RURALITIES - CLIMATE SMART, ECOSYSTEM-ENHANCING AND KNOWLEDGE-BASED RURAL EXPERTISE AND TRAINING CENTRES

D6.1 – RURALITIES HANDBOOK ON THE SYSTEM THINKING METHODOLOGY

Deliverable D6.1

WP6 – FAST-TRACK: ecosystem-enhancing smart innovation cycle

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Abbreviations and acronyms

Acronym	Description
BOT	Behavior over time
CLD	Causal loop diagram
RURALITIES	Climate smart, ecosystem-enhancing and knowledge-based rural expertise and training centres
EC	European Commission
LL	Living lab
MAA	Multi actor approach
SIMSES	Simplified Socio-ecological Systems
STM	Systems thinking methodology
WP	Work Package

Abstract

The project 'Climate smart, ecosystem-enhancing and knowledge-based rural expertise and training centres' (RURALITIES) delivers an ecosystem-enhancing and climate action driven expertise and learning framework organised in hubs e.g., the 'RURALITIES', comprising a series of innovative methodologies with the learner at its core, supported by a comprehensive network of living labs, and a blockchain-based digital platform combining the Internet and wireless technologies, to assist engage, connect and empower actors. This is done via a multi-point approach e.g., multi-actors, multi-disciplines, multi-systems, multi-scale, multi-sectors, and multilevel.

RURALITIES is rooted in the recruitment, preparation, training and coaching of 1.000+ facilitators for a variety of tasks (e.g., trainers, facilitators, role models, hub coordinators, etc.), and who play a significant role in creating the matrix and the platform upon which the learning framework is built, develops and evolves. RURALITIES proposes to ideate, implement, futureproof, validate and deliver the aforementioned expertise and learning centres via real-scale practicing in 6 simplified rural socio-ecological systems (SIMSES) e.g., demonstrators, 2 in Italy, 1 in the United- Kingdom (UK), 1 in Slovenia, 1 in Spain and 1 in Romania. RURALITIES coordinates identified actions of local, regional authorities in supports of rural innovation in regions and economic sectors where rural innovators are not yet engaged in a relevant network.

RURALITIES coordinates identified SIMSES networks promoting rural innovation solutions whilst establishing innovative multipoint 'RURALITIES Hubs' of expertise and training on rural innovation. This is done via coordinating action for the managing authorities and regional bodies influencing regional and national policy instruments in Italy, the UK, Slovenia, Spain and in Romania.

Partners

Number	Short name	Legal name	Country
1	PEDAL	PEDAL CONSULTING SRO	SK
2	RDRP	ASOCIATIA RURAL DEVELOPMENT RESEARCH PLATFORM	RO
3	CETRI	CENTER FOR TECHNOLOGY RESEARCH ANDINNOVATION (CETRI) LTD	CY
4	ASIN	ASOCIACION DE INVESTIGACION DE INDUSTRIAS CARNICAS DEL PRINCIPADO DE ASTURIAS	ES
5	NIC	KEMIJSKI INSTITUT	SI
6	UPM	UNIVERSIDAD POLITECNICA DE MADRID	ES
7	IRI	INSTITUT ZA RAZVOJ I INOVACIJE - IRI	RS
8	PART	PARTICULA GROUP DRUSTVO S OGRANICENOM ODGOVORNOSCU ZA ISTRAZIVANJE RAZVOJ I PROIZVODNJU	HR
9	UNIZG	SVEUCILISTE U ZAGREBU AGRONOMSKI FAKULTET	HR
10	ACTS	AFRICAN CENTRE FOR TECHNOLOGY STUDIES	KE
11	CITT	CENTRO DE INVESTIGACAO E TRANSFERENCIA DE TECNOLOGIA PARA DESENVOLVIMENTO COMUNITARIO	MZ
12	EQUIP	EUROPEAN SOCIETY FOR QUALITY AND PATIENT SAFETY IN GENERAL PRACTICE/ FAMILY MEDICINE	DK
13	MUNI	MUGLA SITKI KOCMAN UNIVERSITY	TR
14	MARIN	MARIN BIYOTEKNOLOJI URUNLERI VE GIDA SANAYI TICARET LIMITED SIRKETI	TR
15	ULB	UNIVERSITE LIBRE DE BRUXELLES	BE
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17	AASTMT	ARAB ACADEMY FOR SCIENCE, TECHNOLOGY AND MARITIME TRANSPORT	EG
18	RRAP	REGIONALNA RAZVOJNA AGENCIJA POSAVJE	SI
19	YXSAV	YXS AVALANA SRL	RO
20	UNIVI	UNIVERSITATEA PENTRU STIINTELE VIETII "ION IONESCU DE LA BRAD" DIN IASI	RO

21	SIRET	ASOCIATIA GRUPUL DE ACTIUNE LOCALA SIRET-MOLDOVA	RO
22	SUA	Sokoine University of Agriculture	TZ
23	UNINO	UNIVERSITE DE NOUAKCHOTT AL AASRIYA	MR
24	IFAYA	INSTITUT FACULTAIRE DES SCIENCESAGRONOMIQUES (IFA) DE YANGAMBI	CD
25	ACD	ALTERNATIVE COMMUNAUTAIRE POUR LE DEVELOPPEMENT DURABLE (ACDD)	CI
26	PROTO	PROTOTIPI LIMITED	NG
27	AMVO	ALMANAR VOLUNTARY ORGANIZATION	SD
28	CDD	COMMUNICATION POUR UN DEVELOPPEMENT DURABLE C.D.D.	TG
29	YTED	YOUTHS IN TECHNOLOGY AND DEVELOPMENT UGANDA LIMITED	UG
30	CTIC	FUNDACION CTIC CENTRO TECNOLOGICO PARA EL DESARROLLO EN ASTURIAS DE LAS TECNOLOGIAS DE LA INFORMACION	ES
31	FHV	FONDAZIONE HOMO VIATOR - SAN TEBALDO	IT
32	MOFE	MONTEFELTRO SVILUPPO SCARL	IT
33	MUSE	MUSEUM GRAPHIA	IT
34	CDM	LA CORTE DELLA MINIERA SRL	IT
35	DEX	DESARROLLO DE ESTRATEGIAS EXTERIORES SA	ES
36	REDA	ASOCIACION RED ASTURIANA DE DESARROLLO RURAL	ES
37	GMV	MONTAGNA VICENTINA SOCIETA COOPERATIVA	IT
38	MARA	MAROC HORIZON D'AVENTURES	MA
39	UNWI	UNIVERSITY OF MALAWI	MW
40	NOMA	0KMNOMADS.ORG	GH
41	UNIM	MAGYAR AGRAR- ES ELETTUDOMANYI EGYETEM	HU
42	ENIC	ECOLE NATIONALE D'INGENIEURS DE CARTHAGE	TN
43	UASZ	UNIVERSITE ASSANE SECK DE ZIGUINCHOR	SN
44	CPF	CONFEDERATION PAYSANNE DU FASO	BF
45	UNAD	UNIVERSITY OF RWANDA	RW
46	ZLAN	ZAMBIA LAND ALLIANCE	ZM
47	EVRO	EVROSAD PROIZVODNJA TRGOVINA EVETOVANJE D.O.O. KRSKO	SI

48	SEVO	TURISTICNO DRUSTVO SENOVO	SI
49	IISAC	ISTITUTO D'ISTRUZIONE SUPERIORE A CECCHI	IT
50	HITP	THE HIGHLANDS AND ISLANDS TRANSPORT PARTNERSHIP	UK
51	ASPI	ASPIRE-IGEN GROUP LIMITED	UK
52	EW	CONSERVATION EDUCATION AND RESEARCH TRUST	UK

1. INTRODUCTION AND CONTEXT OF THE DELIVERABLE

Deliverable D6.1 is described in the RURALITIES Grant Agreement as:" A digital handbook to support practitioners in organizing system thinking exercises on challenges correlated to the rural scene at large, to support characterizing solutions, measures and pathways to answer to these challenges." It is a part of the framework of the WP6 – FAST-TRACK: ecosystem-enhancing smart innovation cycle with broad application in WP5, WP7 and WP8.

D6.1 is directly developed through T6.1 – System Thinking Methodology (STM) which aims to develop a structured system thinking methodology (STM) to address rural challenges by identifying drivers and root causes, proposing innovative systemic solutions, and evaluating impacts, risks, synergies, and trade-offs across various domains.

The systems thinking framework is complementary with the multi-actor approach conducted through T5.1. Even though the handbook is focused primarily on the SIMSES partners and identified facilitators, it is inclusively designed to be utilized by a wide array of identified target groups in the RURALITES repository with different levels of education, skills, and expert knowledge.

Furthermore, D6.1 will provide the systems thinking framework for the support to the promotors of selected RURALITIES initiatives through Task T7.3 (Practice counseling and guidance to selected initiatives) which starts at month 24. The 'RURALITIES FAST-TRACK' Innovation Management Programme will be designed to shorten the innovation cycle (WP-7) by empowering the actors of the SIMSES through the System Thinking methodology.

The systems framework developed through D6.1 will be a part of the RURALITIES capacity-building programme to empower rural actors in WP8. STM will be one of the methodologies that will be taught to identified facilitators and other interested rural actors as a part of the capacity building. D6.1 will inform the learning objectives which will be precisely defined in Deliverable D8.1 (Rural scene education nexus characterization compendium) and Deliverable D8.2 (Multiactors onsite and online learning catalogue).

STM will become a part of training methods and co-creation activities (e.g., living labs, game-based learning, etc.) to foster the development of systems thinking, problem-solving, and communication skills.

2. OBJECTIVES

The handbook serves as an introductory platform for SIMSES partners, facilitators, and other interested actors, offering a solid understanding of system thinking principles, methods, and concepts. Practical application is a key focus. It should guide our target groups through the employment of system thinking tools to analyze complex systems and address real-world problems effectively. Furthermore, the handbook aims to foster the development of critical thinking skills essential for systems analysis and decision-making.

