The Practice of Ethics in Engineering Research

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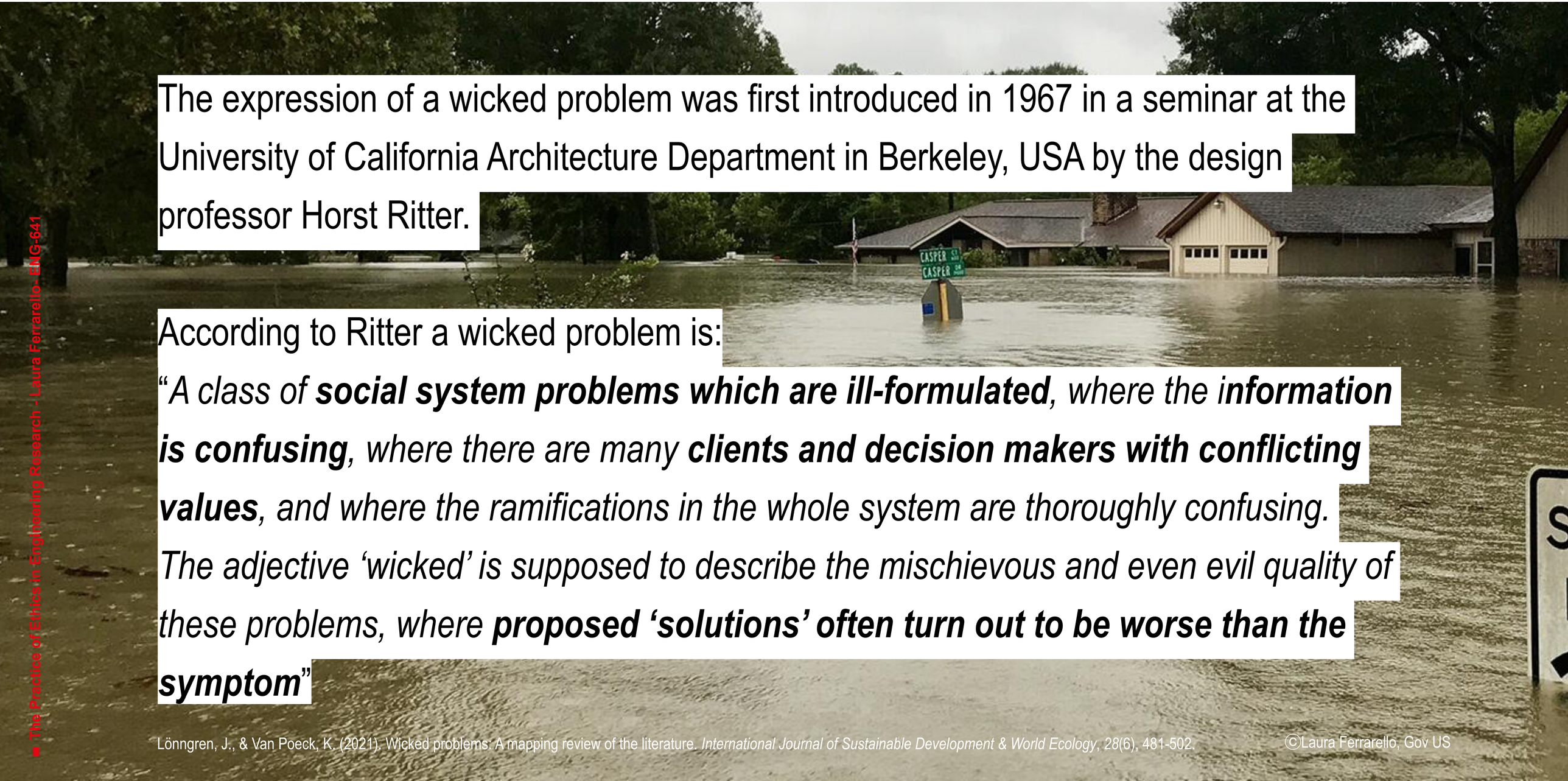
19.11.24

What is a wicked problem?

“Some problems are so complex that you have to be highly intelligent and well informed just to be undecided about them.”

Laurence J. Peter

What is a wicked problem?



The expression of a wicked problem was first introduced in 1967 in a seminar at the University of California Architecture Department in Berkeley, USA by the design professor Horst Ritter.

According to Ritter a wicked problem is:

"*A class of **social system problems which are ill-formulated**, where the i**nformation is confusing**, where there are many **clients and decision makers with conflicting values**, and where the ramifications in the whole system are thoroughly confusing. The adjective 'wicked' is supposed to describe the mischievous and even evil quality of these problems, where **proposed 'solutions' often turn out to be worse than the symptom***"

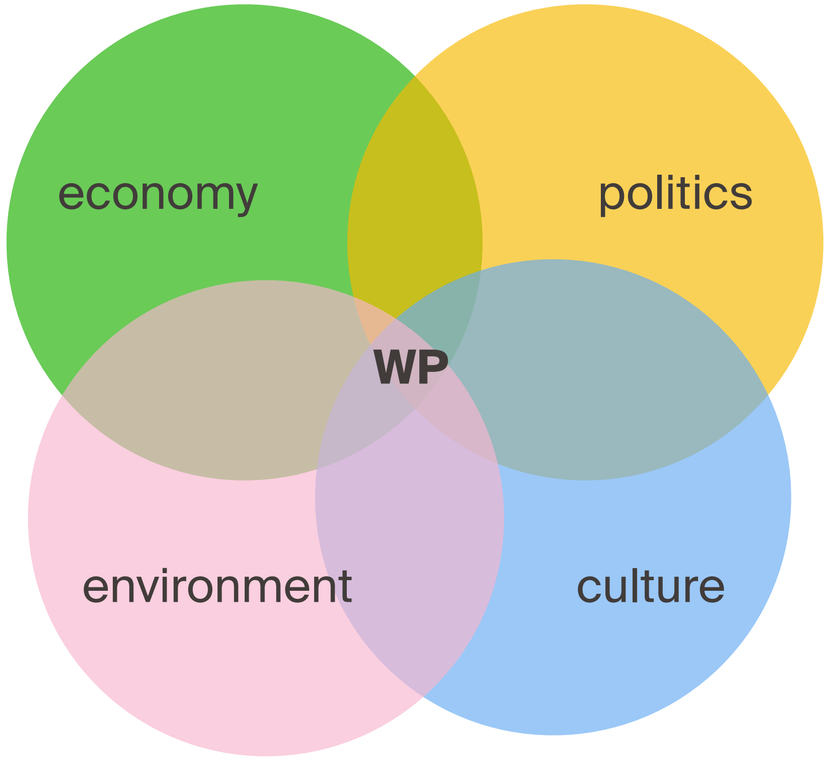
Lönngren, J., & Van Poeck, K. (2021). Wicked problems: A mapping review of the literature. *International Journal of Sustainable Development & World Ecology*, *28*(6), 481-502.

What is a wicked problem?

A wicked problem is often the intersection of different types of multi–scalar systems;

defining problems as wicked enables one to understand that problems have economic, technological, social and environmental factors operating altogether and interdependently.

This is why wicked problems are complex by definition.



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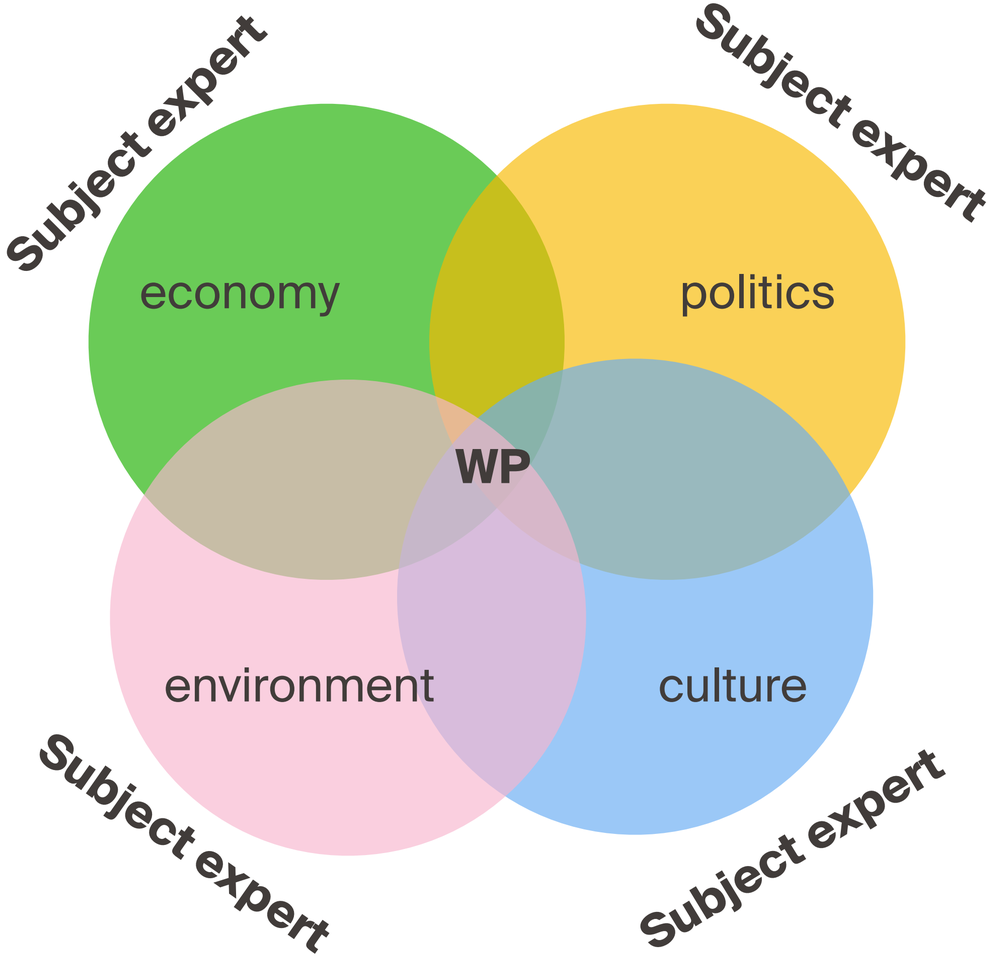
Transition Design Seminar, 2023, https://transitiondesignseminarcmu.net/classes-2/mapping-wicked-problems/

What is a wicked problem?

As these types of problems can't be quantified but described, a method to observe and describe these is the mapping of causal loops, where the positive are understood as loops that enhance a problem, and the negative ones tend to correct and stop the effect of positive loops.

Wicked problems need the participation of multiple perspectives to enrich the description of the problem from different perspectives.



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How can a wicked problem be described?

