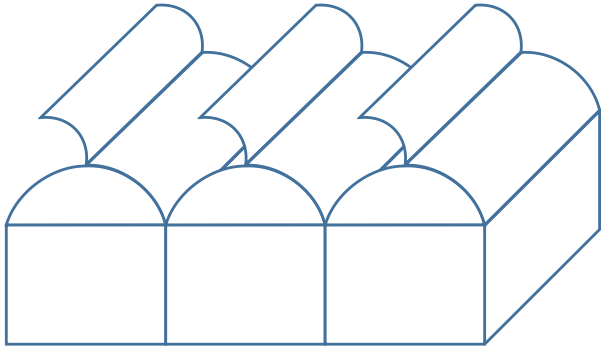


Ongoing research: Greenhouse types

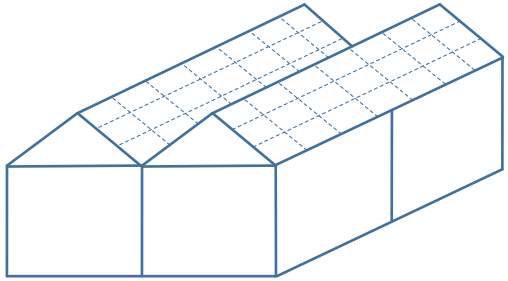
Glasshouse greenhouse