Ultimately, it aims to empower individuals and organizations to navigate and manage complexity, uncertainty, and dynamic change effectively within their respective SIMSES. In that sense, D6.1 is focused on adapting system thinking approaches to define rural challenges in a structured way, to enrich and support co-creation processes and activities conducted within the framework of 'RURALITIES Co-Labs' living labs by SIMSES partners, identified facilitators and other interested rural actors identified through T5.1. Furthermore, D6.1 will assist in shortening the innovation cycle of identified projects and initiatives.

3. THE THEORETICAL BACKGROUND

The theoretical framework used for the purpose of developing the RURALITES systems thinking methodology handbook draws heavily from the definition of system dynamics and its scope formulated by Eric F. Wolstenholme:

What	A rigorous way to help thinking, visualizing, sharing, and communication of the future evolution of complex organizations and issues over time
Why	For the purpose of solving problems and creating more robust designs, which minimize the likelihood of unpleasant surprises and unintended consequences
How	By creating operational maps and simulation models which externalize mental models and capture the interrelationships of physical and behavioral processes, organizational boundaries, policies, information feedback and time delays; and by using these architectures to test the holistic outcomes of alternative plans and ideas
Within	A framework which respects and fosters the needs and values of awareness, openness, responsibility and equality of individuals and teams.

Wolstenholme 1997

Nonetheless, the handbook focuses on the methodology for qualitative system dynamics to accommodate the variety of experiential and educational backgrounds of future users, which were identified through T5.1. The goal is for the handbook to be widely adoptable and used as an operative tool, not limited to computer science experts. The quantitative methods as part of the system dynamics scope will be utilized for SIMSES based on their needs and with the assistance of project partners. This will be done after the SIMSES partners, facilitators and other interested rural actors have conducted the steps outlined in the handbook in multiple iterations through their respective RURALITIES Co-Labs, together with other actors and experts (in accordance with the MAA).

4. THE WAY FORWARD

How will the STM handbook be used by SIMSES?

D6.1 will be used to raise the capacity of SIMSES partners, facilitators, and other interested actors and serve them as a guide to design, plan, and demonstrate system thinking-driven mechanisms to significantly shorten the innovation cycle of solutions aimed at addressing SIMSES targeted needs.

Furthermore, the STM handbook will be utilized during the implementation phase of the living lab methodology through the establishment of RURALITIES Co-Labs. It will provide systems thinking tools to the rural actors and facilitators who will conduct system thinking workshops through their respective Living Lab frameworks to improve the understanding of their systems, which will help the to address the most relevant issues, shorten the innovation life-cycle and maximize impact.

The systems thinking methodology outlined in D6.1 will also inform citizen science initiatives established by SIMSES and RURALITIES partners by helping to identify relevant and latent problems and formulate better and more impactful research questions through a comprehensive understanding of interconnected variables within the particular systems. It will help them to not only examine immediate factors but also broader influences and the scope of determinants. By considering these interconnected elements, citizen scientists and facilitators will be equipped to uncover complex relationships and dynamics that contribute to their objectives.

Furthermore, STM is complementary with MAA which is also mandatory due to the higher number of iterations that STM requires in order to adjust its models to reality cover as many relevant aspects as possible, and include as many different perspectives as possible. STM promotes collaborative problem-solving, utilizing local knowledge, and empowering communities along the process. This collaborative effort has the potential to create synergy with citizen science initiatives as the starting point of action.

How will systems thinking methodology be used in established RURALITIES Co-Labs?

Systems thinking promotes iterative learning, which is complementary to the LL approach and it will inform their efforts to adapt interventions and solutions based on continuous feedback and an evolving understanding of the complexities of rural systems in which they are operating.

STM allows living labs to analyze the interconnected elements of rural environments, including economic, social, environmental, and infrastructural factors. By comprehensively mapping these elements, LLs will be enabled to gain insights into the dynamics shaping rural development challenges. STM also supports MAA by involving diverse actors, including local communities, policymakers, and experts, so LLs can harness various forms of experiences and tacit knowledge to co-create innovative solutions tailored to specific rural contexts. The iterative learning process facilitated by STM allows LLs to continuously refine and adapt their interventions based on feedback, shortening the innovation cycle, and fostering sustainable solutions.

By identifying feedback loops and creating causal loop diagrams and behavior over time diagrams together with the rural actors within these systems will give LLs tools to recognize how different interventions might work, and how they could produce unintended consequences, guiding more effective decision-making. STM will ensure that solutions and innovations co-created by LLs consider the broader context and potential ripple effects.

STM workshops will be held in RURALITIES Co-Labs to equip the SIMSES partners, facilitators, and interested actors with STM tools and a general understanding of the approach. This will be followed by the execution of the methodology step by step and the integration of STM into the work of the LLs.

ANNEXES

Annex 1 – Systems thinking methodology handbook

RURALITIES SYSTEMS THINKING METHODOLOGY HANDBOOK

Introduction

This handbook serves as a comprehensive guide to understanding and applying system thinking methodologies to address rural challenges, particularly within the context of the RURALITIES project. It emphasizes the importance of co-creation, cross-sectoral collaboration, and the integration of explicit and tacit knowledge to find innovative solutions and create actionable pathways for sustainable rural development. The handbook also provides practical tools and examples to assist practitioners in their efforts to address rural challenges effectively. However, all these methods need to be studied further and sharpened by practical application and iterations. The best is to start with a facilitator who is already skilled in the field of system dynamics and systems thinking.

It is important to note that the steps outlined in this handbook are not "set in stone" and could be expanded as the skills of the practitioners are increased. In addition, the examples used are simplified and don't necessarily represent exact depictions of how things work in particular systems. They are here for educational purposes and are always part of the greater system which has more variables that connect to the depicted ones. That by itself changes the implications of its behavior, so take them with reserve.

Purpose of the Handbook

The handbook will provide a fundamental understanding of systems as such, the framework of system dynamics, and various practical complementary methods for using this framework in real-life scenarios. It is designed to facilitate informed decision-making and resource optimization for the purpose of co-creating and developing strategies that trigger sustainable outcomes by identifying leverage points where minor adjustments can yield significant effects and changes in the system behavior.

Furthermore, the handbook should be used to cultivate mutual comprehension of relevant issues among local social actors, in accordance with the RURALITES multi-actor approach (MAA), to foster collaborative learning and establish harmonized perspectives in particular SIMSES. This should enable synergetic efforts among social actors aimed at effective problem-solving through various forms of collective efforts (e.g., development of policy proposals).

On the other hand, we will share pertinent tools for the assessment of potential ramifications of proposed actions, policies, products, or services, preempting unintended consequences, and optimizing outcomes and long-term impact.

Understanding System Thinking

What do we mean when we talk about systems? Systems can be simply defined as: "[a] collection of parts that interact in a meaningful, inseparable way to function as a whole" (Ford 2019). Systems thinking can be interpreted as a transdisciplinary framework that focuses on identifying and comprehending the important components that underly how things function in reality. It teaches us how to recognize links between these components and understand how they interact with each other, and how will the system behave if things change – what will be the intended outcomes and unintended consequences if we intervene and change some variables.

Systems thinking equips us with a unique conceptual framework that we can use as guidance for better understanding the often daunting complexity of reality.

With systems thinking we want to delve deeper into the unseen causalities, the “rules of the game”, to understand the events and issues we are facing and which can be clearly seen. To represent these levels, systems thinkers usually use the Iceberg model.

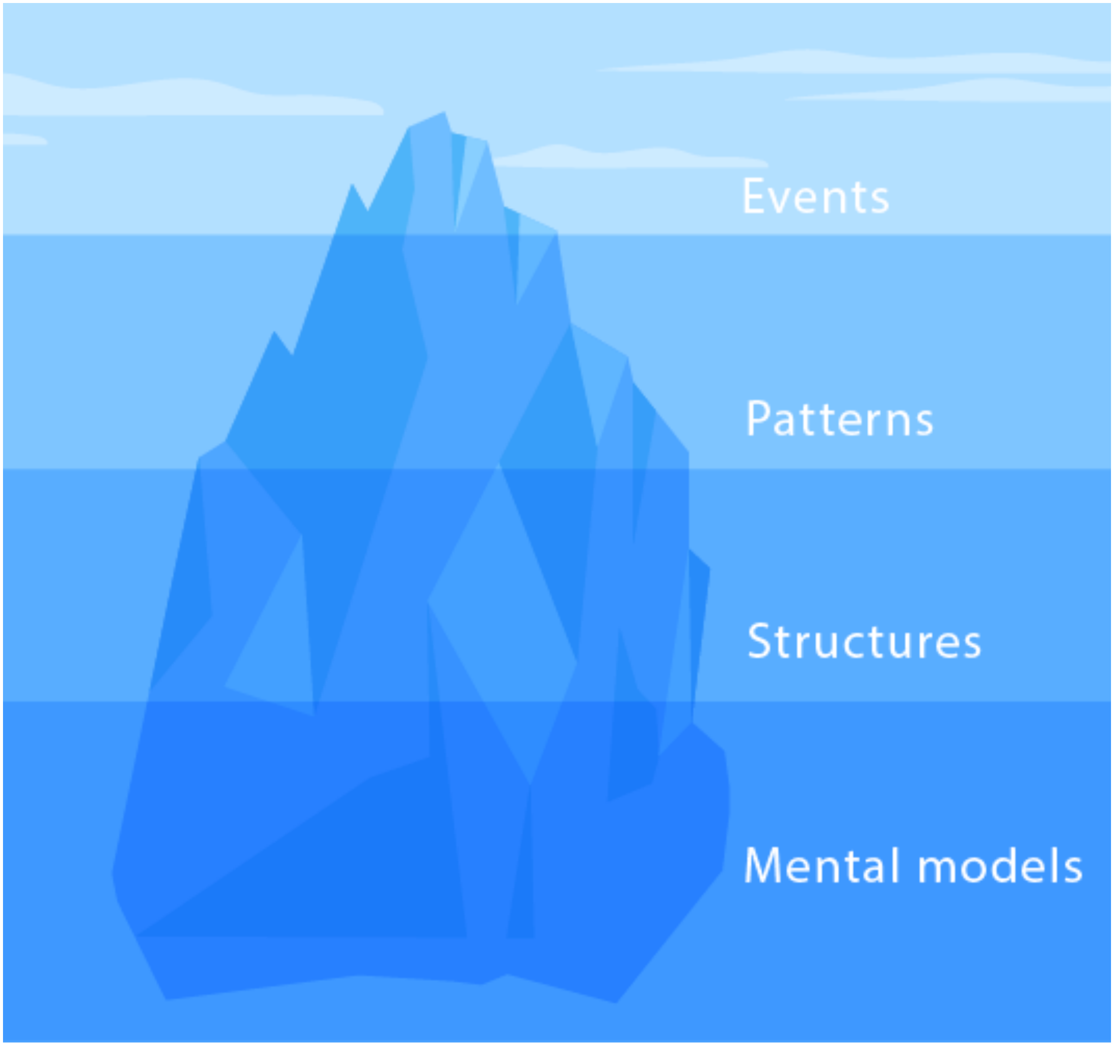


Figure 1 Iceberg model (Designed by Freepik)

