COMPLEXITY AND SYSTEMS THINKING

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COMPLEXITY AND 'WICKED' PROBLEMS

We live in a world increasingly characterised by 'wicked' problems. These are problems that are difficult to define, are resistant to straightforward solutions and inherently complex; they are interwoven with other issues. They often arise because of the intertwined nature of the 'polycrisis' – a simultaneous degradation of social, economic and ecological systems. We are living in the 'Anthropocene' – a new geological era in which human activity is a dominant force in shaping planetary dynamics.

Climate change as a 'wicked' problem

Climate change is difficult to define and solve because it involves complex, interconnected issues like greenhouse gas emissions, deforestation, extreme weather and rising sea levels, all of which impact global systems like agriculture, health and economies. There is no single solution—efforts to mitigate climate change must balance environmental, economic and social considerations, and solutions vary by region. Additionally, climate change's effects evolve over time and its long-term consequences are uncertain. With diverse stakeholders, including governments, industries and communities, each with differing values and priorities, finding a consensus on how to address it is a major challenge. The evolving, multifaceted nature of the problem makes it a prime example of a wicked problem.

## How to identify complexity in systems

Complex systems share common characteristics, although vary greatly in others, such as location, types of stakeholders, extent, etc. These common characteristics are:

▶ The system comprises **relationships** between elements. The parts of the system are connected to each other in ways that go beyond just mechanical interactions.

▶ Its **context** (geographic, cultural, economic, etc.) affects how the system behaves.

▶ It is **radically open** to influences from outside of the system itself.

▶ The system is **adaptive** to change. The system can adjust to new situations. How well it does this depends on its ability to learn and remember. Control is shared across the system's parts and their connections.

▶ **It is dynamic.** When the relationships between the parts of the system change, the system's behaviour changes too, often in

unpredictable ways. This creates feedback loops and uncertainty. Feedback loops occur where actions either reinforce or counteract previous actions. Positive feedback loops (reinforcing cycles) can amplify

issues, while negative feedback loops (balancing cycles) can stabilise them. Identifying these loops is essential to understanding how the problem behaves and where to intervene effectively.

Figure 1: Illustration of a complex adaptive system related to the fishing industry
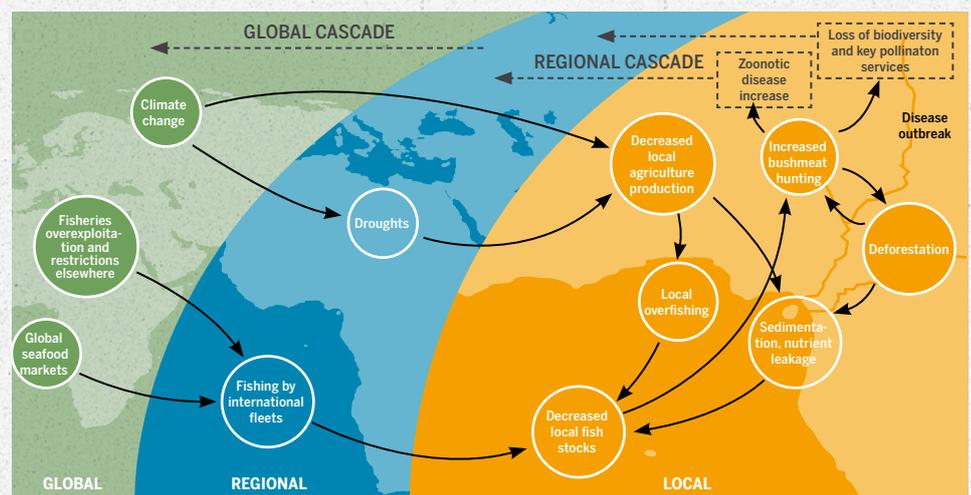
It involves **complex causality,** where changing one element can trigger cascading effects, making it hard to isolate the problem or predict all consequences. It also exhibits non-linear behaviour, where small changes can have large impacts or big efforts may yield minimal results, making solutions unpredictable. Additionally, it can lead to emergent properties—unpredictable outcomes arising from interactions of simpler components, which can create unforeseen challenges.

SYSTEMS THINKING: A WAY OF SEEING THE WORLD TO SOLVE COMPLEX PROBLEMS

Many of the world's most pressing issues—such as war, hunger, poverty and environmental destruction—are fundamentally failures of systems. A system is an interconnected set of elements that is coherently organised in a way that achieves something; it involves living elements. If there are no interconnections between the living elements with their own functions, it is not considered a system. These problems can't be resolved by addressing a single aspect in isolation, as even small details can have a huge impact, undermining the effectiveness of overly narrow approaches. These issues are embedded in context, involve many stakeholders (relational), are influenced by external factors (radically open) and changing circumstances that force adaptation, which can have unforeseen effects (dynamic and complex causality). There are therefore complex issues. Systems thinking enables us to better understand the landscape in which we are working.

EMERGENT OUTCOMES FROM COMPLEX ADAPTIVE SYSTEMS

An example of an emergent outcome from a complex adaptive system is the spread of COVID-19. The pandemic's global impact was not solely determined by the virus, but by the complex interactions between human behaviour, government policies, healthcare systems and global travel. While individual actions, like social distancing, or policies, like lockdowns, had small effects, their combined interactions led to the rapid spread of the virus.