Based upon Rittel and Webber (1973)

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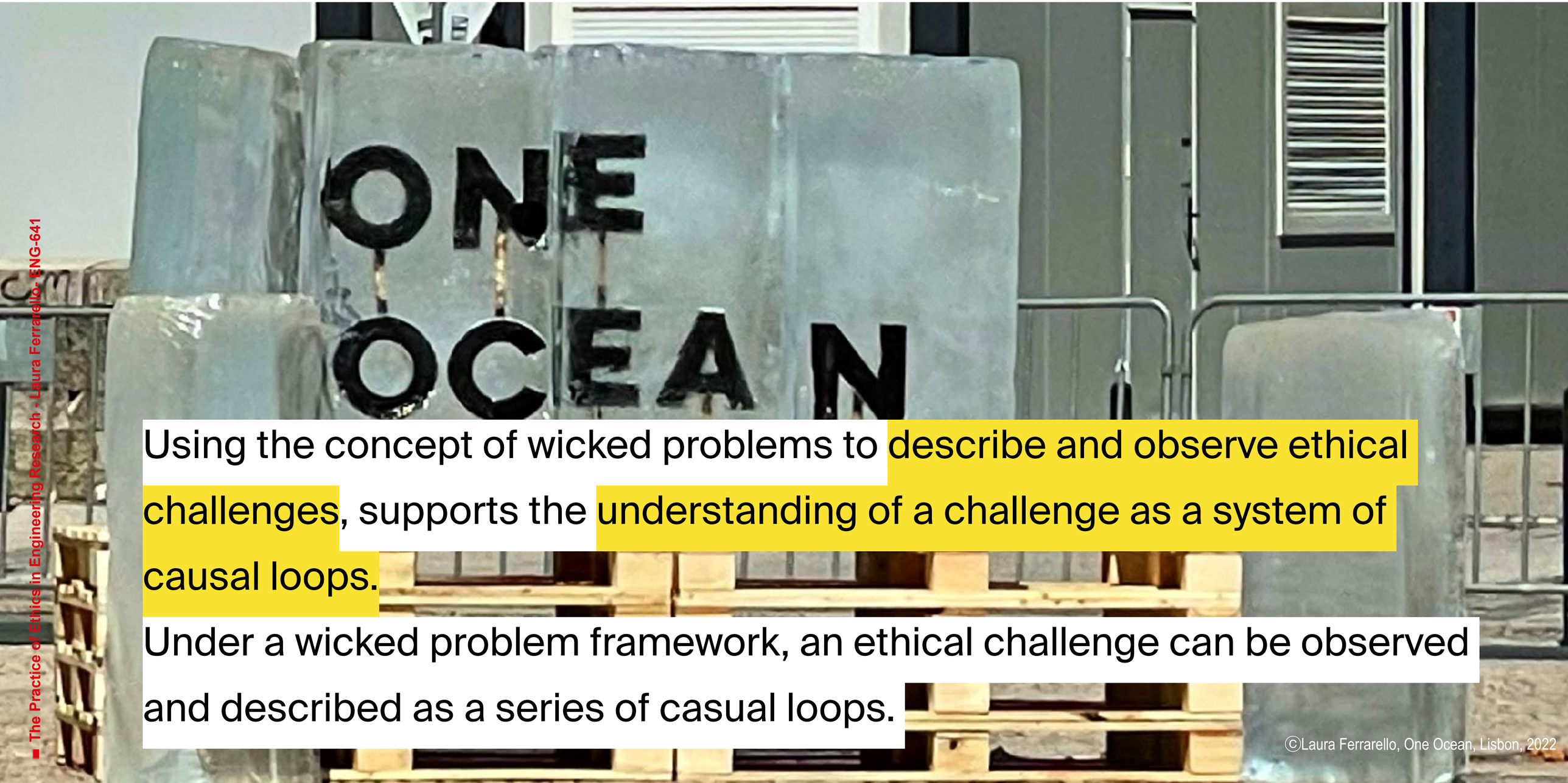
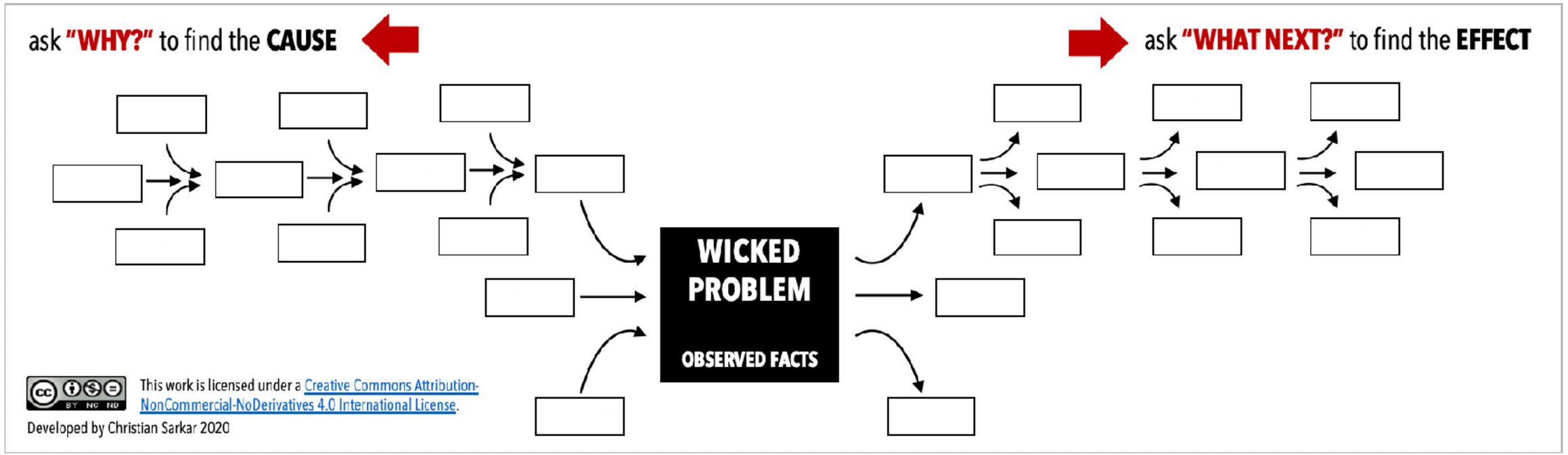
Wicked problems and ethics



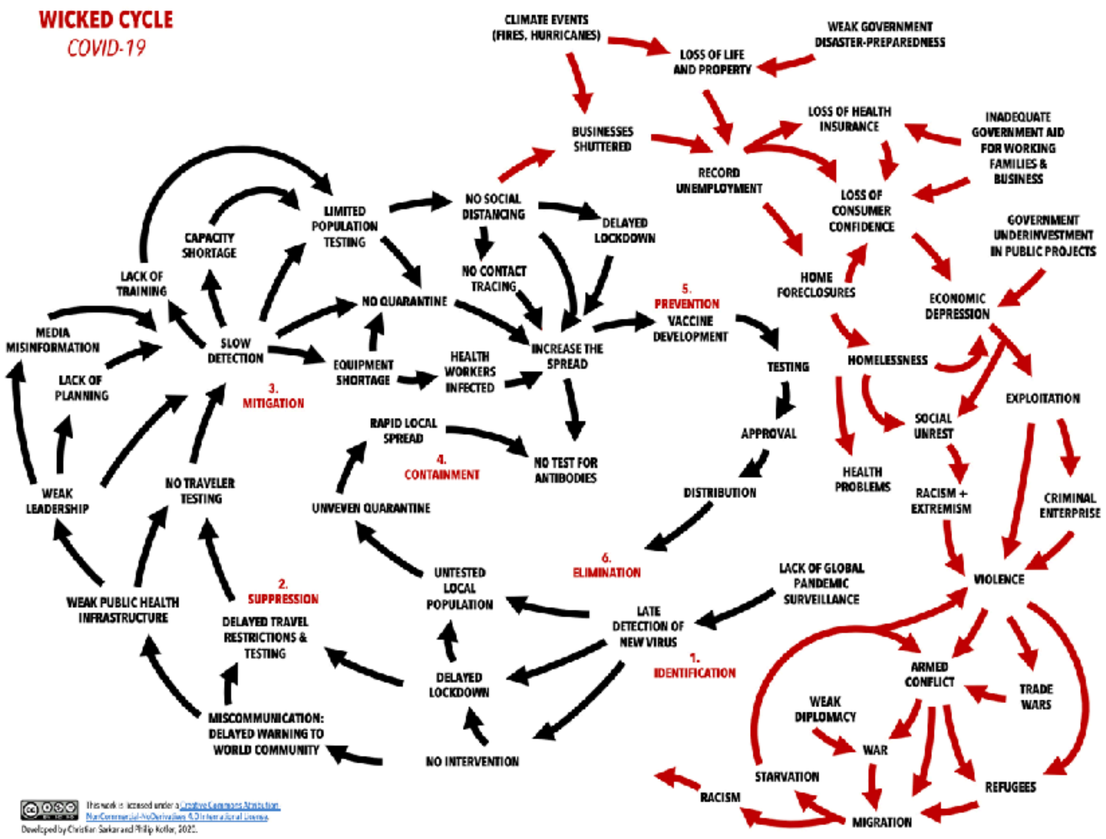
Using the concept of wicked problems to describe and observe ethical challenges, supports the understanding of a challenge as a system of causal loops.

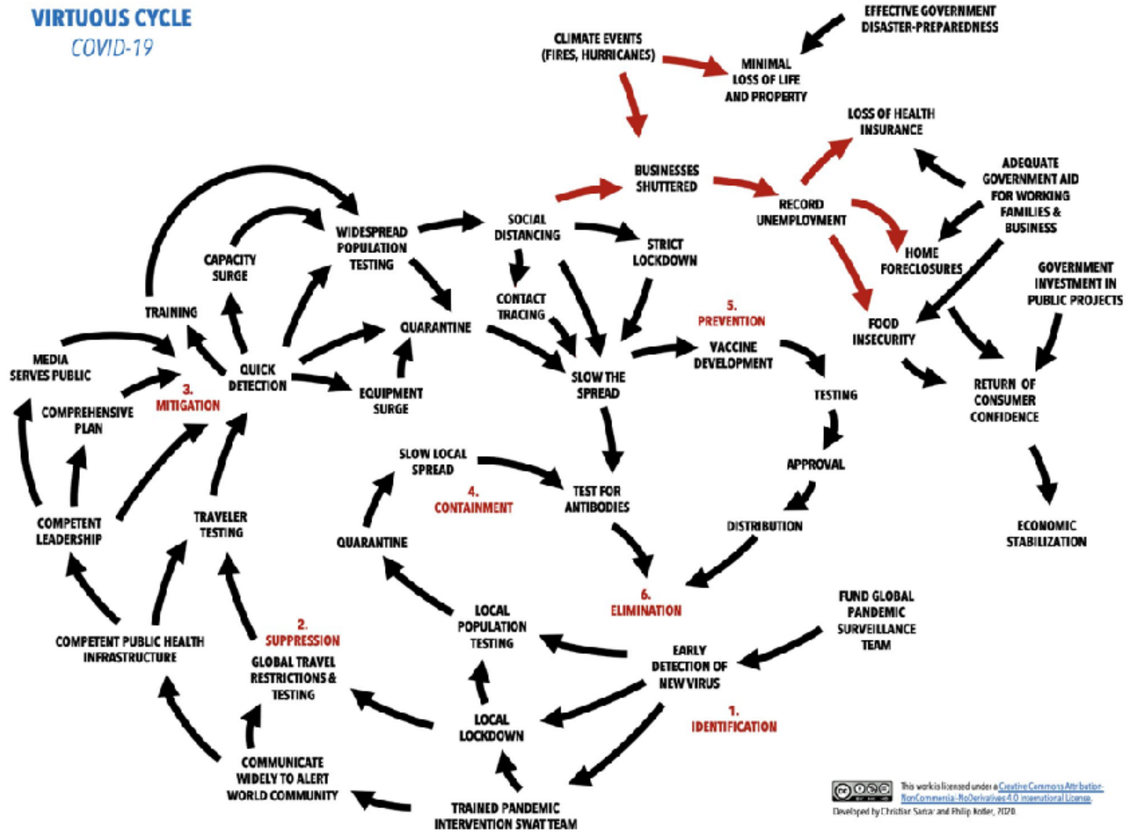
Under a wicked problem framework, an ethical challenge can be observed and described as a series of casual loops.