When we take a look at the Iceberg model, we can see that it depicts four major elements. Events are the visible real-life scenarios that happen all around us. We can observe the events, we interact with them and we react to them. However, they are on the surface, but the vast majority of things that enable those events to happen, that influence them (patterns, structural factors, and mental models) remain hidden “beneath”. Systems thinking requires us to delve deeper into the understanding of reality and shift from observing events to the underlying mechanisms that cause them. Usually when we react to events we tend to keep ourselves at that level of understanding, continuously identifying events that we believe cause other events when they are most likely results of deeper structural mechanisms. Events are simply at the shallow end of the causal network and we need to ask many “why” questions to get to the other levels presented through the iceberg model.

Example: Cows grazing on one particular field.

We also often notice patterns which are certain events appearing multiple times, over and over again. We can define patterns as repeating events over time. By observing events over a period of time, even with common sense we can sometimes notice these patterns and reoccurrences and even in many cases predict some events based on the linked patterns. However, correlation by itself doesn’t mean causation. This is simply a regularity that is driven by deeper elements of the system over time which are not known on this level of observation.

Example: Cows grazing on that field regularly, every last week of the month.

Bellow patterns lay structures that represent the ways in which systems are set up and variables linked. They contain information about how these patterns and events are linked, and how the system actually behaves as unseen factors drive the events and patterns we perceive on a daily basis. On this level, we need to search for answers if we wish to interfere and change the system according to a certain objective.

Example: Economic structure (profit-oriented optimization framework), scientific/ecological (grazing system), geographical/special factors (proximity of land), property relations (field is in the owner's private possession), etc.

Mental models represent models of our thinking and thinking of the actors within certain systems. These include beliefs, attitudes, and values, various forms of biases and assumptions as well as macro phenomena such as culture and social paradigms.

This level of the iceberg formally contains the most potent transformative power, but it is at the same time the hardest to tap into, adjust, and change. There is also a frequent discrepancy between our view of how the systems operate in the real world and how they really operate (reality bias).

Example: Farmers’ beliefs, values, and knowledge of the grazing strategy.

The iceberg model offers insight into the origins of problems by dealing with beneath-surface appearances so we can uncover core problems and develop more effective solutions.

It is important to note that all of these dimensions are interconnected by numerous links in different systems. By systematically deconstructing these links and elements we can pinpoint the main sources of problems and facilitate proactive problem-solving mechanisms.

System Thinking Methodology Step-By-Step Application

As we have outlined the main concepts and an idea of what systems thinking methodology is and what can be used for, we will start describing ways of practical implementation to support practitioners in organizing system thinking activities on relevant challenges, to support the development of solutions, measures, and pathways to answer to these challenges.

We will break down some steps that will tackle the Iceberg model in a way that will show us what can we do to address its different levels. We can observe events, we can identify patterns and present them through behavior over time diagrams, map the system structure using causal loop diagrams (CLDs), create Stock and flow diagrams, and computer modeling, and plan interventions that can manifest in all these levels including mental models by testing our assumptions, identifying leverage points, and so on.

When planning and executing the following steps, try to involve key actors and experts in the process to utilize diverse perspectives, practical knowledge, and expertise. It is important to consult other methodologies and disciplines that can enrich our understanding of particular problems and causal mechanisms. It is also beneficial for all relevant actors to benefit from getting to know different parts of the system that they have neglected, and the whole group to harmonize in a way by having a more homogenous view of the issues as they have co-created the system map. This increases group cohesion as a byproduct as well as leaves things open for re-modeling, and discussion, including all relevant inputs.

We will outline 6 major steps which are divided into sub-steps. The steps are more intertwined in reality than it might seem when we go over them in the written form, especially due to the nature of system mapping exercises which are done in many iterations, covering a wide range of inputs. This makes it mandatory to often go a few steps back to readjust some parameters, which affect the following steps, so we have to go forward and adjust those as well, and so on. This shouldn't be discouraging, yet seen as evidence of the antidogmatic nature of systems thinking as an open yet rigorous set of methods for understanding the world around us.

Step 1 – Setting up the Framework

Defining a problem

The first step that will lay the foundation of your systems thinking process is answering the question: "What do we want to learn/find out?". So first we need to identify and structure the problem that we have recognized or that we are dealing with. This will be our focus throughout the process, our anchor point on which we will return continuously while mapping and connecting other variables.

We can formulate a problem through a statement and a bit wider explanation of a context.

Sometimes we also realize that our initial problem is just one part of a much larger issue and only changing the small part would not necessarily change the larger issue. In this case, consider realigning our focus to address the actual problem that needs change.

Here is an example:

In the XY area, intensive agricultural practices used over the course of 50 years have led to significant soil degradation, with 80% of arable land experiencing erosion and nutrient depletion. This threatens the sustainability of the farming sector in the area and compromises food security for the local population.

It is important to keep in mind several things when we are choosing and defining a problem for systems thinking.

1. Make sure that the problem is chronic, long-lasting, or recurring. This is important because if we have a problem showing up one time or we find one event problematic, it is an isolated case that will stop existing as it finishes. We cannot base our systems thinking process around it as there are no intrinsic systemic elements itself, but it is an occurrence that can be a product of a wide array of circumstantial factors.
2. We have to be familiar with the history of the problem and have some data about it in order to describe it and to notice some trends.

Behavior over time diagrams

We always start at the level of events and move down to understand deeper levels of the iceberg model. So we always start by noticing events, which is our inspiration to start using systems thinking. The next step is noticing the pattern of major variables that you have identified in your problem formulation. As we have established and observed the pattern of certain behavior or phenomena and have set a good quality framework during this step, we can tap into the next level of the iceberg model which is the structure. At the structure level, we will search for the answers of what is causing the pattern that is the events.

Behavior over time (BOT) diagrams are a useful tool to outline how one or multiple variables behave over time. At this stage, we are concentrating on the past, so we want to note down our observations of key variables as patterns of behavior over the past time. Nevertheless, their explanatory power is determined by the stage at which it was produced, that is by which methods, so when they are recreated at later stages, they will tend to reference the future development, that is, the behavior of variables.

For example, they can be inferred from CLDs simply to show tendencies that are informed by causal links, and get some kind of an idea of system dynamics. This is great for group sessions and can trigger productive discussions which might modify our CLDs. Finally, after producing stock and flow diagrams which are the base for computer modeling, our BOTs will be a result of system simulations. They will be more grounded and validated by data and sharpened models.

At this stage, they are created through observation of the behavior of key variables over past time as they represent our patterns. This can be done at the initial brainstorming stages and the main purpose is to inform the next steps. They are also useful for shifting our focus from static thinking and recognizing trends over time, fostering deeper understanding which makes them great for preparing for more advanced system dynamics work.

Getting started is simple. We start by drawing two axes where time runs along the horizontal one and the variable of interest along the vertical one as so:

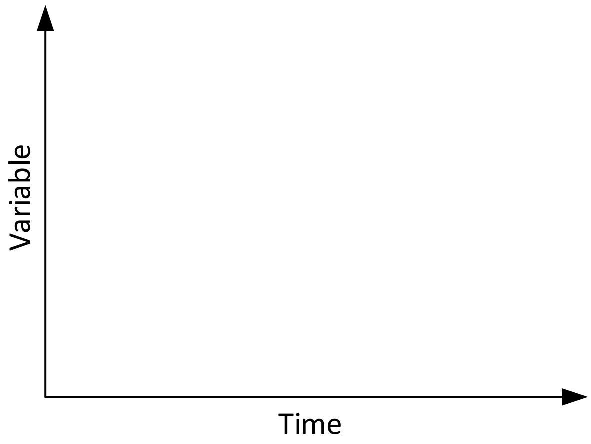


Figure 2 BOT diagram structure

The fundamental principle is ensuring that "Time" runs along the horizontal axis, while the variable of interest, whose behavior over time we want to analyze, is inserted on the vertical axis.

Define the variable that will be graphed. We can take any variable from our CLDs that increases or decreases over time. They can be precisely measurable (e.g., the number of cows) or less precisely measurable, conceptual, and subjective (e.g., environmental attitudes). Time units should be adapted to fit the chosen variable and the context (e.g., hours, days, years, etc.).

When creating stock and flow diagrams we will need to think thoroughly about the variable units. However, at this stage, the trends are generalized and come from the causal relationships outlined in our CLDs. More precise and validated BOT diagrams can be made after we have created stock and flow diagrams. By making stock and flow diagrams we will need to define variables in a more precise way which will improve the quality of our BOT diagrams as well. The best quality BOT diagrams which will show us the most precise approximation of system behavior are the ones that come as a result of stock and flow diagrams that are converted to a computer model.

For now, let's outline some variables from our hypothetical problem description.