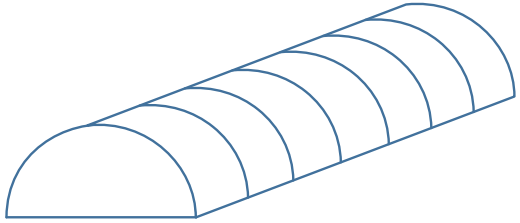
Multi-tunnel greenhouse



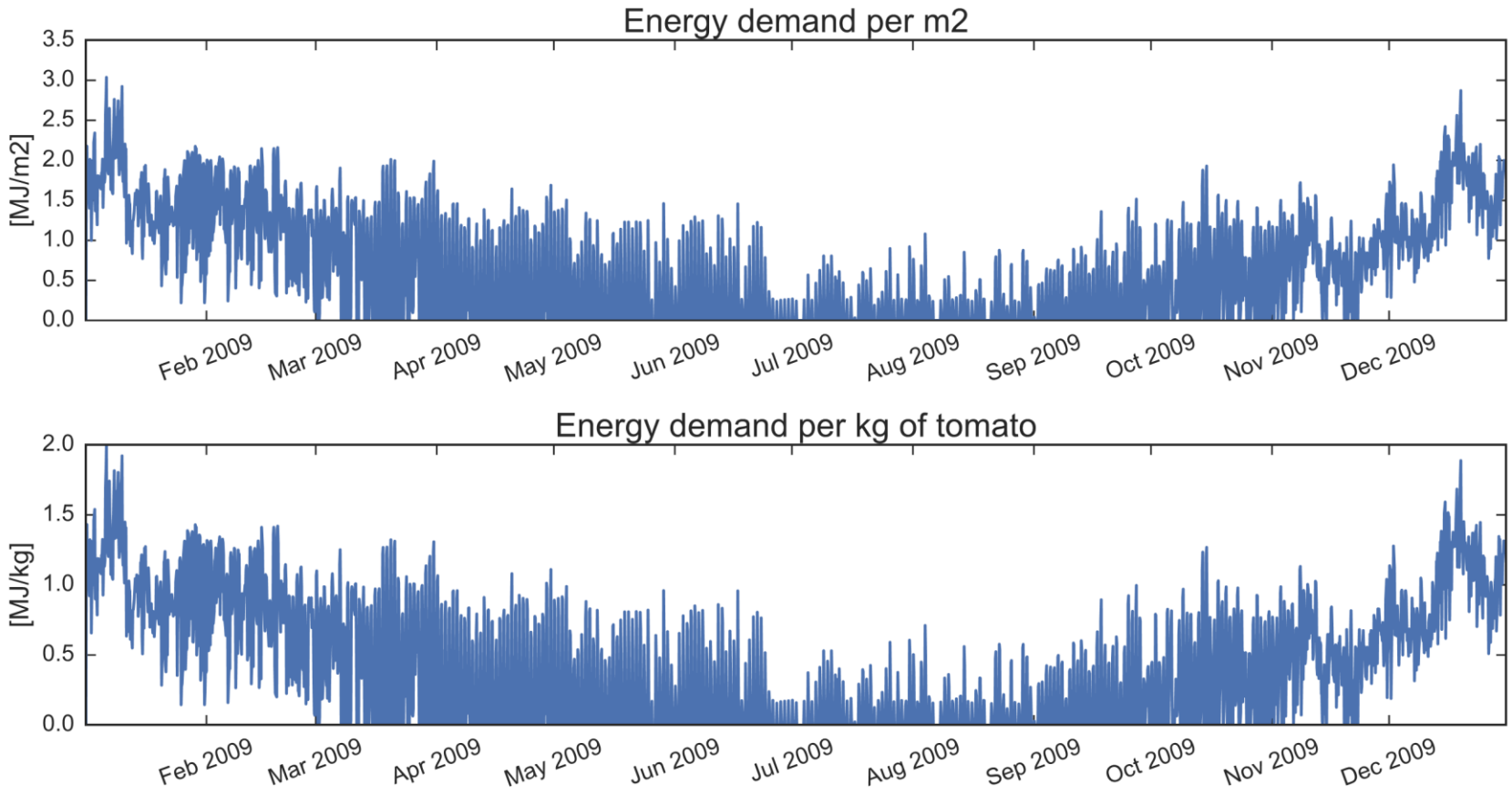
Parral greenhouse