Ethical dilemmas as wicked problems



Ethical dilemmas as wicked problems

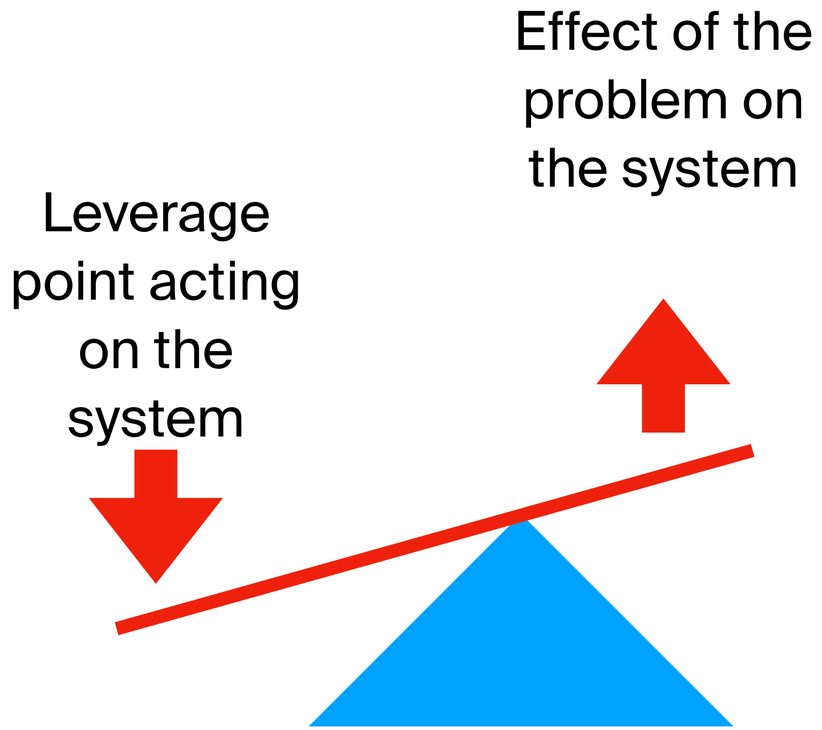




Harnessing wicked problem mapping: Leverage Points

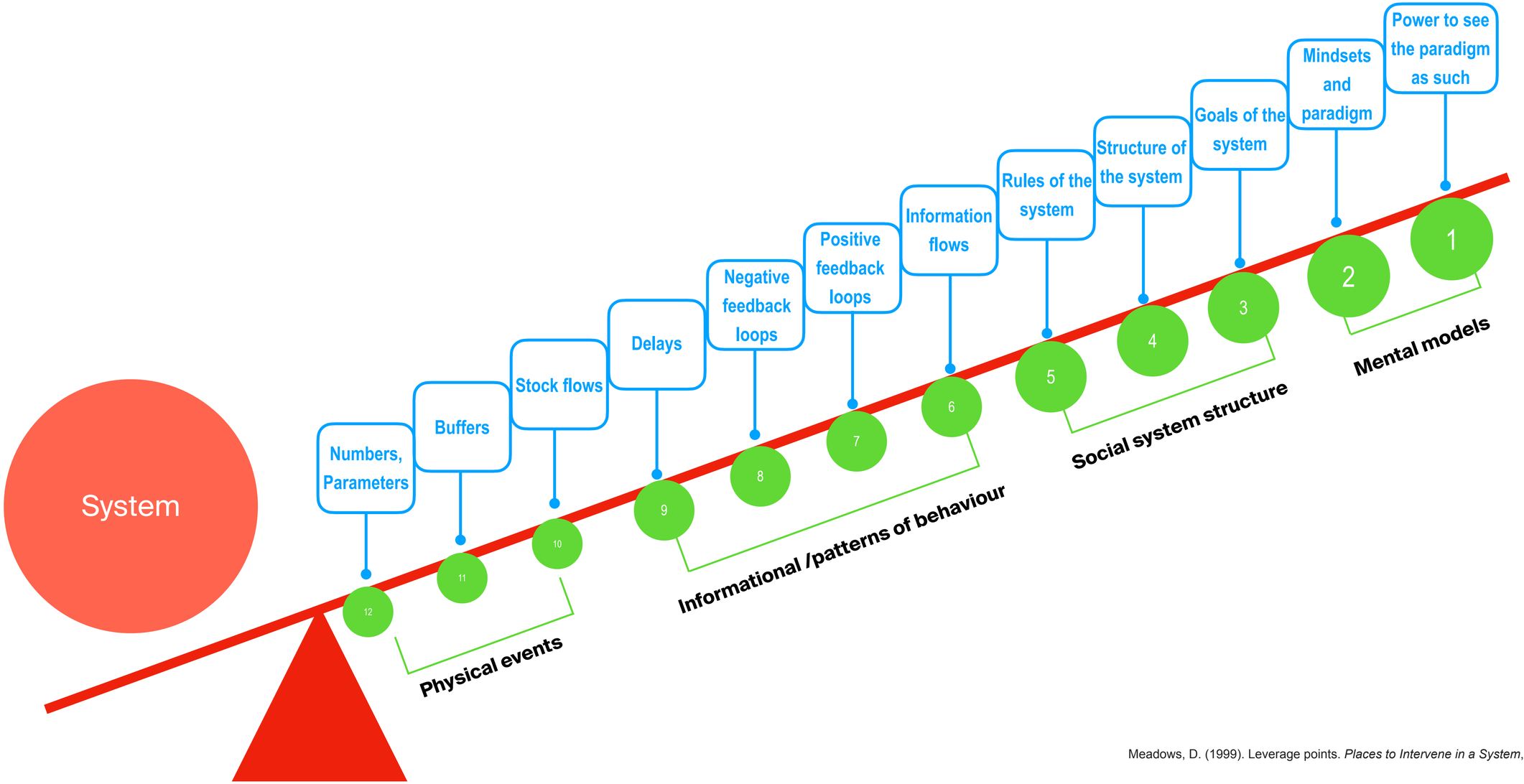
"Leverage points" are elements of a system which are able to shift the order a system works and provoke change. Their influence vary according to the way a point leverages the system.

For instance, increasing the public's literacy on uses of digital technologies, can be a leverage change on how data collection is regulated.



Meadows, D. (1999). Leverage points. *Places to Intervene in a System*, *19*, 28.

Leverage Points



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Leverage Points

Points of system interventions in increasing order of effectiveness

12. Constants, parameters, numbers –e.g., subsidies, taxes, standards– that define the rate at which things happen in the system.
11. The sizes of buffers–e.g., the money you keep in the bank that helps you manage exceptional expenses.
10. The structure of material stocks and flows – e.g., changing the transport networks, can improve transportation and increase the number of people traveling on it, but this is very expensive and the result is not guaranteed.
9. The lengths of delays, relative to the rate of system change (e.g., building an energy plant responds to energy demand but it takes time).
8. The strength of negative feedback loops, relative to the impacts they are trying to correct against. negative feedback loops are mechanisms that try to keep a specific measurement around a specific goal. (e.g., a thermostat has a goal temperature and it turns heating on to keep that temperature)
7. The gain around driving positive feedback loops (e.g., the more you have in the bank the more interest you earn).

Meadows, D. (1999). Leverage points. *Places to Intervene in a System*, *19*, 28.

Leverage Points

Points of system interventions in increasing order of effectiveness

6. The structure of information flows, which is changing how information is propagated and how it's made visible in the system (e.g., making energy consumption visible grow awareness of use and it can induce less consumption).
5. The rules of the system (such as incentives, punishments, constraints) define its scope, its boundaries.
4. The power to add, change, evolve, or self-organise system structure. These are structural transformation of the system, usually due to new elements appearing (e.g., new technologies)
3. The goals of the system have the power to transform and define each and every leverage point. With a clear goal, the system's parameters try to reach it.
2. The mindset of the system (e.g., values, social contexts, beliefs).
1. The power to transcend paradigms and to be able to see the subjectivity of reality, which means being critical of understanding that no paradigm is "true" and can change, thus creating a new system with new paradigms.

Meadows, D. (1999). Leverage points. *Places to Intervene in a System*, *19*, 28.

Example: fostering climate adaption in agriculture

Issue

Because of climate change, water availability might be limited**.** Lower Saxony temperature will rise by about 1.0 to 3.5C compared to the reference period (1971–2000). An extended cultivation period and a possible intensification of agricultural production will additionally increase water demand in the future.

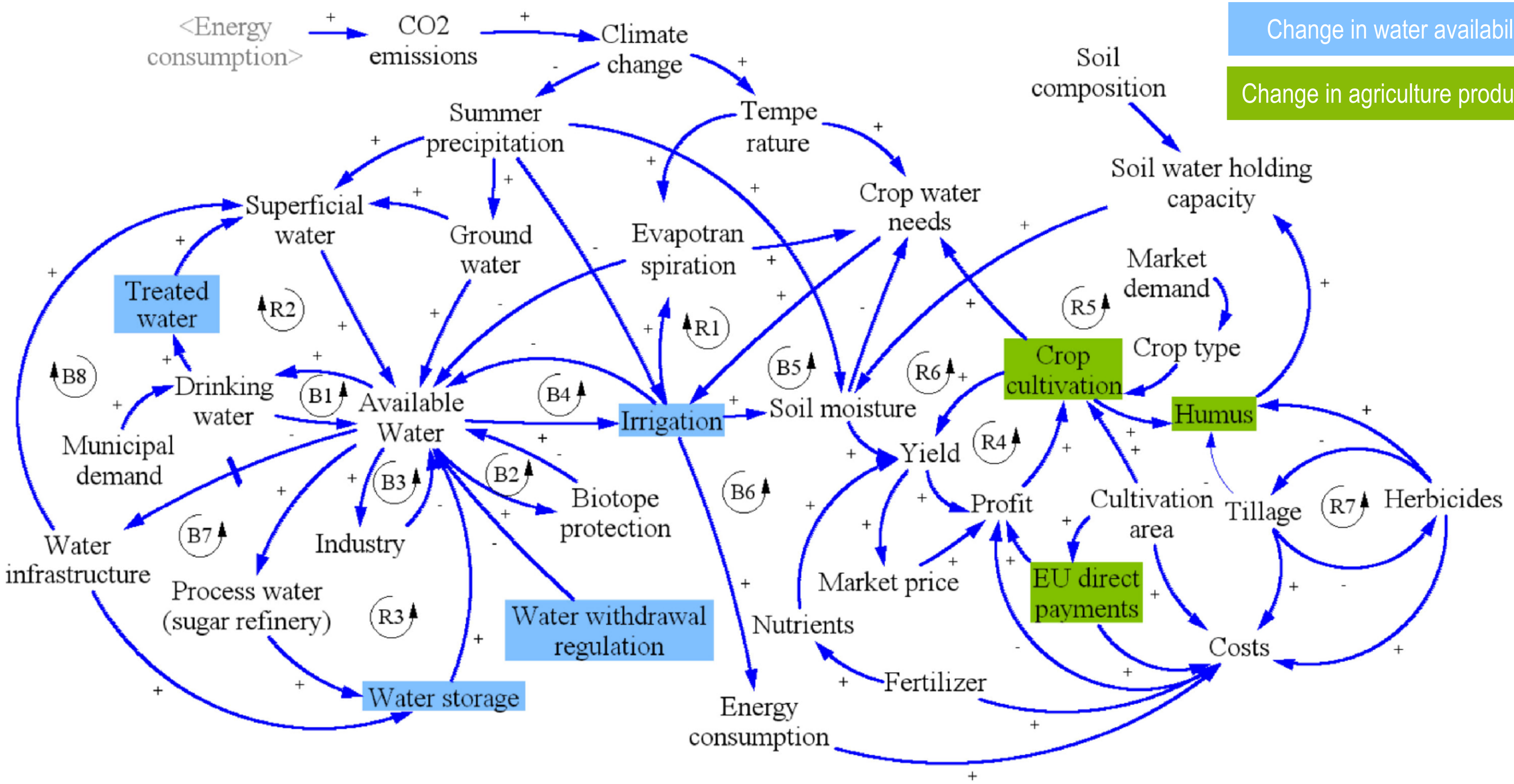
Method

To address these challenges, leverage point are used for developing effective climate change adaptation measures.