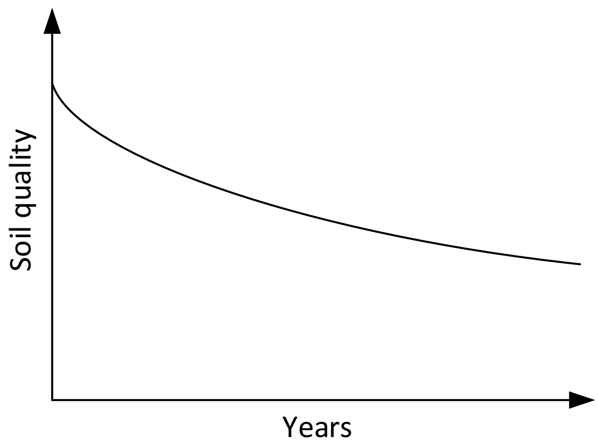


Figure 3 BOT diagram example (Soil quality)

Soil quality is a measurable variable and we might have quantitative data (e.g., percentage of humus), and assuming soil measurements have been taken over the course of several decades (events) we can now notice a pattern that we present using the BOT diagram. Nonetheless, if we imagine that one of our key variables is something less tangible (e.g., motivation of field workers), we would still create BOT diagrams with any input and information we have. This is just one of the initial steps, it doesn't have to be, and it cannot be 100% backed up by data and pedant like a scientific research process. It is a part of the process, and validation, more information and data will come with iterations and with other modeling exercises.

There are four common patterns (ideal types) of behavior that frequently emerge in systems:

1. Exponential Growth: The variable's value increases exponentially over time.
2. Goal-Seeking Behavior: The variable moves towards a certain state of equilibrium (goal) over time, starting either above or below it.
3. S-Shaped Growth: The variable starts growing exponentially, after which we observe goal-seeking behavior that leads to the variable reaching a certain equilibrium.
4. Oscillation: The variable fluctuates around a certain level. Initially, it may resemble exponential growth, then transition into s-shaped growth before reversing direction.

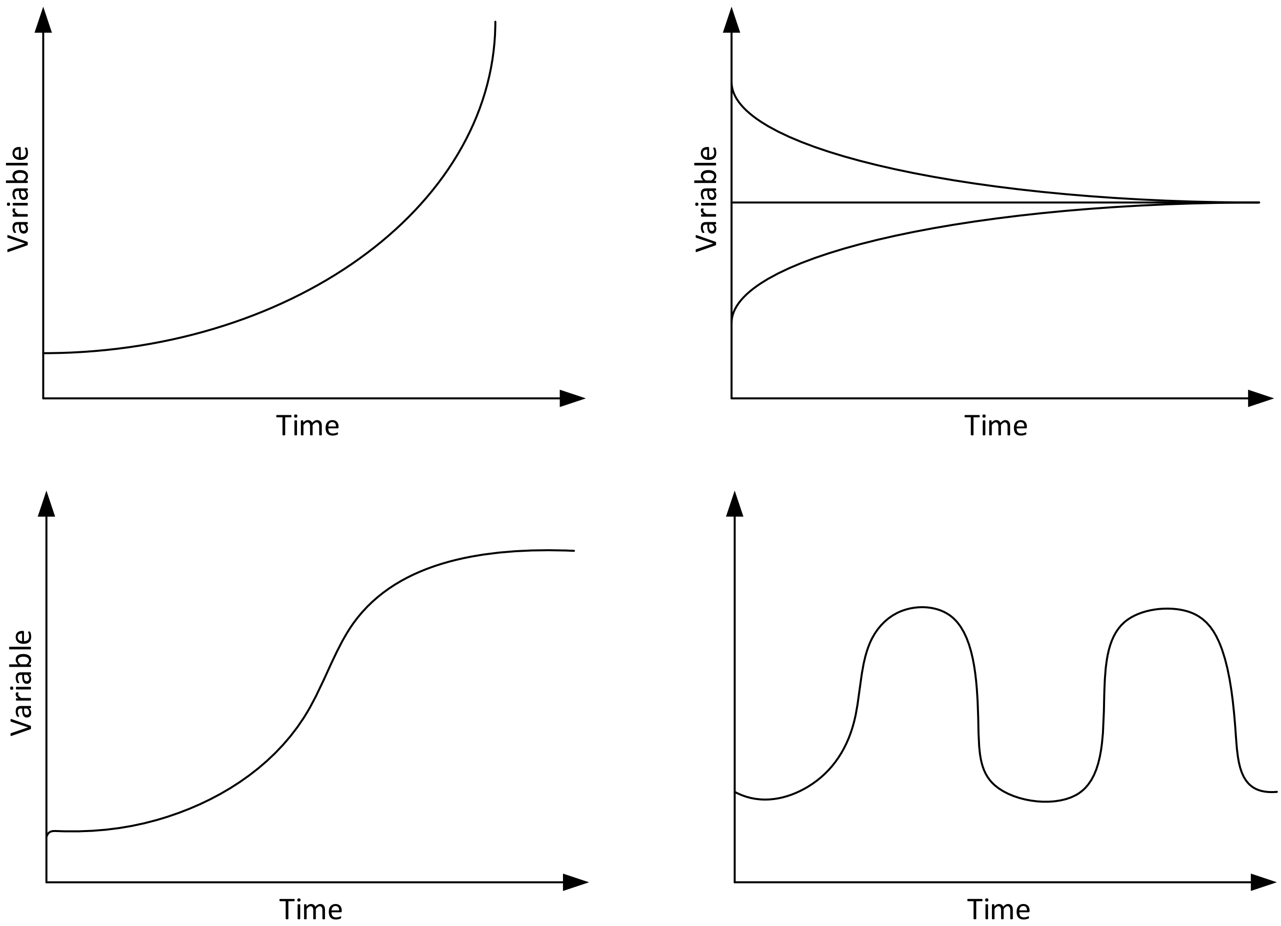


Figure 4 BOT diagram common patterns

Formulating research questions

After defining the problem and drawing BOTs, the next step is to formulate research questions that will guide us through the whole process so we don't stray away from what we want to achieve.

For example:

- Which factors (agricultural, social practices) have contributed most significantly to soil degradation in the XY area?
- Which methods could increase soil health in the XY area?
- Which strategies or actions could be effectively implemented to enhance resilience and food security in the XY area?
- Which factors could contribute to the adoption of sustainable agricultural practices among farmers?

We can notice that some questions are related to the problem itself and seek explanations, yet others tend to use knowledge about the problem but focus on finding solutions. Both types of research questions are valid in the context of systems thinking.

Nonetheless, we should avoid questions that already imply some part of an answer such as:

- How could different soil conservation methods, such as planting cover crops and using no-till methods, increase soil health in the XY area?
- How can sustainable land management strategies be effectively implemented to enhance resilience and food security in the XY area?

We should avoid questions that contain hidden causal implications that we aren't sure about, such as:

- Are genetically modified crops the primary cause of soil degradation in the XY area, considering their widespread adoption in recent decades?
- How can we combat the decline in soil fertility in the XY area being that the electromagnetic radiation from telecommunications infrastructure is constantly present?

Setting Objectives

Setting objectives will guide us to be in line with our intentions and motives which can be various. Why are we doing this? We may want to create innovations and shorten the innovation cycle, create a change. We may want to improve policy, increase the engagement level of relevant local actors, etc.

To define clear objectives, we must be specific and concise. Try to avoid vague language or ambiguous terms that can lead to confusion and make sure that they are relevant and significant, but not unrealistic or unattainable within the given scope of the system. Prioritize objectives based on their importance and impact.

Establishing the System Scope

The scope of our system must be considered and established to avoid issues down the line. Boundaries must be drawn that are appropriate and useful to achieve our set of objectives. In reality, problems are rarely isolated in one field, sector, social group, or spatial area. We must work to recognize how we can include the most important variables in our system mapping without losing focus and making it unnecessarily complex.

One issue can come from making the scope too small, so we lose the bigger picture, map out only a subsystem that is insufficient to answer our objectives, and give us more information about our problem, unintended consequences of potential actions, etc. On the other hand, if we make the scope too big, we risk that it becomes daunting, confusing, and unmanageable. This would inhibit us from seeing things clearly and getting the most benefits from systems thinking as such.

Keep in mind that systems that we are uncovering are always formalized and simplified forms of reality. If we keep adding every little element to it, it hypothetically approaches the level of complexity that reality itself possesses. Although this seems like a perfect scenario, this is not the goal of systems thinking as it would disable us from clearly seeing what is important.

We should consider all possible variables, but keep the focus on the most important ones. One more important thing is to keep an open mind and track which variables we have included and which we have left out. Our models aren't set in stone and they can be widened or narrowed down when we are faced with new evidence and information.

Let's take an example problem related to the sustainability of the farming sector and the following research question: "Which factors could contribute to the wider adoption of sustainable agricultural practices among farmers?