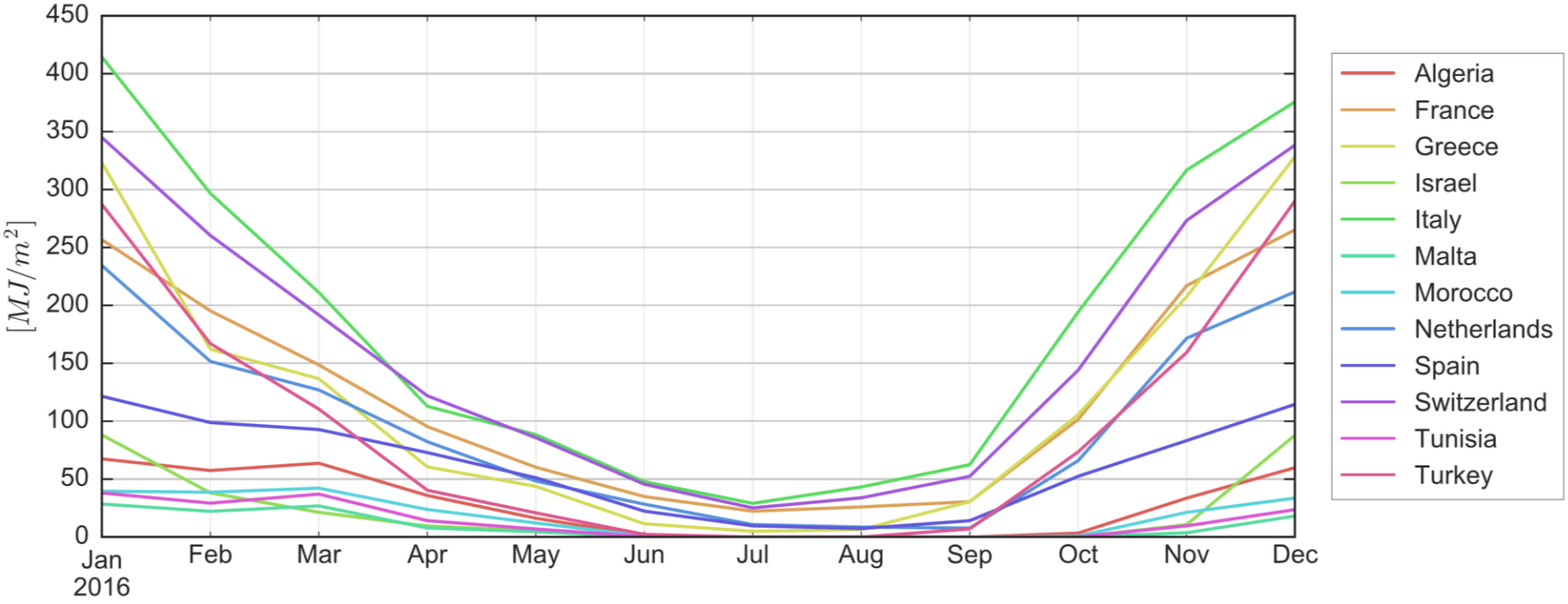
Low-tunnel greenhouse



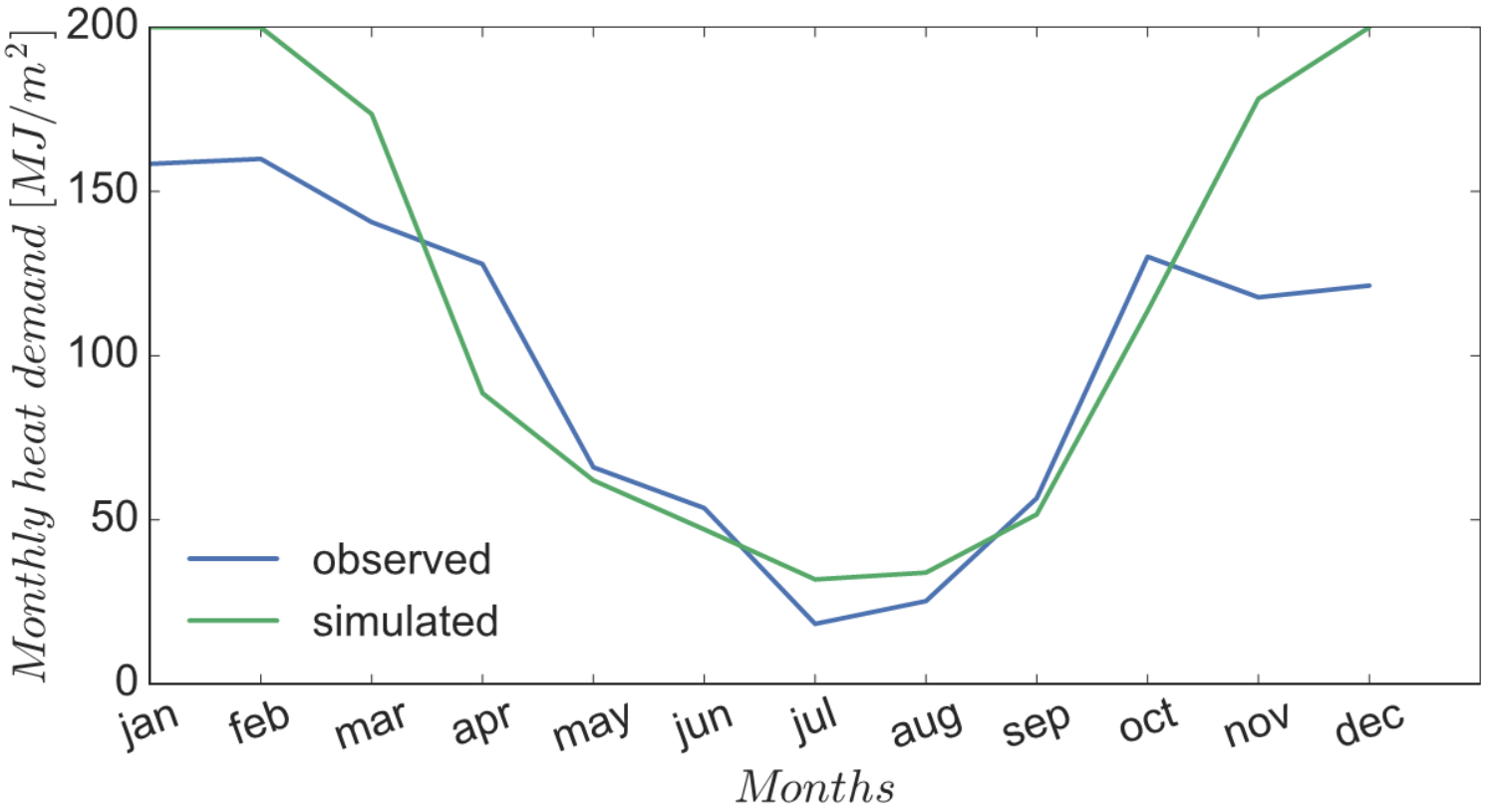
Ongoing research: Greenhouse model results