These Leverage Points (LP) emerges from the feedback loop analysis carried through a qualitative system dynamics model (QSDMs) that visualises the structure of a system through causal relations.

Egerer, S., Cotera, R. V., Celliers, L., & Costa, M. M. (2021). A leverage points analysis of a qualitative system dynamics model for climate change adaptation in agriculture. *Agricultural Systems*, *189*, 103052.

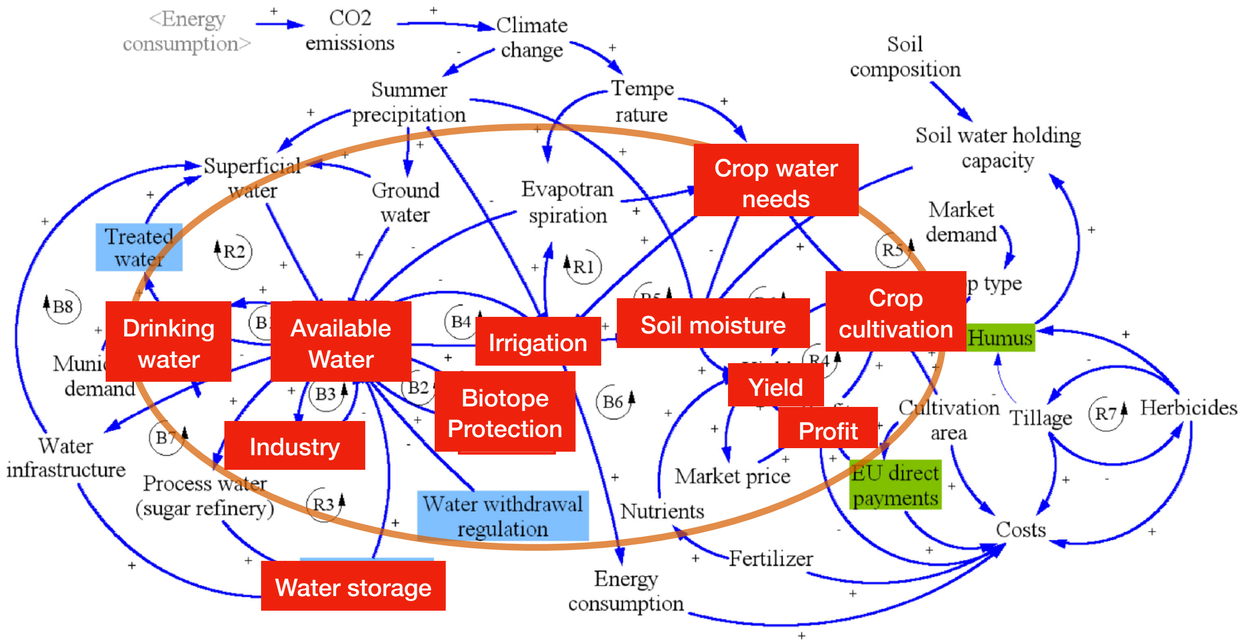
Selecting the parameters of the system

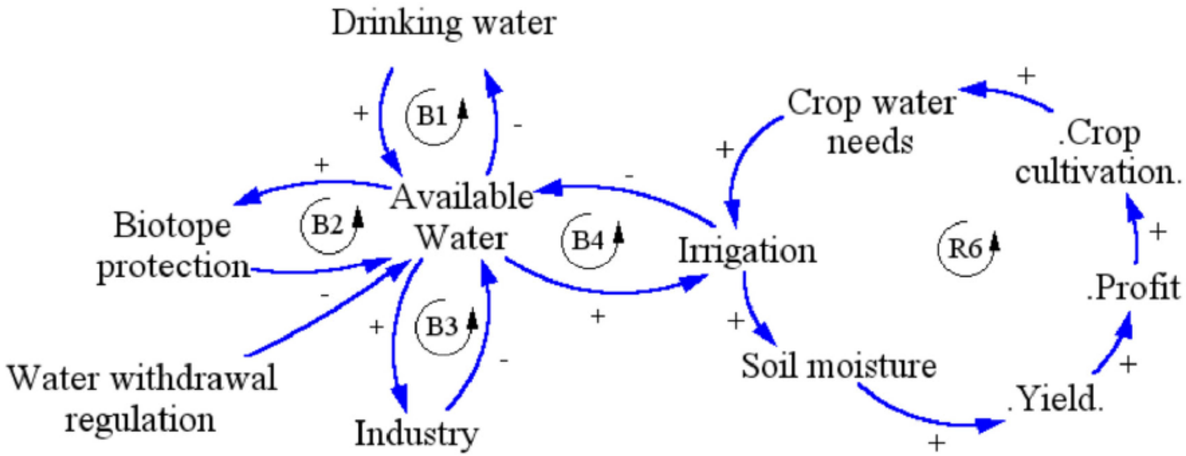


The parameters in blue and green are those where stakeholders have control of and can act upon.

Leverage points emerging from the casual loop analysis

LP1: Water withdrawal regulation



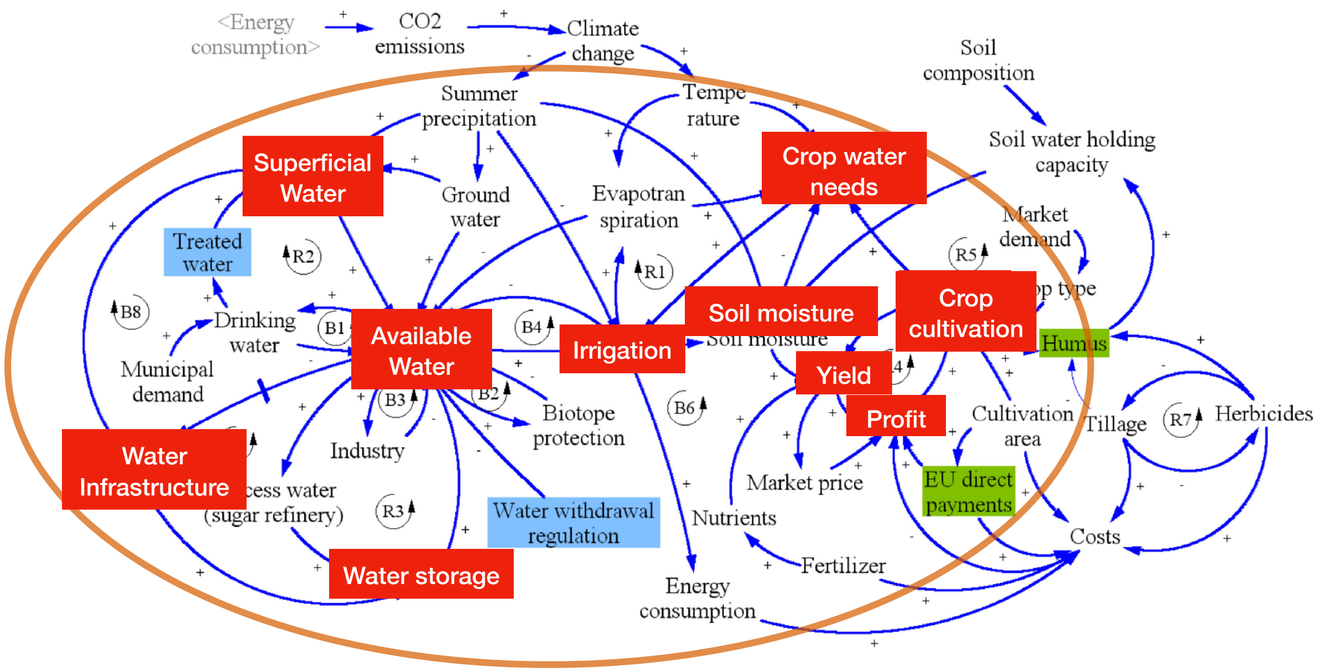


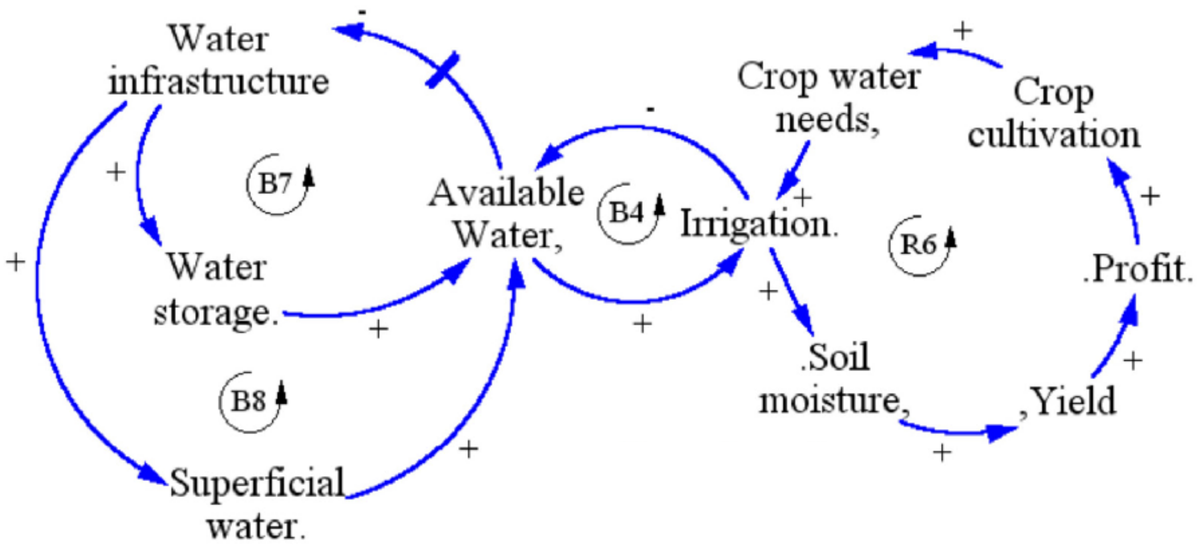
Closed feedback loops are isolated and factors on which there is no control are deleted.