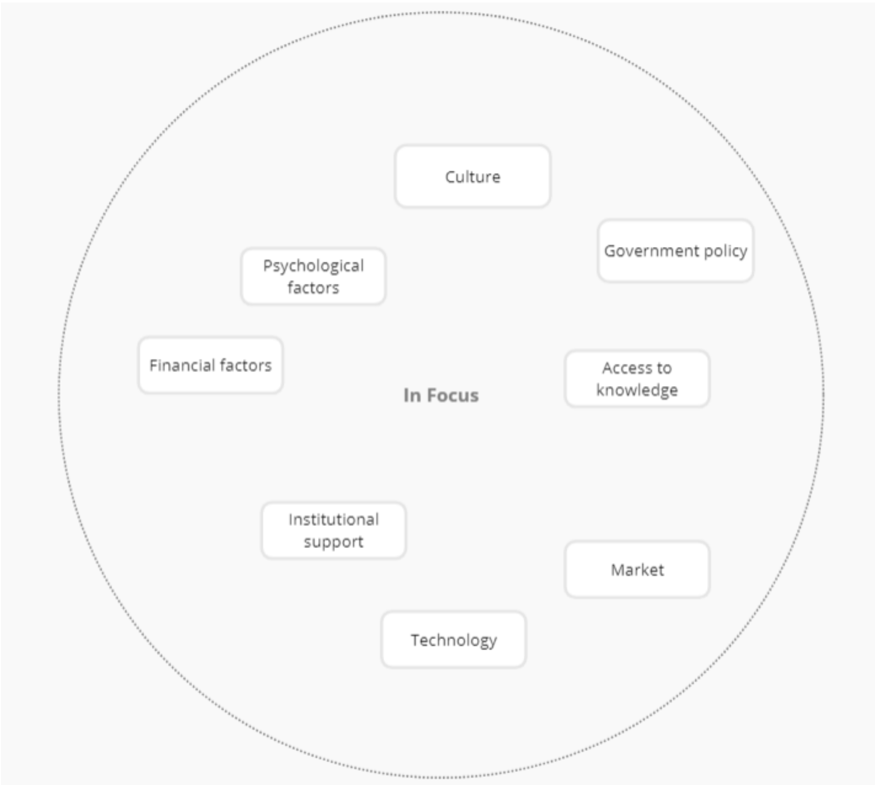


Figure 5 Example: Variables in Focus

Let's say that this is our first mapping exercise with a small team, an inner circle, as a starting point. So, after we did the initial data gathering using some of the above-mentioned methods, we have outlined some categories and decided on which we will focus on. These categories are in focus due to their relevance and impact, and others we consciously chose to neglect are still mapped and we might decide to include them in our focus during subsequent iterations if we are faced with new information, evidence, or a perspective. This often happens at later stages when we present our models to wider participants which is highly encouraged.

Not only we might include categories that are labeled as less important during the initial phase. But we might decide to exclude some of the initial ones as they prove to be less relevant. Keep in mind that our models are always up to a debate and discussion, they are never perfects and we should never present them as such to further some agenda. They are always up to questioning and the more scrutiny they endure and get modified along the way, the more powerful they become in an explanatory sense.

Figure 6 Example: Variables out of Focus

These are some categories that we choose to exclude from further mapping and modeling, but we keep an eye on them and have them ready if we decide to widen our scope at some point.

Data collection

At this stage, we should gather as much relevant information within the targeted scope, about our problem, and research question. This will serve as initial data to start working on the mapping activities. Keep in mind that iterations are crucial for systems thinking and that tour maps can never be done and concluded as there is always new information that could be acquired or new potential additions in terms of unforeseen or neglected variables that could narrow or widen our scope.

Data could be collected using various methods such as structured or semi-structured interviews, surveys, workshops, focus groups, media reports, historical and statistical records, policy documents, previous studies, literature reviews, documentation reviews, and descriptive Data Collection using the Multi Actor Approach.

Identifying elements of the system

The next stage focuses on taking the categories that are in our focus and breaking them down into concrete elements (variables).

This includes:

- Identifying and naming the main variable which is in the center of our system model and tackles and aligns with our problem definition and research question.
- Identifying variables that directly or indirectly influence the identified key problem and, therefore the central variable.

It is important to notice that the central variable is a center of our system models, but it is like that because we have zoomed a part of a wider context from our perspective as we wish for these models to be useful and explanatory in our cases, not exhaustively represent all reality. We could zoom in on any part of the system which would make other variables central from our point of inquiry if we define the problem and research question differently. However, these are all part of the same reality.

Let's take the following as a main variable which is part of our example related to sustainable farming:

- Sustainable farms (our objective is to understand what can we do to increase the number of sustainable farms)

Variables should be derived from the data collection method, group processes (e.g., brainstorming, workshops, etc.), consultations with experts as well as other system maps and models. Some of the variables would be the following:

- Market value of sustainable products
- Social stigma
- Social support by significant others
- Market recognition
- Supply of adequate mechanization
- Social factors
- Market
- Traditional values
- Supply of raw materials
- Social Status
- Awareness of unconventional types of production
- Access to educational material
- Costs of acquiring new mechanization
- Visibility of good practices

- Channels of knowledge exchange
- Financial factors
- Access to knowledge
- Short-term decrease in yields
- Practical expert support
- Subsidies
- Support from the scientific community

This process of defining and naming variables could be initially done by the primary team of individuals who are doing the mapping and then through iterations developed together with other social actors and interested parties. Nonetheless, it can also be done first as a group session as well, and then refined in terms of correct naming and formulating the variables by the primary team based on some of the key practical principles:

- Ensure the names are clear, precise, and concise - prioritize simplicity and avoid vague terms and concepts (e.g., "carbon footprint" instead of "harmful climate change-inducing emissions").
- Use nouns instead of verbs (e.g., " Pesticide Application " instead of "Conducting Pesticide Application").
- Don't add pre-conceived values to your variables – keep them as neutral as possible (e.g., "quality of feed" instead of "good quality of feed").
- Avoid ambiguous or overly complex variable names that may confuse different social actors and individuals or obstruct understanding.
- Keep variables neutral in terms of positive and negative direction (e.g., "Crop Yield" instead of "Increasing crop yields").
- If it is for some reason necessary to add connotations use positive connotations instead of negative ones (e.g., "Yield Increase" instead of "Yield Decrease").
- Ensure variables are measurable and observable (e.g., if needed use "level of", "amount of", etc.).
- Document definitions of variables as well as the methods and indicators related to their measuring to maintain consistency, transparency, and clarity.
- Differentiate between perceived and actual states (e.g., "Perceived local Government Transparency" vs. "Actual local Government Transparency").
- Test the comprehensiveness and usability of variable names during iterations.

Categorizing elements of the system

Within this step, we are going to take all listed variables and group them into compatible categories that we have included in our scope. This will help us track relevant fields of influence and increase the readability and interpretability of our diagrams. When system maps and models get complex and when variables start piling up, it is very useful to have different categories which will prevent us from getting lost in the sea of variables and particularities. It also allows us to step back and take a look at these categories to more clearly see if we could/should add some others that we have temporarily left out of our scope.

Some categories related to our example of levels of adoption of sustainable agricultural practices would be the following:

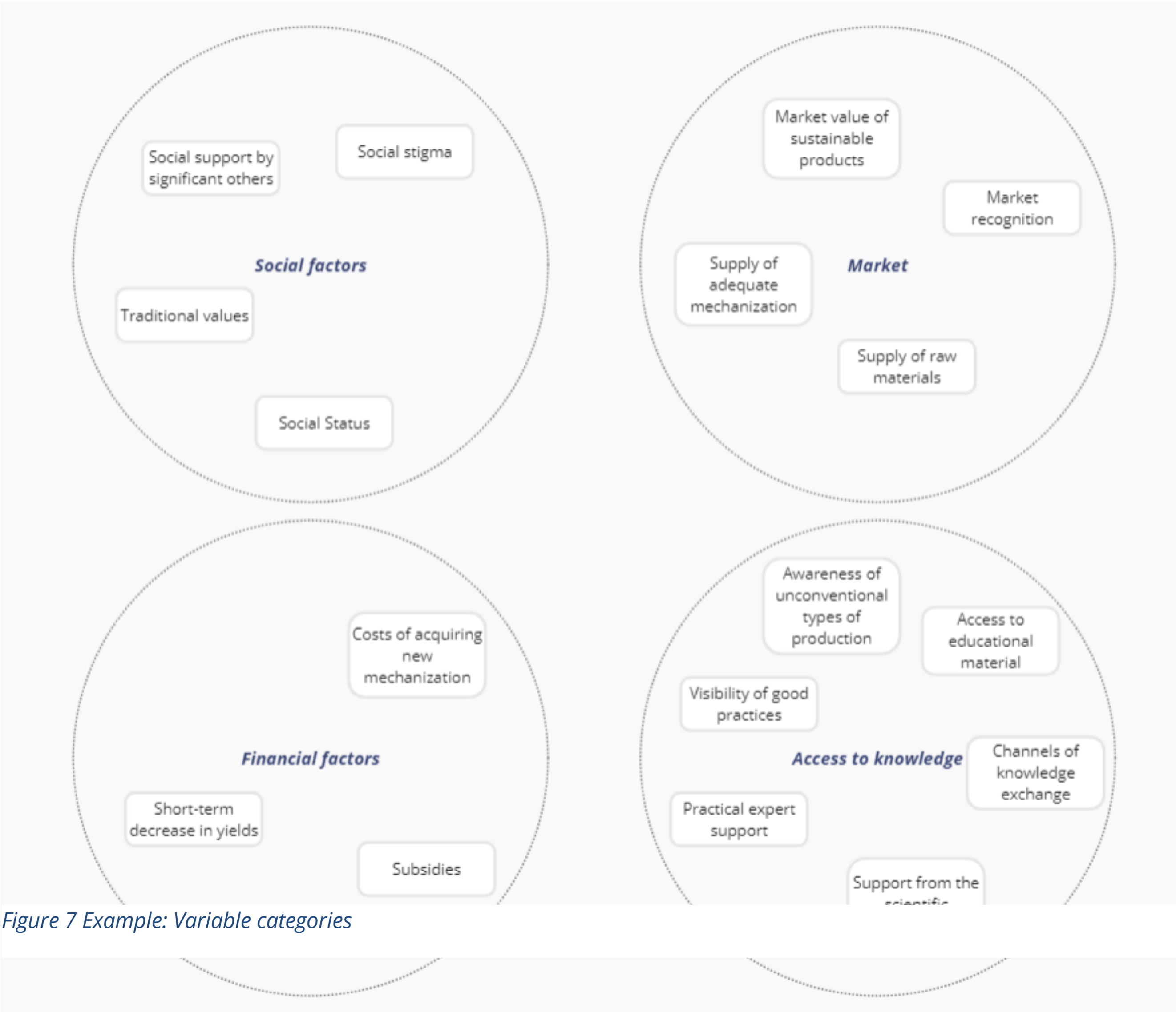


Figure 7 Example: Variable categories

Figure 7 Example: Variable categories

Step 2 – Causal loop diagrams

As we have observed relevant events, identified key variables, noticed patterns, and presented them through BOT diagrams, we need to delve into the 3rd layer of the iceberg model. We need to better understand the structure so we can tackle the behavior of the system in question and change these patterns and, therefore the events. We will start with creating causal loop diagrams.