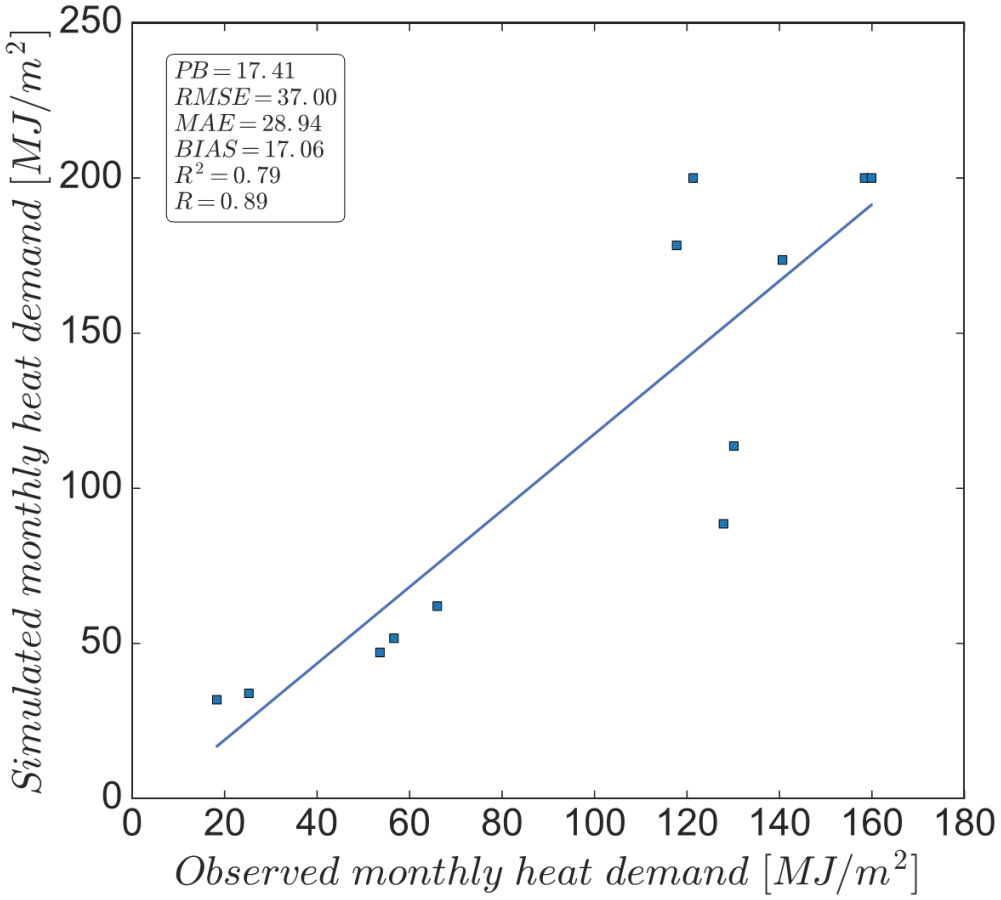
Ongoing research: Greenhouse model results