Egerer, S., Cotera, R. V., Celliers, L., & Costa, M. M. (2021). A leverage points analysis of a qualitative system dynamics model for climate change adaptation in agriculture. *Agricultural Systems*, *189*, 103052.

Leverage points emerging from the casual loop analysis

LP2: Water reuse and storage





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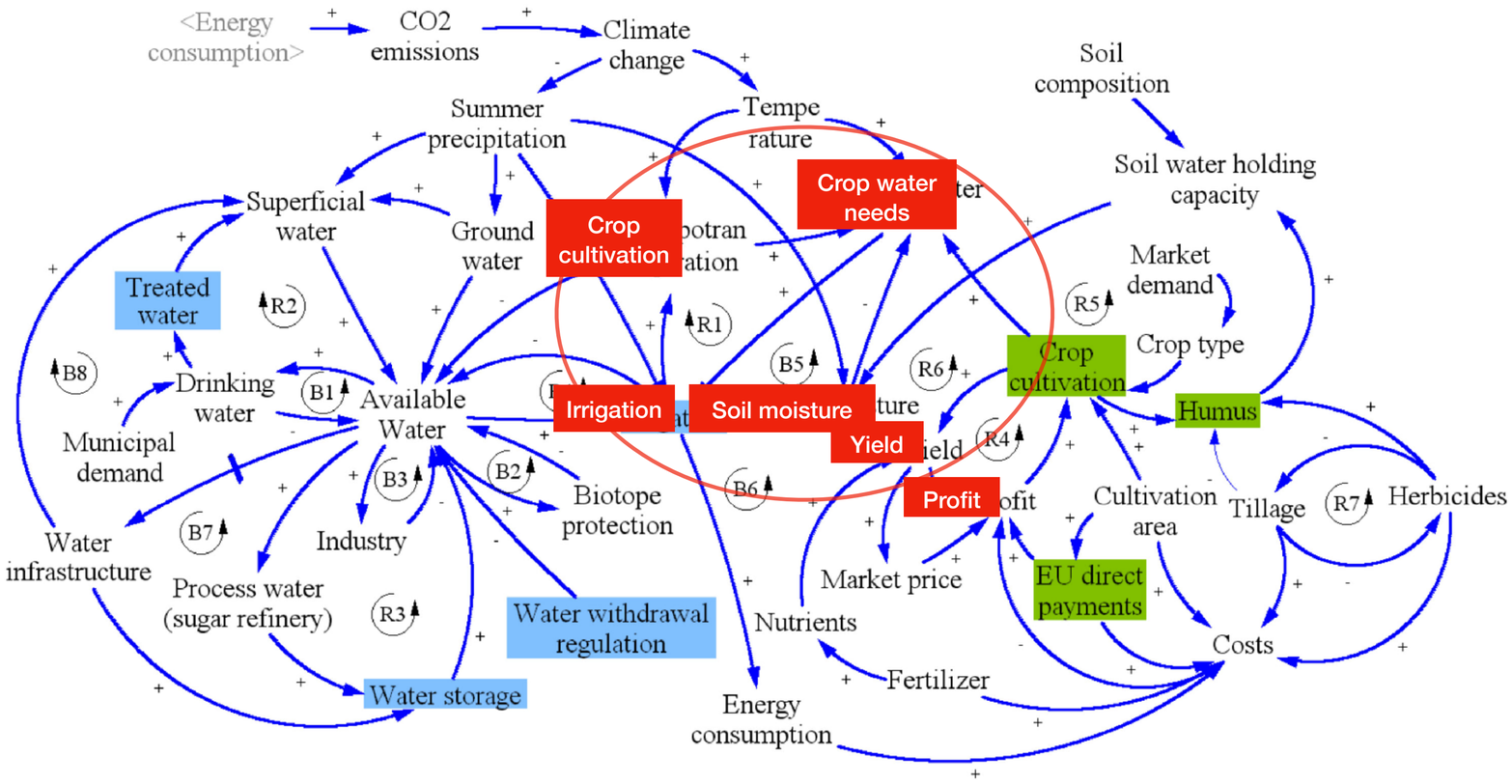
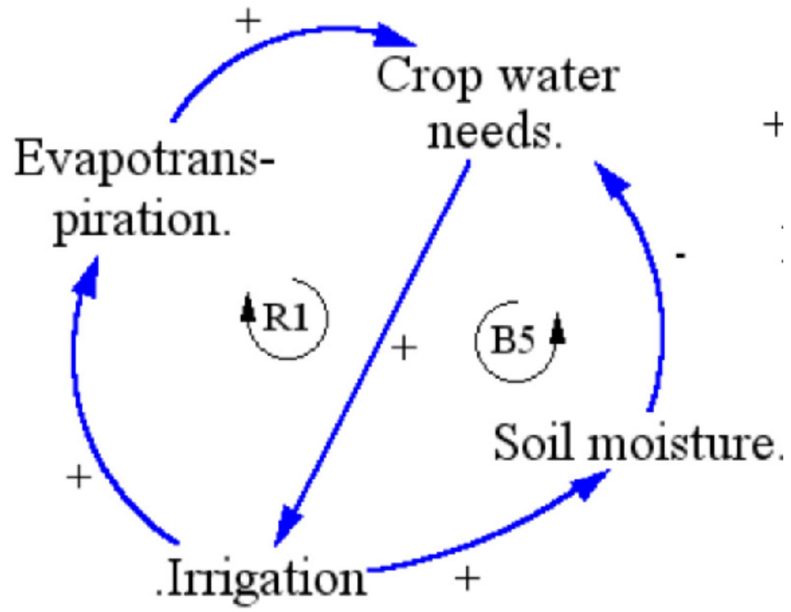
Leverage points emerging from the casual loop analysis

LP3: Water use efficiency





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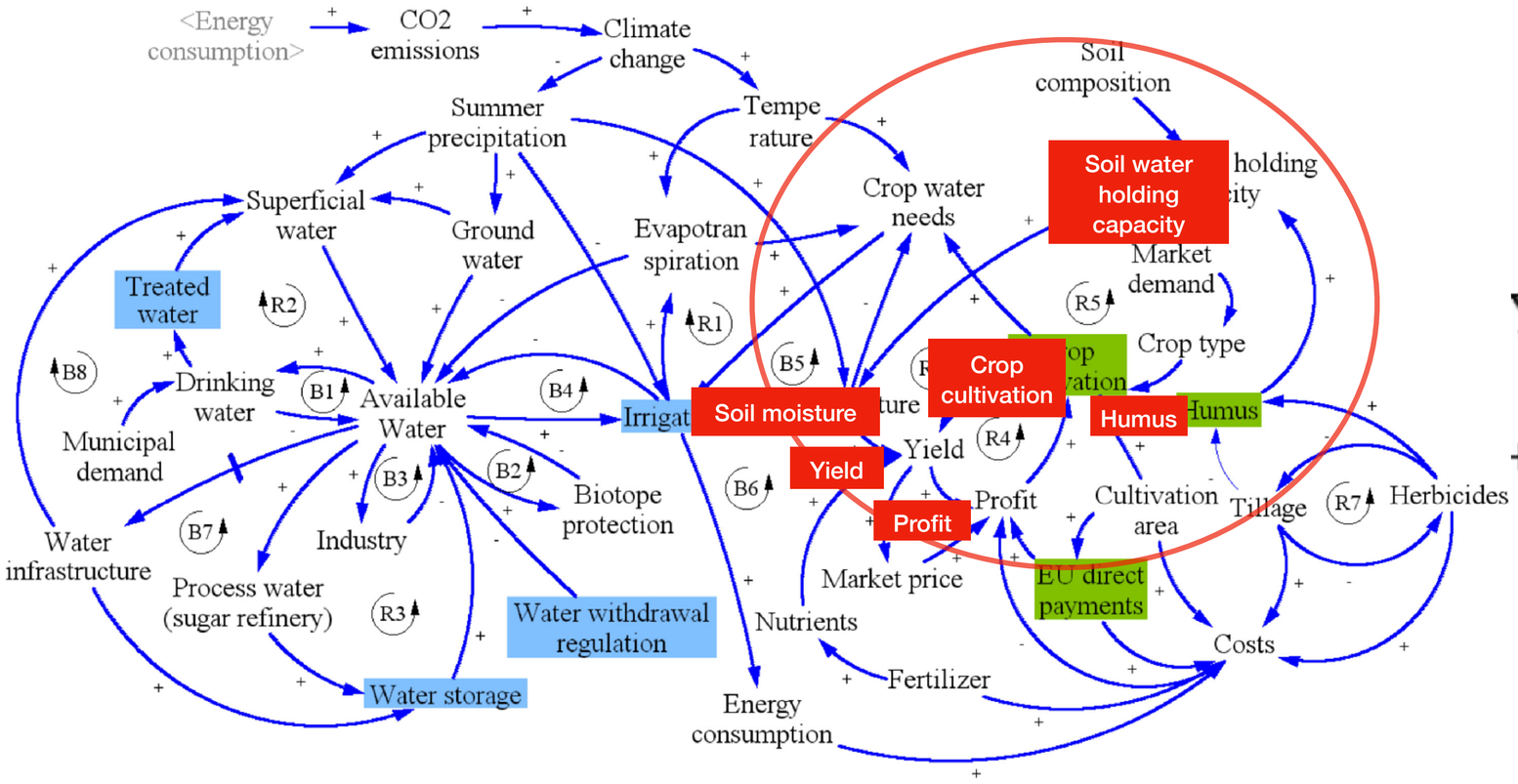
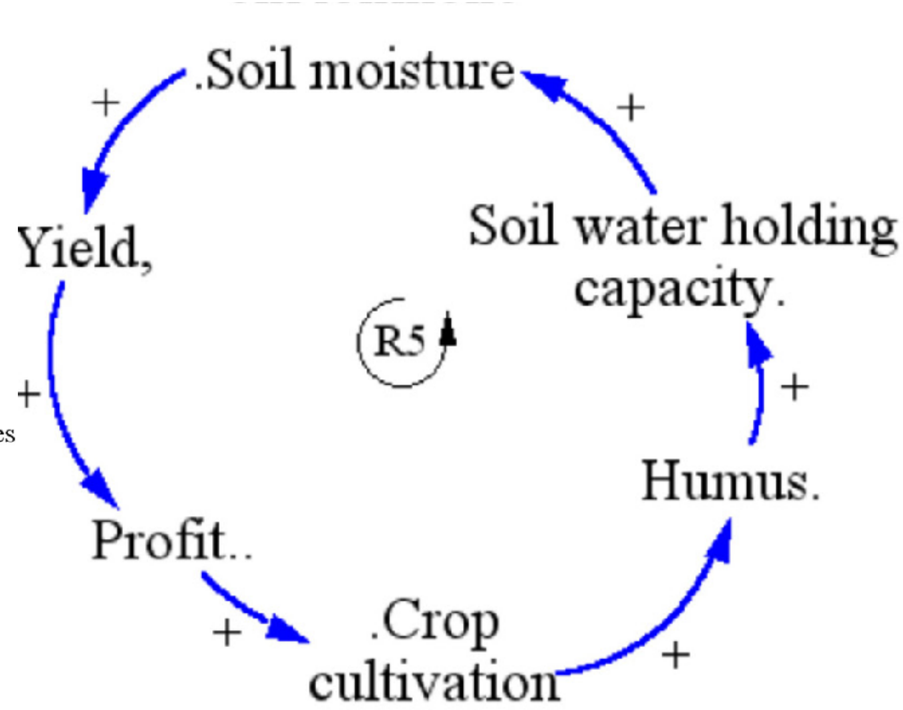
Leverage points emerging from the casual loop analysis