CLDs represent conceptual models that help us to understand causal connections between our variables and their links to the central problem at hand. They consist of many feedback loops as the smaller units.

CLDs consist of the following units in the order from particularities to the whole: Elements – Causal Links - Feedback Loops – Causal loop diagram

On the following pages, we will provide brief steps for creating CLDs. For equipment we can use simple pen and paper, but it is much more easier and user friendly to use some of the available digital tools, especially when working with groups. Some of the free tools are the following:

- Miro board – Online collaborative platform, functioning as a whiteboard and free at the level needed for creating CLDs. Users can draw, add sticky notes, and collaborate in real-time, making it suitable for visualizing and quickly adjusting CLDs even at the highest level of complexity.
- Loopy - Free web-based tool specifically designed for creating CLDs. It allows practitioners to quickly and efficiently sketch out feedback loops using intuitive drag-and-drop functionality. Loopy's simplicity makes it ideal for practicing systems thinking skills and initial brainstorming activities.
- Kumu - A powerful visualization tool for mapping. Kumu's advanced features make it suitable for detailed systems mapping.

Linking identified variables

When we have our problem structured, scope, elements, objectives, and data, we can start outlining causal links. It is all in these connections and links, otherwise, we are not talking about a system, but just stationary sets of things, and elements.

Let's start with a simple, isolated example, and for the purpose of explaining the causal mapping process. Let's say that we have a herd of cows that are grazing in one grass field. We now have two components but still don't have a system. We know that these two components are influencing one another somehow, but we yet don't know how. As sentences primarily follow linear logic and some components within systems are acting at once, we use causal feedback loops as basic operating units of the system to map out these links. We can present our example through the following diagram:

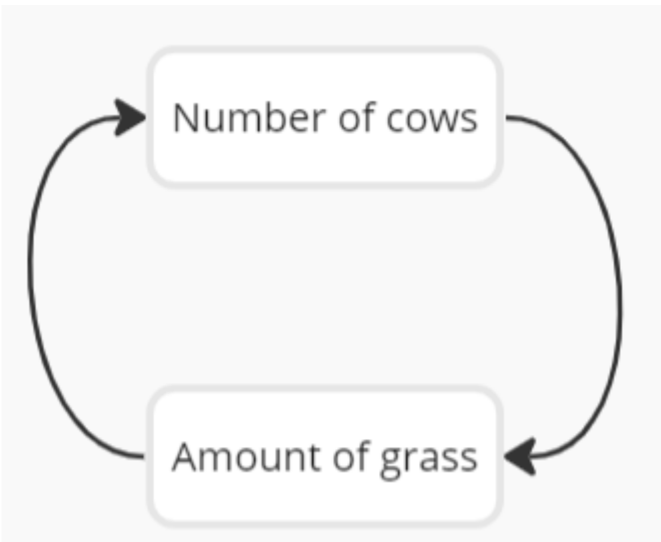


Figure 8 CLD Example: Links

Here, the arrows simply indicate that there is some causal link between the two variables, but it doesn't outline the nature of that connection. However, let's say we notice that the cows cannot graze on this small field forever as the amount of grass will decrease after a while, so we decide to hike here regularly to see what happens. So, after a few months, we notice a pattern. Cows are taken to this field and they eat almost all the grass within a few weeks and then they are taken to another field (rotational grazing). After a while, when the grass grows, the cows are returned to the same place.

Defining causalities

Now we have started to uncover fragments of a system as we have added links to these components as well as the nature of causality between the two. This causal loop consists of two variables – the number of cows and the amount of grass on the field. We can show it in the following way.

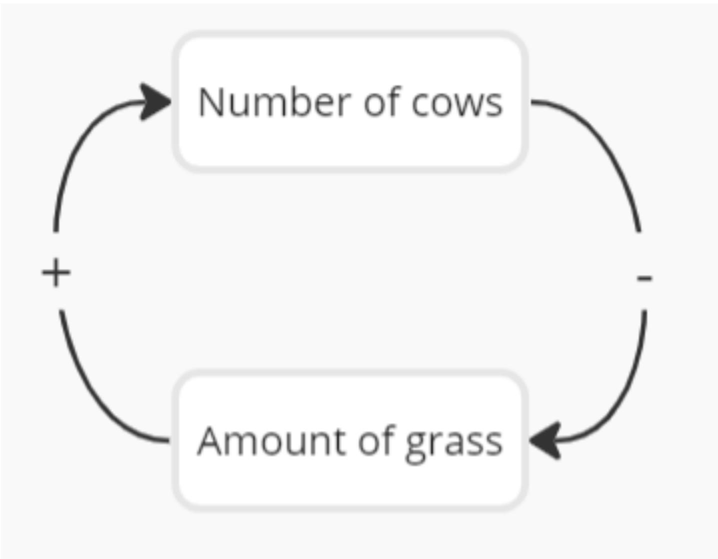
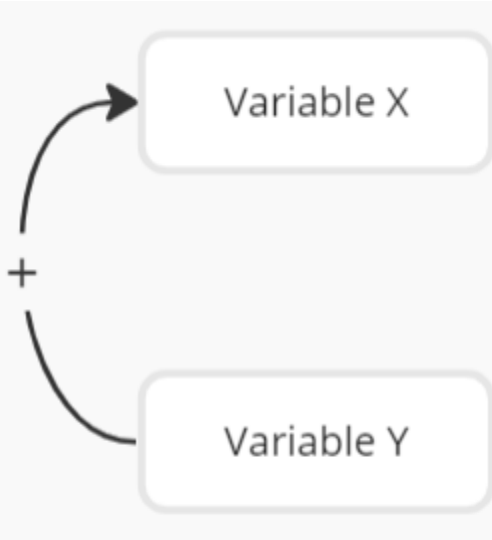


Figure 9 CLD Example: Causal values

We have now outlined a small causal loop which we have presented using a causal loop diagram. This causal loop is very isolated and small and it is a part of a greater system. Nonetheless, on this simple diagram, we can start seeing some behavioral aspects of the system. In words, when the amount of grass increases, the number of cows increases as well which decreases the amount of grass which decreases the number of cows which absence increases the amount of grass which increases the number of cows, and so on.

Be careful not to mistake correlations for causations. If you notice correlations meaning that data or witnessed experience shows a pattern in which one variable is always showing up after another, but you cannot exactly pinpoint or even hypothesize about a causal mechanism that could be connecting those two variables, you can map them but don't put them in the CLD yet. This is rather a sign that you should do more research to find the missing variable that is connected with both od these variables in a way that is manifested by correlation. Not finding this variable would make your causal loop fallacious.

To explain the “+” and “-“ signs.



The **“+”** sign tells us that the two variables are linked in such a way that as one of them changes in one direction the other changes in a same direction.

Therefore, if the **variable X increases** the **variable Y increases** as well. But if the **variable X** decreases the **variable Y decreases** as well.

The **“-”** sign tells us that the two variables are linked in such a way that as one of them changes in one direction the other changes in an opposite direction.

Therefore, if the **variable X increases** the **variable Y decreases**. But if the

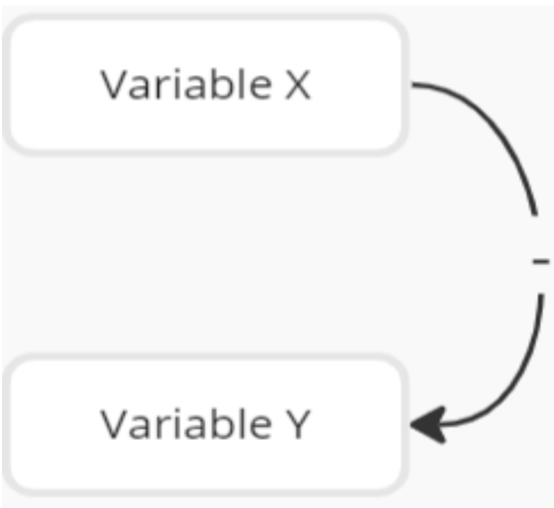
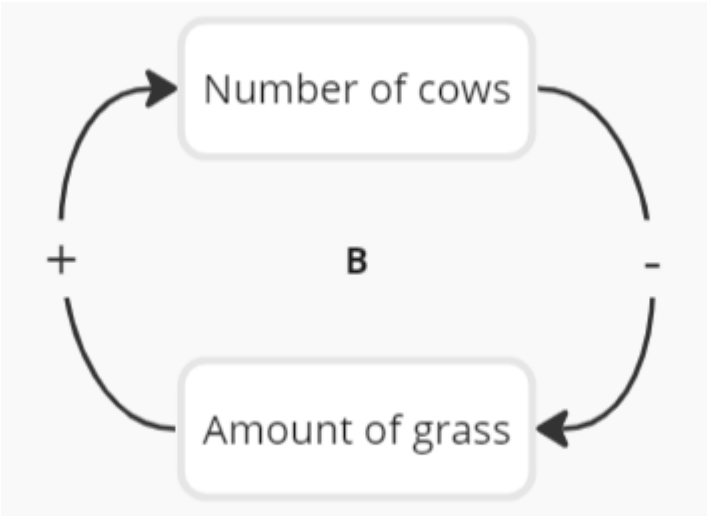


Figure 10 Causal links

Identifying feedback loops

Systems produce a certain behavior of their own, as time goes on and the causal links between components continue to manifest and produce certain consequences. To go back to our simple example of one causal loop within a system. No matter how much time passes in this closed causal loop, if nothing disturbs it, we will not run out of cows or grass. Why? Because we can see that we are dealing with a balancing (or negative) causal loop. So, let’s label it as such and explain.



When we put “R” in the center of a loop, we characterize it as a reinforcing loop as it will produce a certain growth or a decline over time.