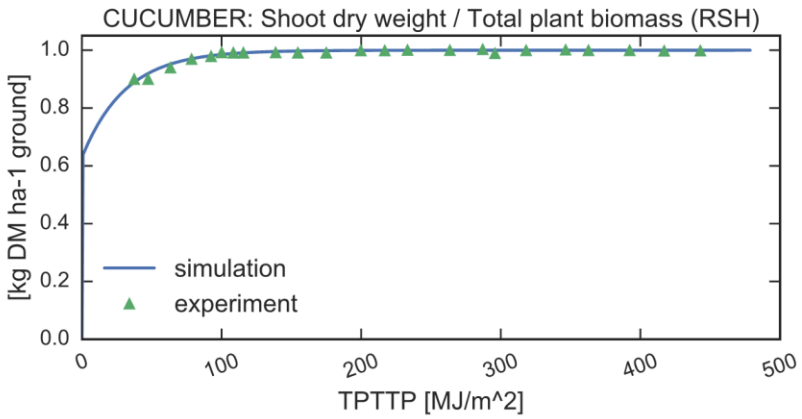
Ongoing research: Validation

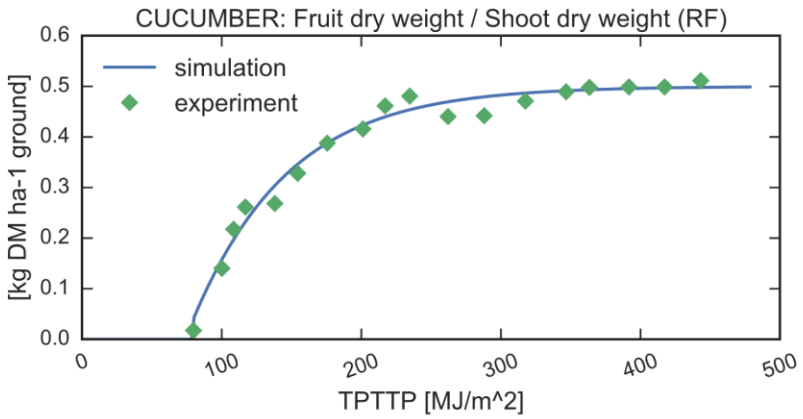


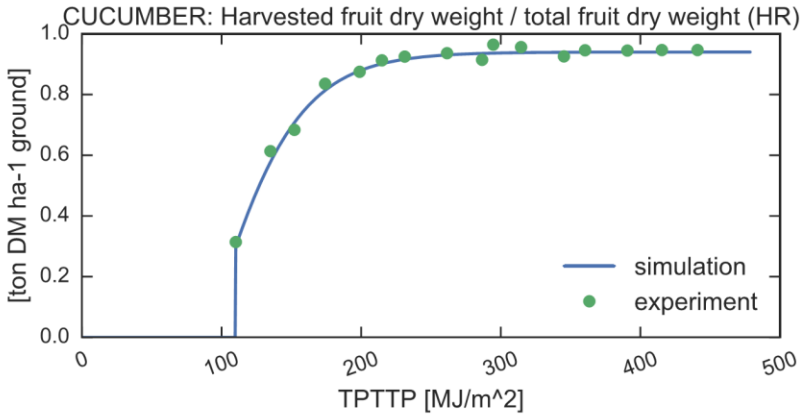
Ongoing research: Validation