LP4: Humus enrichment





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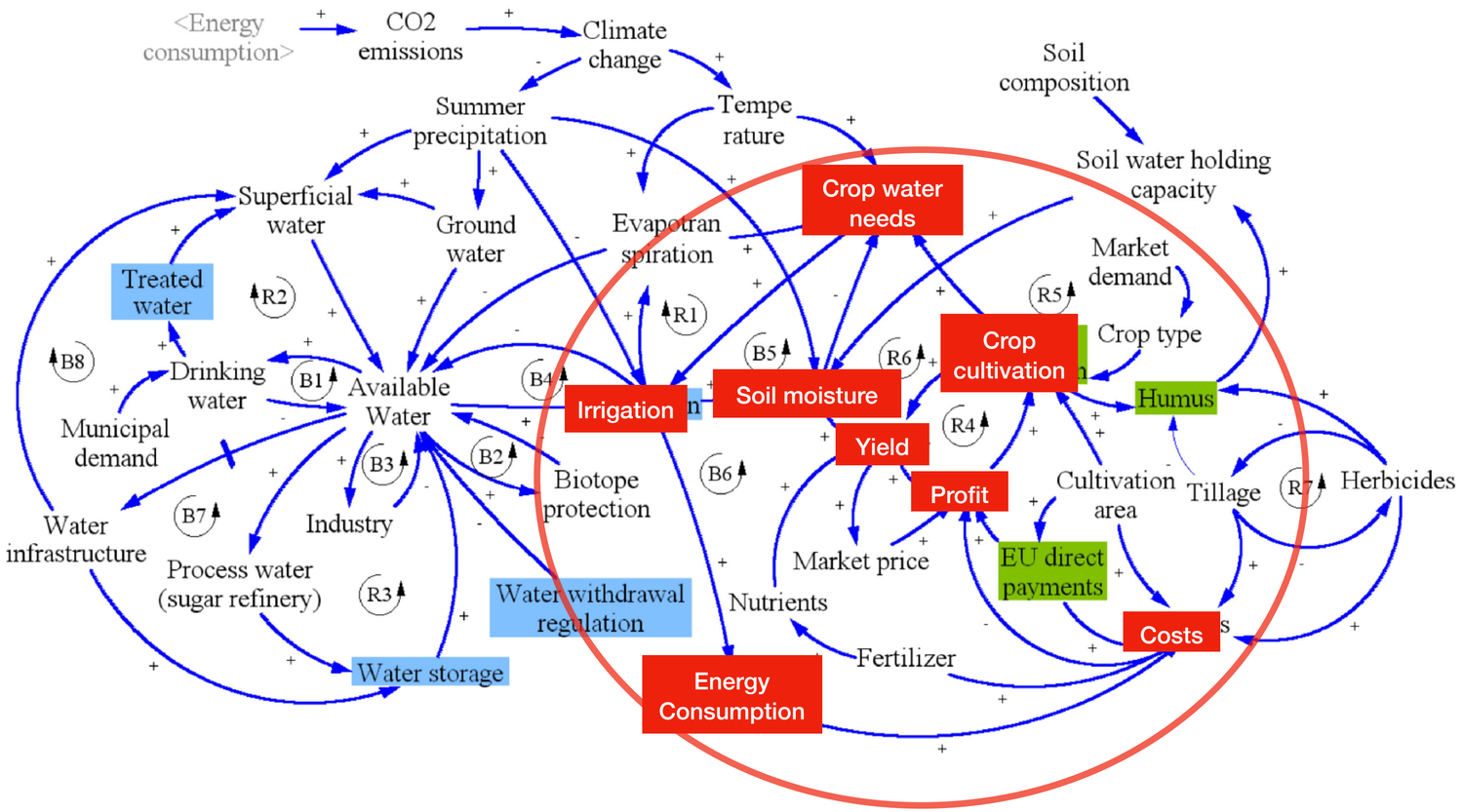
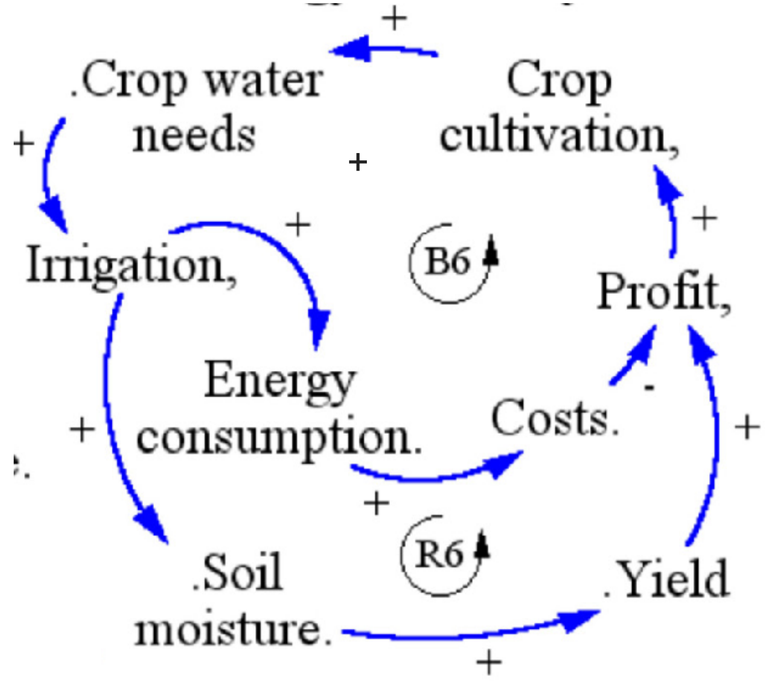
Leverage points emerging from the casual loop analysis

LP5: Irrigation –Energy Efficiency





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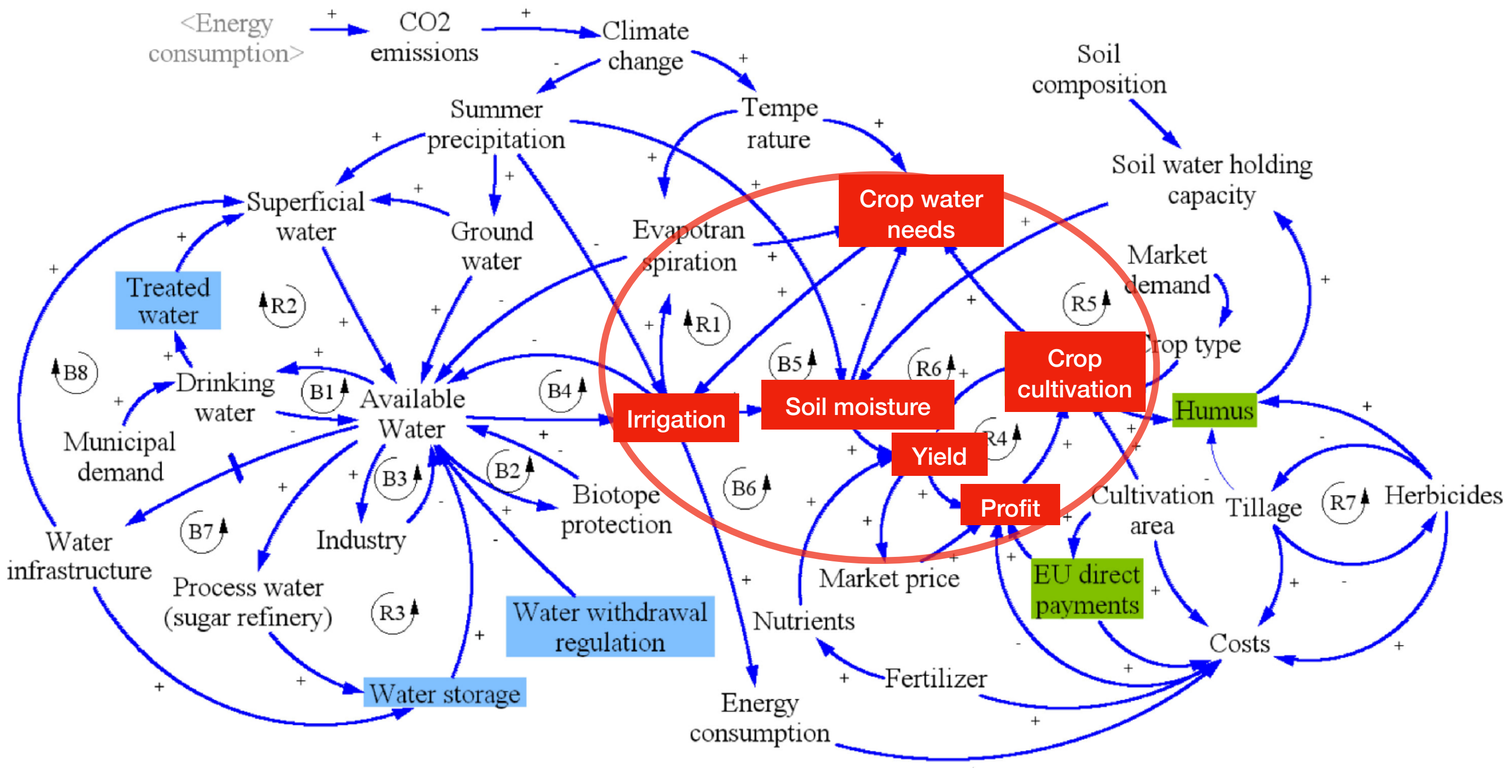
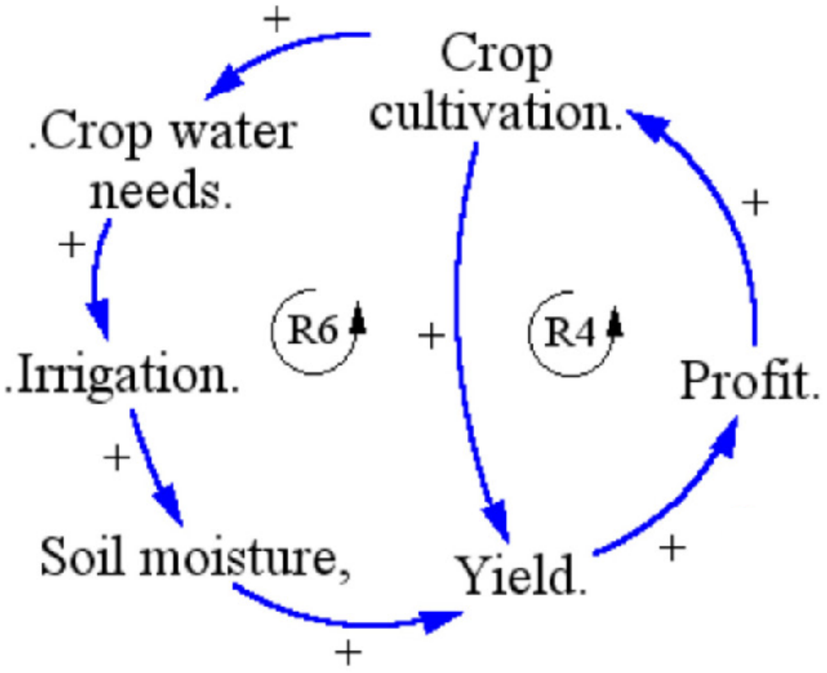
Leverage points emerging from the casual loop analysis