When we put “B” in the center of a loop, we characterize it as a balancing loop as it will balance itself over time, that is, it will tend to establish an equilibrium.

The balancing or reinforcing nature of the loop will depend on the type and quantity of the links between the variables. We can distinguish between the two by going through the changes like through a narrative and see if the stock (amount of grass and the number of cows) is continuously increasing/decreasing or if it tends to be balanced over several iterations. The easier way is simply to count the number of negative links. If the number is odd, it is a balancing loop, and if it is even, we have a reinforcing loop (or if it is 0).

A good example of a reinforcing loop is related to the “cow demographics”. Let’s look at the cow natality rates.

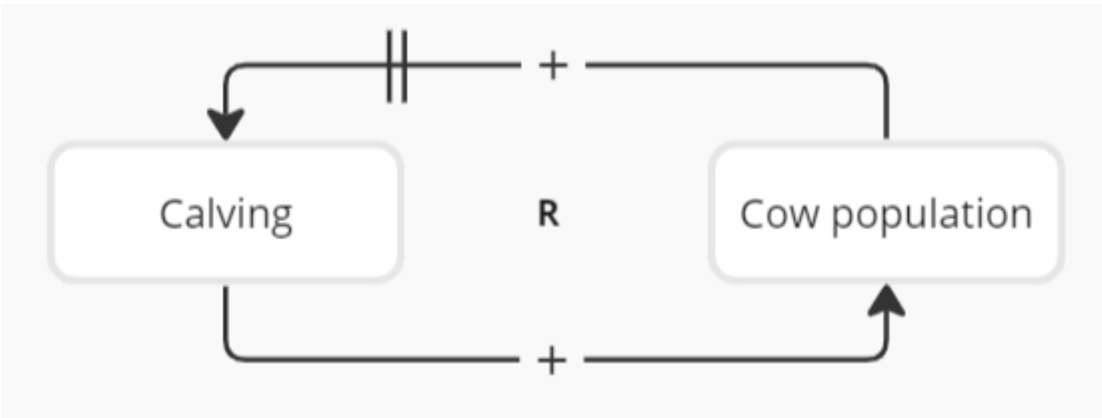


Figure 12 Example: Reinforcing feedback loop

More cows leads to more cows calving, and more cows calving leads to more cows which again leads to more calving, and so on. And *vice versa*. Less calving leads to fewer cows and fewer cows leads to less calving which leads to fewer cows, etc. Here we see the tendency of reinforcing loops to decrease or increase the stocks.

Of course, we are aware that this exemplary loop is part of a wider system, and both cow population and calving have elements that are causally entangled with them and have an influence on their manifestation.

If we zoom out just a bit:

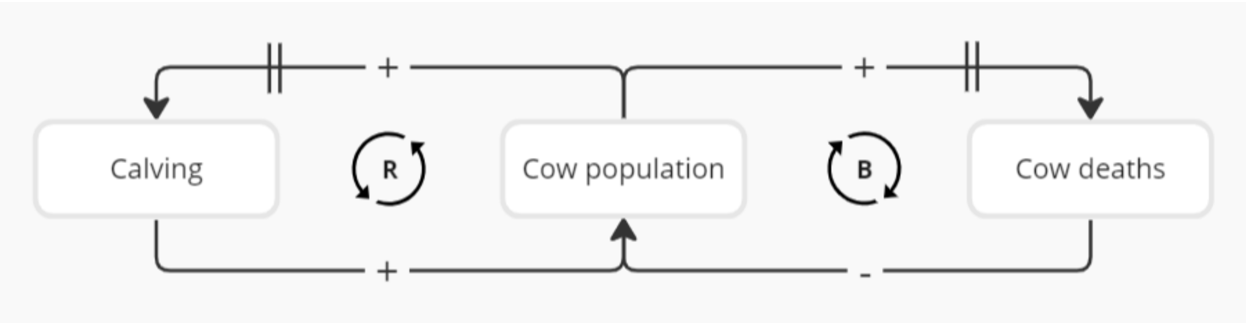


Figure 13 Example: Simple CLS with more variables

More cows lead to more cows dying, and more cows dying leads to fewer cows in the population which leads to fewer cows dying, and fewer cows dying leads to the increase in cow population which leads to more cows dying, and so on. Here we can see how the balancing loop tends to lead the variables to some form of an equilibrium.

Notice that we have also added a direction of loops (clockwise and counterclockwise). This helps with the readability of your diagrams.

Identifying delayed effects

Now, let us continue with the mapping of our previous example and add more variables to the mix. Aside from grazing, the cows are also leaving manure on that field, which is influencing the soil quality, which contributes to the growth of grass.

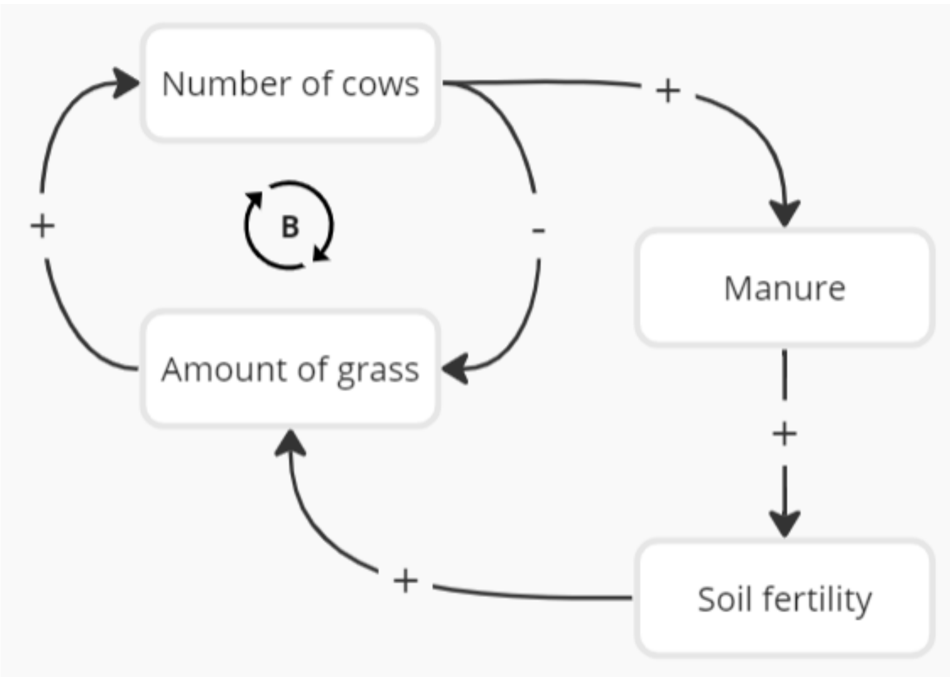


Figure 14 Example: Extra variables with no delayed effect shown

However, this effect is not happening in such a short cycle as the one presented. These effects are taking place in the long run. Now we have a time imbalance which we must somehow present as well. We will do this by putting two tripes over the link which has a certain time delay between the cause and effect.

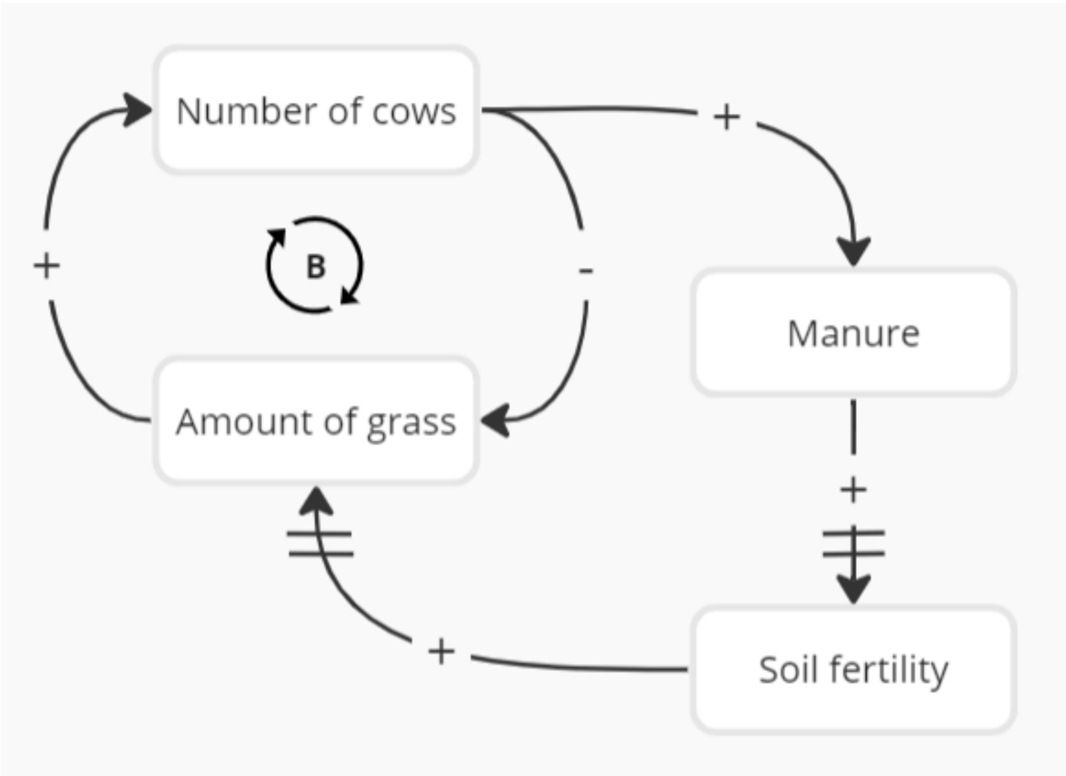


Figure 15 Example: Extra variables with delayed effect shown

The components of systems can include both tangible and intangible things such as people, infrastructure, emotions, power structures, etc. We and everything around us are intertwined somehow with other variables that function as a system. If we change something, other system's components are likely to be affected, directly or indirectly, and sooner or later. The more we are aware of the interconnectedness of the components and their causal nature, we better see and define challenges and we can be more informed when making decisions that affect the system (policies, measures, etc.) and the more our decisions and interventions in the system will be meaningful, impactful and will be closer to the desired goals and stay further from undesired consequences.