Another example is the **immune system**. The immune system is not an identifiable element in the body; it emerges from a dynamic interaction of and relationships between different factors (system elements) in the body. The result is something bigger than the function of each element, and it disappears when the system is broken down into its parts.

What is systems thinking?

Systems thinking is an approach to understanding the world by focusing on the interconnectedness of its components, rather than just examining individual parts in isolation. It is based on the idea that complex systems—whether they are biological, social or mechanical—operate as wholes, where changes in one part can affect the whole system. By looking at the relationships, patterns and structures within a system, systems thinking helps us to better understand how things function and how they can be influenced or changed. Key concepts of systems thinking are:

▶ **Interconnections:** Systems thinking emphasises the connections and relationships between the parts of a system. Everything is seen as interdependent, and changes in one area can have ripple effects throughout the system.

▶ **Feedback loops:** Feedback is a central concept in systems thinking. Positive feedback loops amplify changes or reinforce a trend, while negative feedback loops counteract or dampen changes, helping to stabilise the system. These loops are critical for understanding how systems evolve and self-regulate.

▶ **Holism:** Systems thinking looks at the whole system rather than just its parts. It stresses that system behaviour cannot always be understood by simply analysing the individual components because the system's behaviour emerges from interactions between parts.

▶ **Emergence:** This is the idea that new properties or behaviours emerge in a system that are not present in the individual components. In other words, the whole can be greater (or different) than the sum of its parts.

▶ **Dynamic complexity:** Systems thinking recognises that complex systems behave in unpredictable ways over time. Changes may not be immediately apparent, and cause-and-effect relationships can be difficult to trace due to delayed effects or unforeseen consequences.

▶ **Leverage points:** These are places within a system where small changes can have a big impact. Identifying leverage points can help to guide interventions or changes in a system, especially when trying to solve complex problems.

An example of a feedback loop is the relationship between **soil health** and **crop yields**. In a positive (reinforcing) feedback loop, excessive use of chemical fertilisers boosts yields initially but degrades soil health over time, requiring even more chemicals to maintain productivity. In contrast, a negative feedback loop occurs when sustainable farming practices improve soil health, leading to better yields without chemicals.

This creates a balance, stabilising food production and reducing environmental impact.

Another example is the relationship between **fish populations** and **fishing efforts**. When fish stocks are overfished, their populations decline, reducing the number of fish available for capture. As fish numbers decrease, fishing efforts often intensify to maintain catch

levels, which further depletes the population. This creates a positive (reinforcing) feedback loop; overfishing leads to even smaller fish populations, requiring increasingly intense fishing practices. In contrast, if fishing efforts are reduced and fish populations are allowed to recover, a negative (balancing) feedback loop can occur, where healthier fish stocks support sustainable catches and help stabilise the ecosystem.

MAPPING THE SYSTEM IN WHICH YOU WORK OR WANT TO INTERVENE

Understanding an entire system can be challenging as we often only see parts of it influenced by our values, biases and limited knowledge. This can lead to misguided interventions in addressing issues like hunger, poverty or climate change, as not all relevant elements (such as stakeholders, policies and cultures) are considered.

1. **Define the system and its purpose:** Boundaries are helpful in defining the system you want to explore. Boundaries define what is included or excluded from a system, shaping its scope and focus. They help identify which components and interactions are part of the system, but these boundaries can be flexible and vary depending on context. There are different types of boundaries:

   Physical boundaries: Tangible limits, like geographic areas or structures.

   Conceptual boundaries: Defined by ideas, such as focusing on specific elements like food or health.

   Temporal boundaries: Based on time frames, like short-term versus long-term impacts.

   Functional boundaries: Drawn around specific functions, such as food production, wild harvesting, outpatient care, etc.

   Social boundaries: Define which stakeholders are included or excluded, like small-scale farmers or commercial farmers or both.

   Systemic boundaries: Encompass the entire set of interacting components in a system, like an ecosystem (wetland, forest, marine area) or a landscape that shares similar characteristics.

2. **Identify the key components:** Identify and list the main elements – the people, processes and resources. Remember to think outside of your knowledge and worldview, ask others for input to try and ensure that you don't miss any important stakeholders or influencing elements.

3. **Map the relationships and feedback loops:** Map how the different components interact and influence each other. Identify positive and negative feedback that drives system behaviour.

4. **Identify key drivers and leverage points:** Recognise factors (internal and external) that influence outcomes and where small changes can have big impacts.

5. **Draw your system:** Draft a map that shows the elements, the interactions and feedback loops. Identify recurring trends and major obstacles or potential support.

6. **Get feedback:** Share your map with those within and without the system to validate it.

7. **Test small interventions to see how the system responds before scaling up.**

A food system comprises all the elements (environment, people, inputs, processes, infrastructures, institutions, etc.) and activities related to the production, processing, distribution, preparation and consumption of food, and the outputs of these activities, including socio-economic and environmental outcomes. Boundaries can thus be put in place at different geographical levels (global, regional, local, etc.); they can also be put in to distinguish between small-scale and commercial food systems, and between those practising conventional or organic agriculture.