LP6: Crop Cultivation





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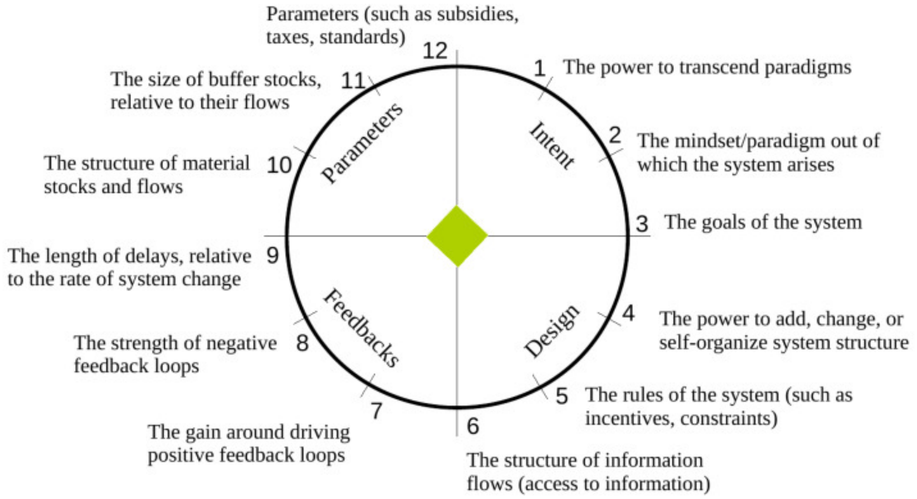
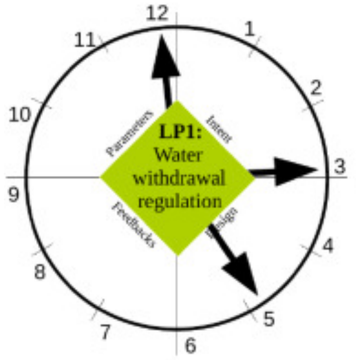
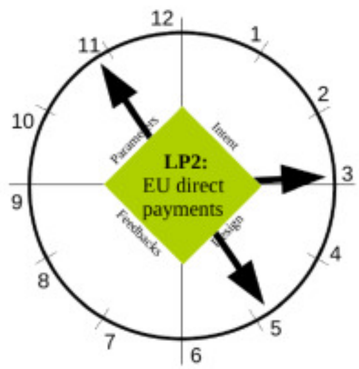
Classifying LP impact for changing the system goal



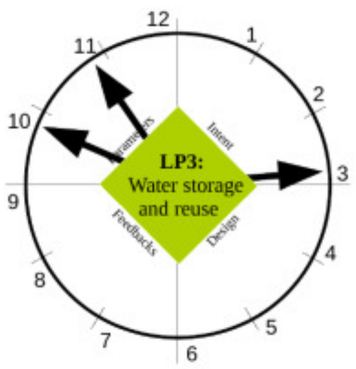


Water withdrawal regulation is related to the use of available water.

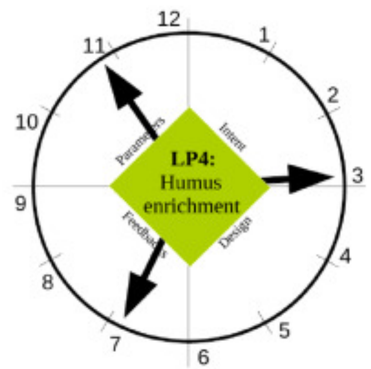
This LP can be both 12 (parameter), 3 (the goal of the system) and 5 (rule governing the system).



Incentives from EU, securing the farmers' income, is a LP 11 (buffer) as it contributes to the farming profit to mitigate risk associated to climate change. EU payments are also LP 3 (the goal of the system) and 5 (rule governing the system.



Increasing the amount of available water is a LP 11 (buffer). As this would require the development of new infrastructure for storing more water, this is expensive and results can't be guaranteed (LP 10).



Humus enrichment increases the soil's water holding capacity (LP 11), and the water-use efficiency in agricultural production (LP 3), which however depends on the gains of the loop (LP7).

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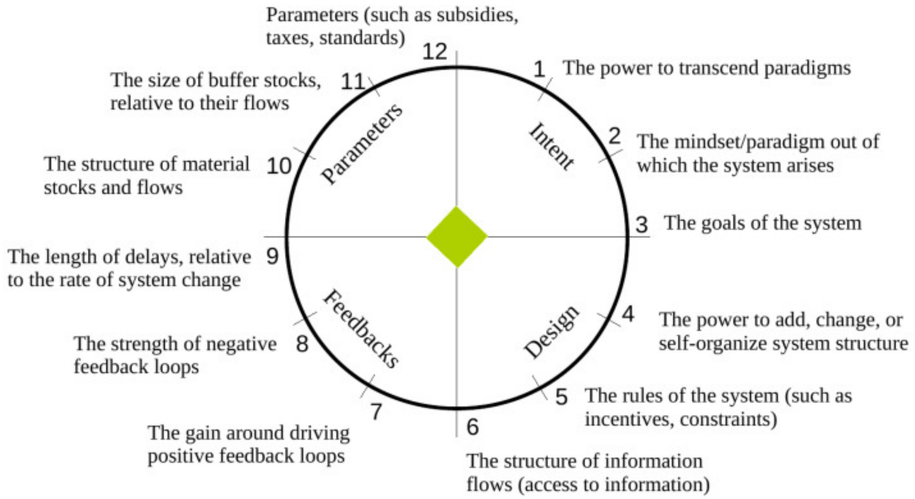
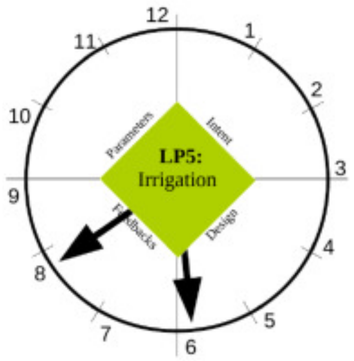
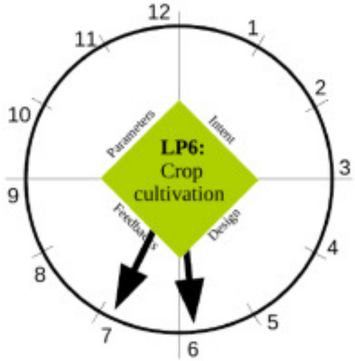
Classifying the impact of changing the system goal



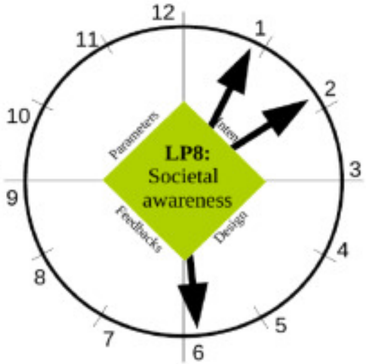


Irrigation is a LP 6 as it structures the water flow. Regulating water-use efficiency is a balancing (negative) loop whose strength depends on the energy efficiency (LP 8), and gains depend on its costs (LP7).



High–economic value water-demanding crops increase cultivation and gain. These positive reinforcing loops depend on income (LP 7) and irrigation (LP6).

National and federal financial support of water-efficient irrigation management are both LP5 (rules) LP 3 (goal).



Making farmers aware of possible future water shortages can draw cultural change (LP1, & 2). As awareness has systemic impact on sustainable agriculture management, regulation on water usage (LP6) can stimulate it.

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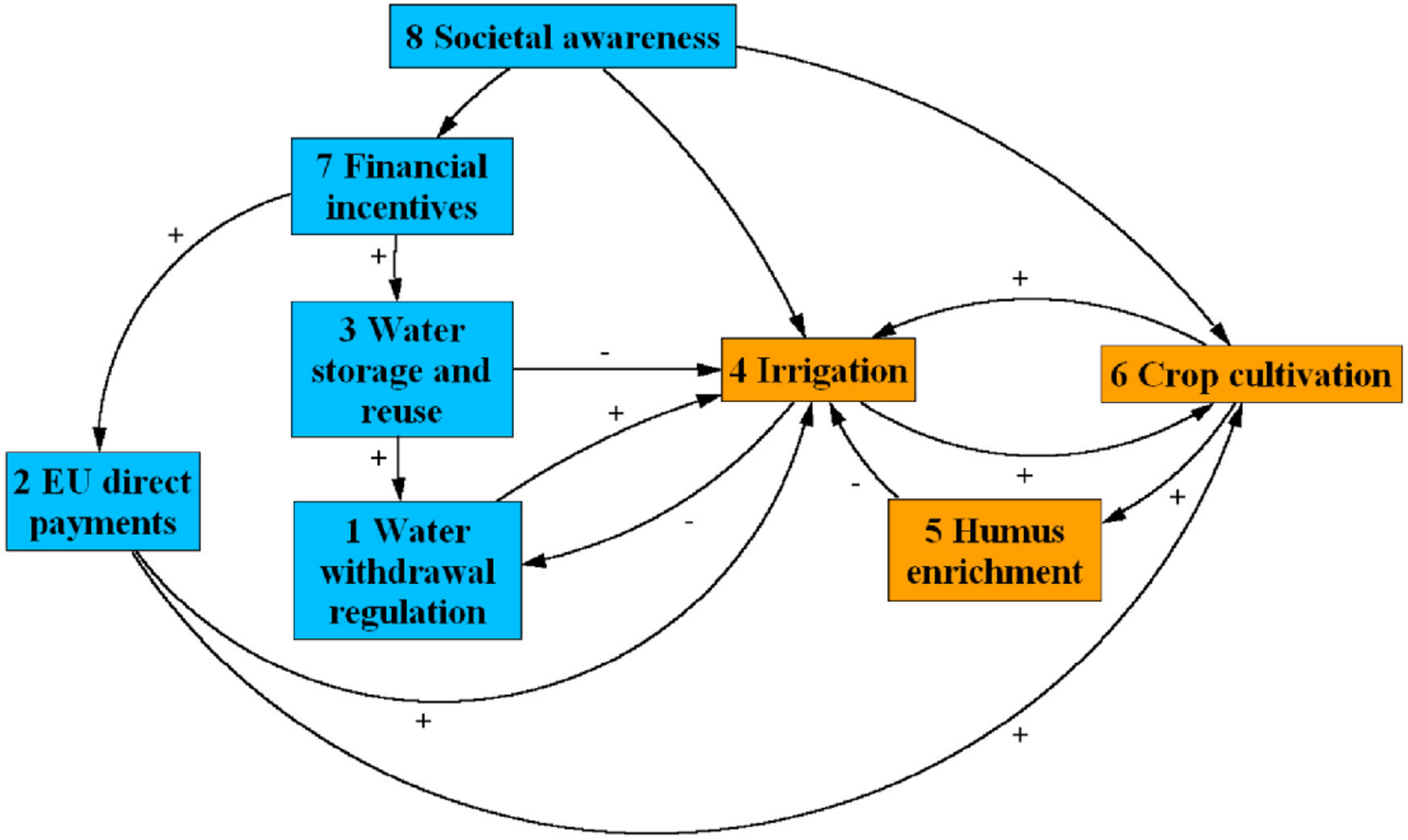
Prioritise interventions through leverage points

This diagram represents the relation between the LPs to outline who should take responsibility for and what actions should be taken.