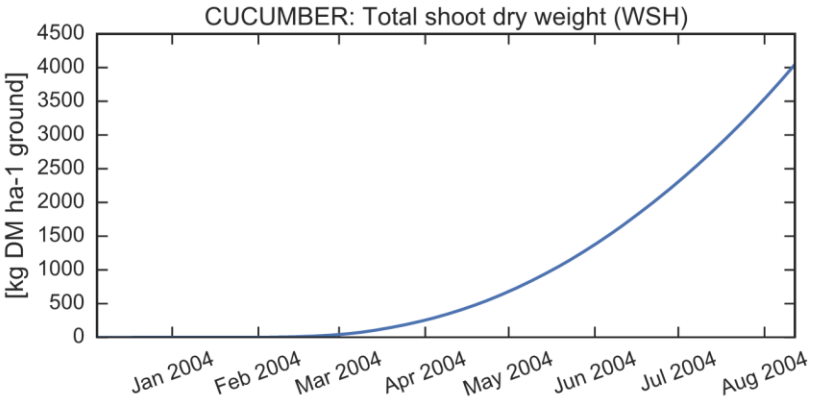


Ongoing research: greenhouse crop model

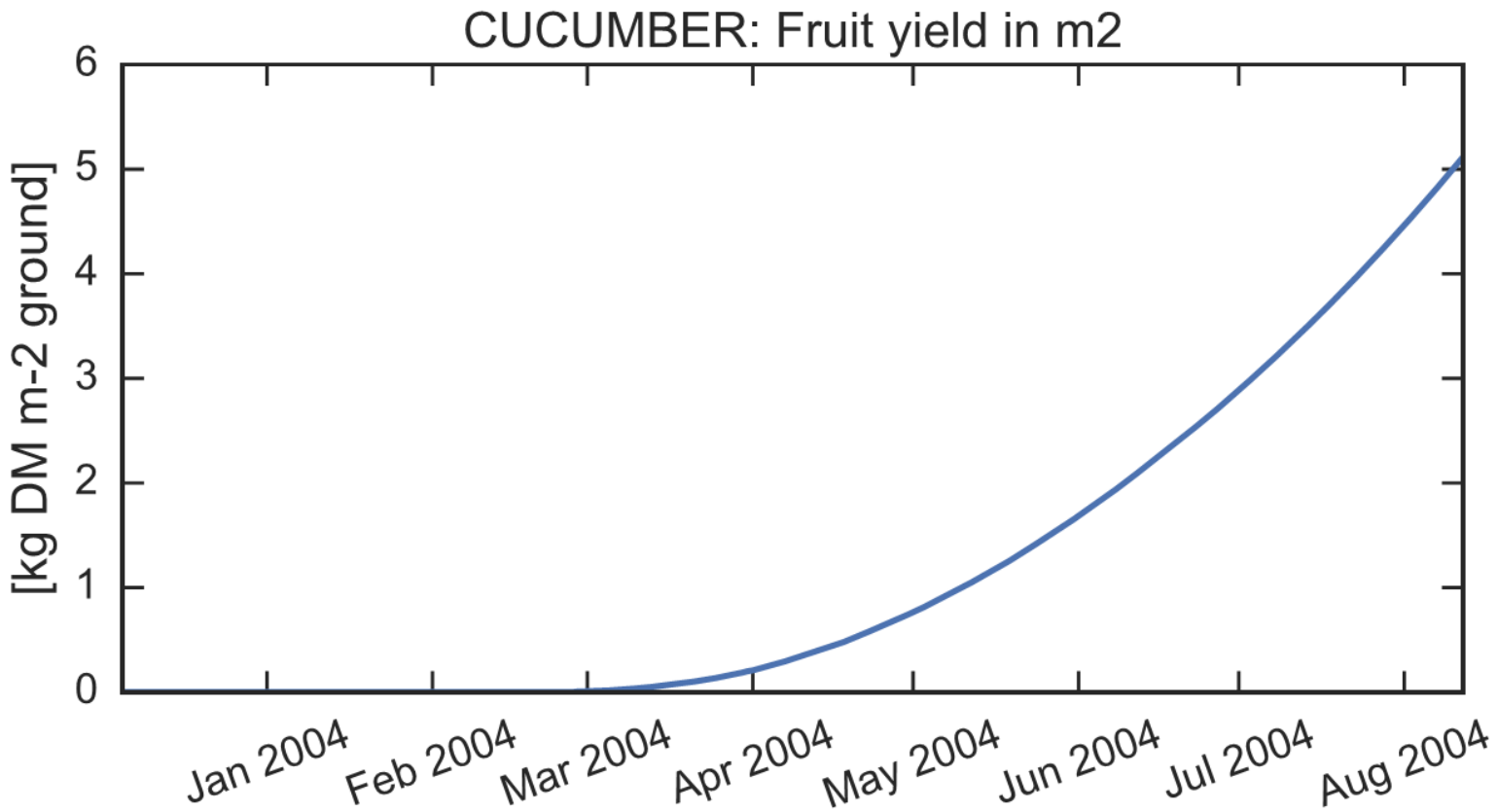








Ongoing research: greenhouse crop model



Thank you for your attention!