Horizontally, it shows what interventions should be prioritised from a policy (blue) or farming level (orange). Vertically, it shows the LPs impact, decreasing from top to bottom.

Farm-level LPs are interrelated, but have limited feedback to the policy level.



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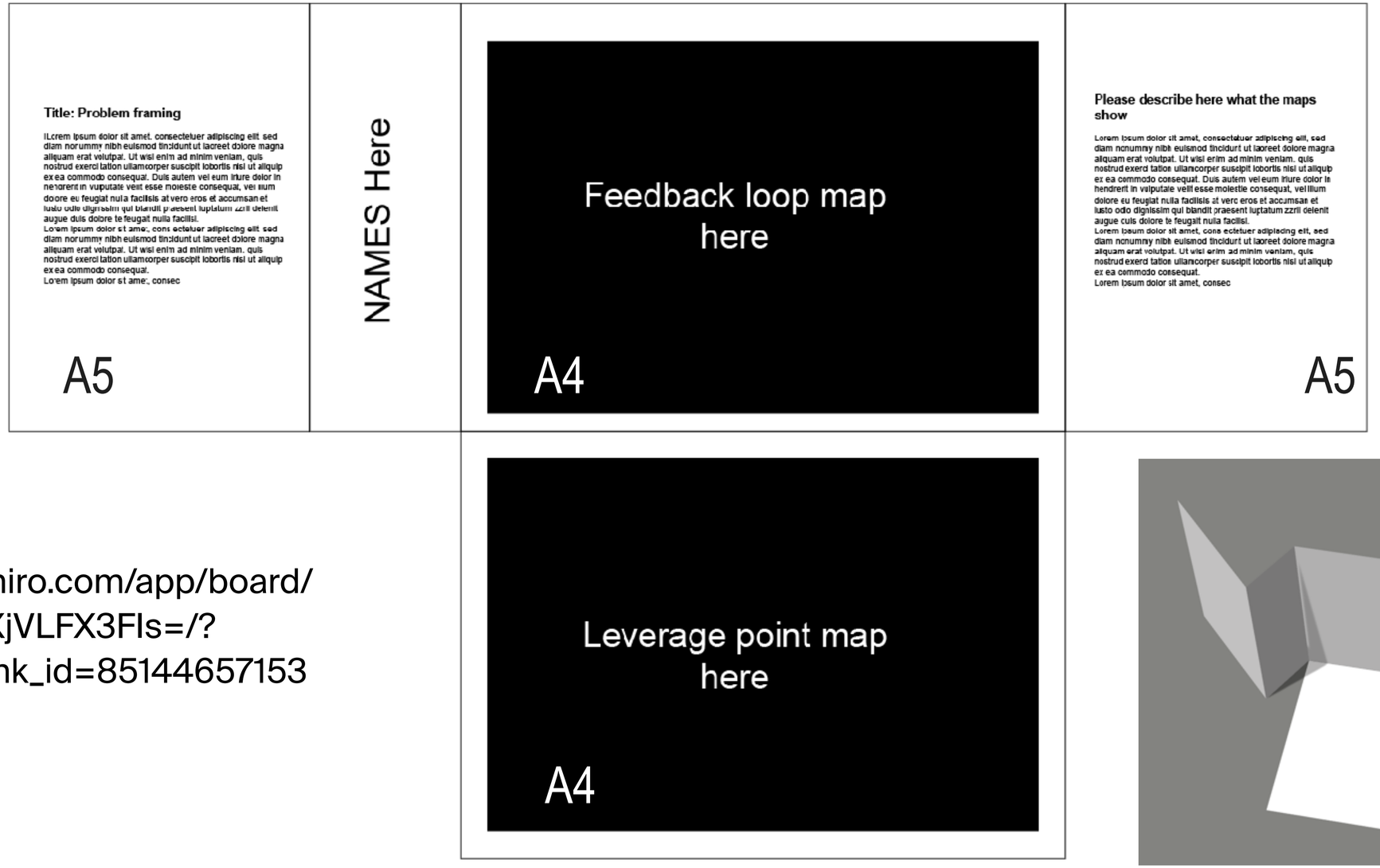
Mapping your chosen ethical dilemma with WPM and LPs



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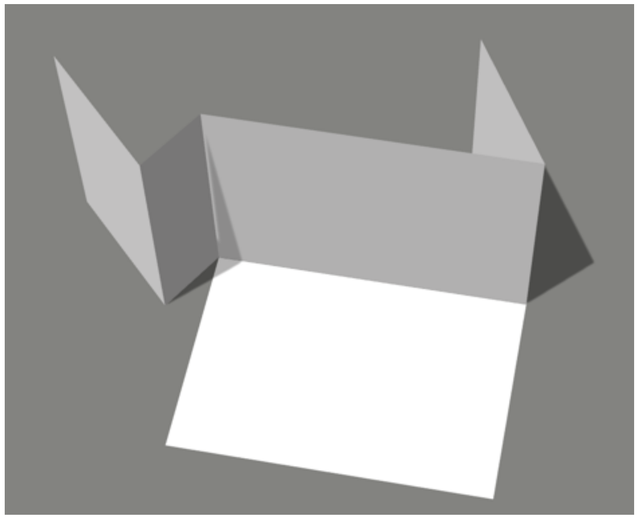

Mapping your chosen ethical dilemma with WPM and LPs

The Wicked Problem Map of Quantum Technology

Quantum technology presents a dual-edged sword with profound benefits and intricate challenges. On one hand, it promises revolutionary advances in computing power, cryptography, and materials science, holding the potential to reshape various technological landscapes and drive societal innovation.

However, the deployment of quantum technology also introduces a complex web of concerns. Socially, it raises questions about job displacement, altered work dynamics, and ethical considerations tied to privacy (all summarized in the term "**Social impact**" in the wicked problem map). Environmentally, the technology demands meticulous attention to its energy-intensive processes, potential manufacturing impacts, and responsible disposal practices (see "**Environmental impact**" in the map). Additionally, the absence of established international regulations and ethical frameworks poses challenges in ensuring the responsible development and use of quantum technology.

In this wicked problem map we present the interconnected nature of these factors emphasizing the need for a holistic approach to navigate the intricate landscape of quantum technology, considering both its transformative potential and the intricate socio-environmental-technological challenges that may arise.

Hannes Kohlmann
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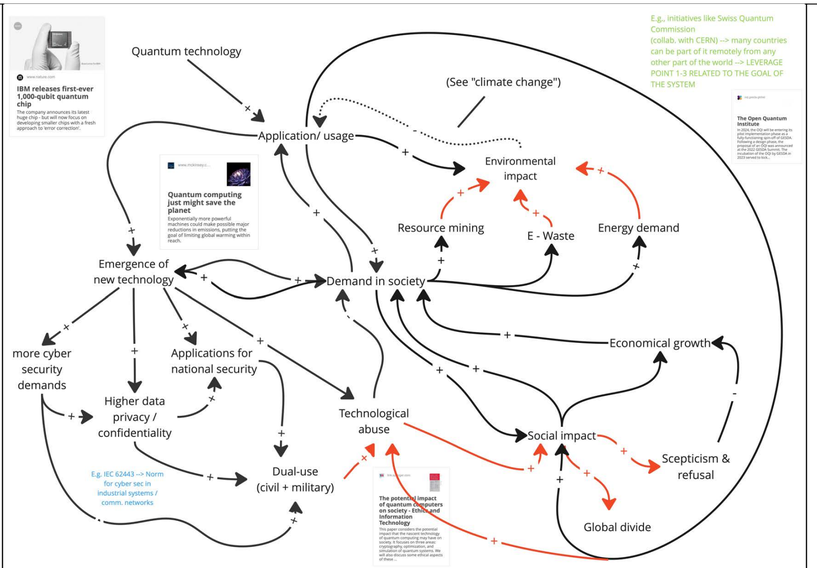
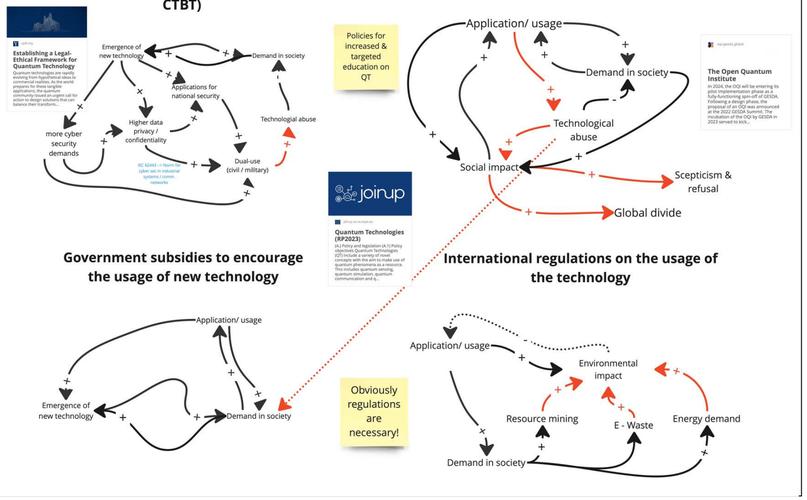


International Treaty on friendly usage of QT (comparable to the Nuclear Test-Ban Treaty, CTBT)

1. **Making policies to educate people and spread awareness about the benifits of quantum technology**
2. **International collaborations to reduce global divide**



Leverage points:

- **International Treaty on friendly usage of QT** should be driven by the motive to not use the technology in a violent way; conviction by the international court, if the treaty is violated

- **(International) Policies** for increased focus on education in QT serves for nations'/peoples' knowhow on the right usage of the technology.
  - This decreases the impact of negative aspects (red arrows) in the wicked problem map
  - The **international collaborations** should serve the purpose to minimize global and social divide

- **Governmental subsidies** to encourage the **development of new technologies** driven by QT and linked with the policies and regulations the positive impact on the (demand) in society will be enhanced.

- Need to setup **international regulations** to define the usage of the technology. At the national level screening committees should be formed. Each user of the QT should submit a **project proposal** to the screening committe. The objective of the **screening committee** will be to evaluate the proposal based on the international regulations and provide the **clearance to use the technology** for the proposed application; thereby, the judicial/regulated usage of the technology is enforced.

Mapping your chosen ethical dilemma with WPM and LPs

What do you need to do:

19th November

Make groups and chose an ethical dilemma and what stakeholder you represent.

26th November

As a group, develop a casual system map that describes the problem, as indicated in the example. Use the stakeholder's hat to draw the map.

3rd December

Finalise the causal map and start the analysis of the feedback loops to identify the LPs.

10th December

Finalise the LP analysis of impact and write two brief descriptions of the ethical challenge and of the map