Here is an example of how a CLD looks like in a more advanced stage (Jagustović et al. 2019):

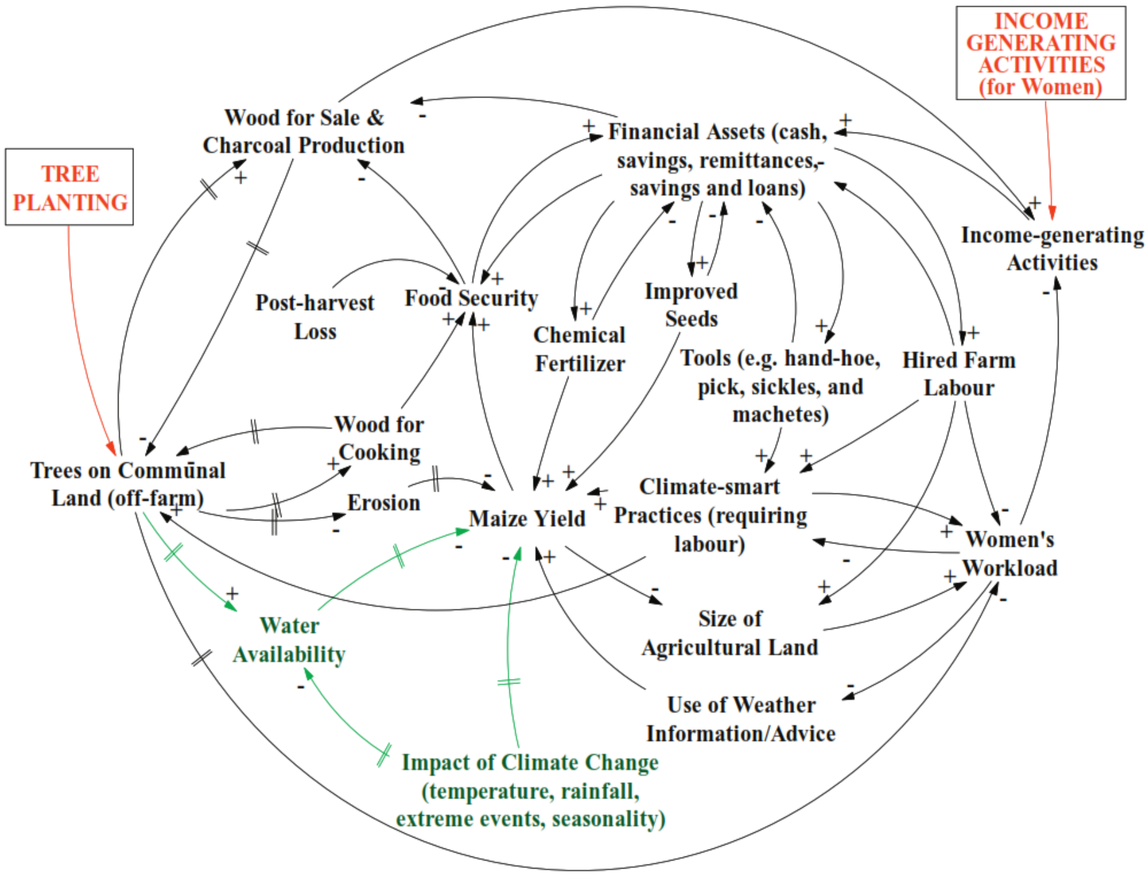


Figure 16 Example of a CLD in an advanced stage of development

This is an example of mapping a system from the perspective of women farmers related to climate-smart agriculture in Doggoh-Jirapa, northern Ghana. Analyzing other CLDs at various levels of development is quite useful as a training practice, to sharpen our skills and logical apparatus. Just always remember that we should never claim that our models are done, 100% accurate and present them as absolute evidence for reaching a pre-determined goal.

Let's finish this chapter with some useful Dos and don'ts.

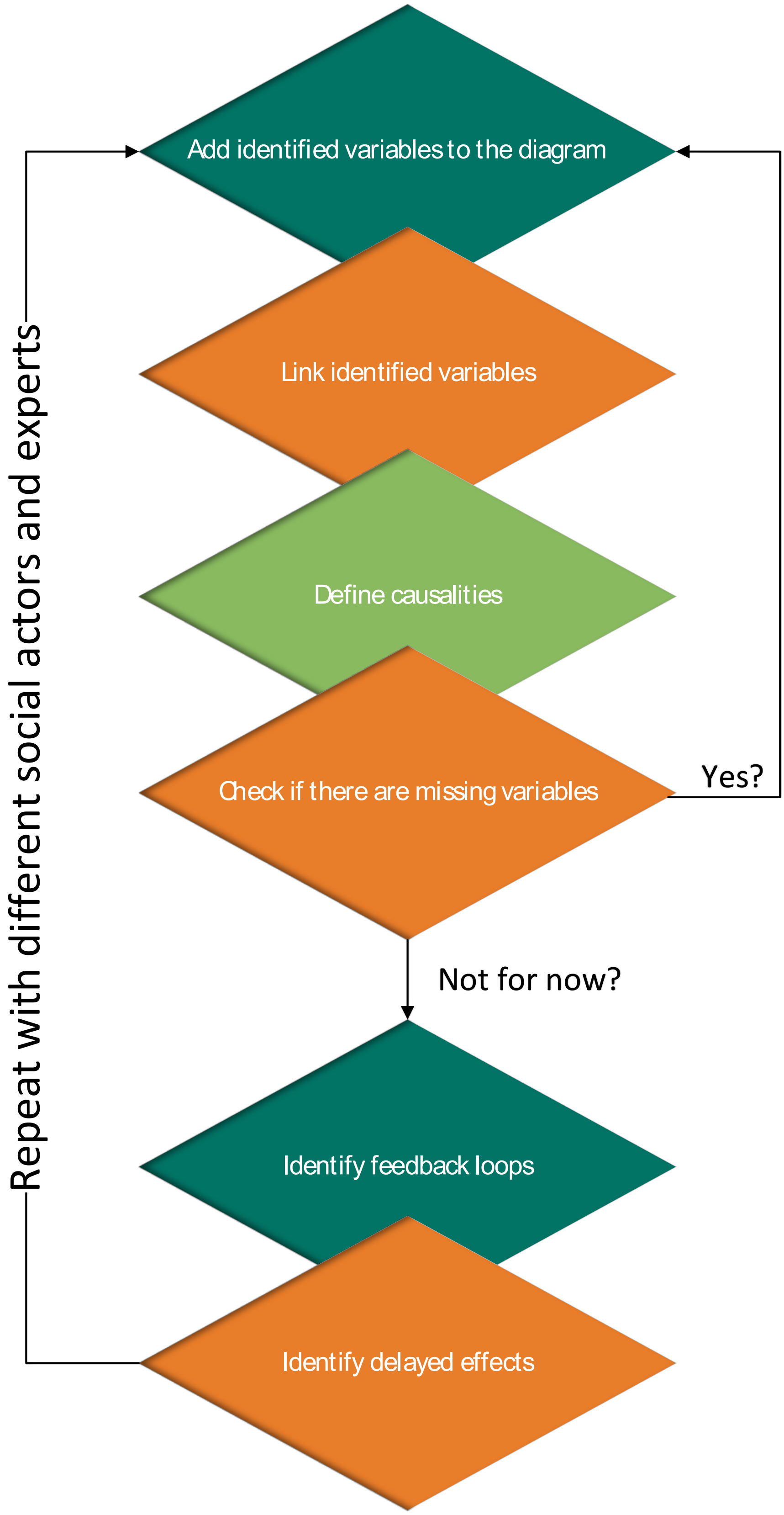
Do:

- Collect data from diverse sources
- Include multiple perspectives to capture different dimensions of the system and its elements.
- Iterate and refine the model
- Identify Key Drivers with the most significant impact on the system's behavior and outcomes.
- Regularly review set boundaries and adjust according to the new insights.

Don't:

- Overlook the multi-actor approach and fail to include all relevant actors in the process and their valuable input. Don't ignore their feedback in case it doesn't match your assumptions.
- Mistake assumptions for data-supported evidence. Assumptions are useful for exploring how things work, but we should never present them as validated variables.
- Oversimplify the system or its elements.
- Cherry-pick the data and insights – Don't dismiss contradictory evidence that challenges your initial assumptions about the system.
- Present your models as finite representations of a system. System thinking methodology is a tool for acquiring deeper understanding, they can always be improved as it represents much higher levels of complexity.

The steps and iterations can be outlined in the following way:


Add identified variables to the diagram
Link identified variables
Define causalities
Check if there are missing variables
Yes?
Not for now?
Identify feedback loops
Identify delayed effects
Repeat with different social actors and experts

Archetypes

System archetypes are certain system structures that theorists and practitioners have observed over and over again throughout many years of mapping and modeling systems of various scales and within many contexts. Learning and understanding system archetypes will help us improve our systems thinking knowledge, and make it easier for us to spot recurring structures. Think of them as forms whose understanding will jumpstart our understanding of systems in general as the keep coming up. And even if they don't come up in their ideal version (e.g., maybe they have more variables included in their loops, but the core point and results stay the same), the variations are easier to grasp if we look at them, at first, as deviations from these ideal types.

We can compare them loosely to standards in jazz music, most successful negotiation tactics, or staple dishes in a particular cuisine that use key cooking methods. By learning these, we get to the essence of things faster in terms of our understanding and even use them as a type of lenses at first, during the learning process, as we look at new, complex CLDs. Archetypes in the system dynamics literature and practice have straightforward names that are intuitive, many of them tell stories in their titles that you recognize already or you will start recognizing in daily life.

Here, we will show just one simple example. The following archetype is called "Fixes that fail".

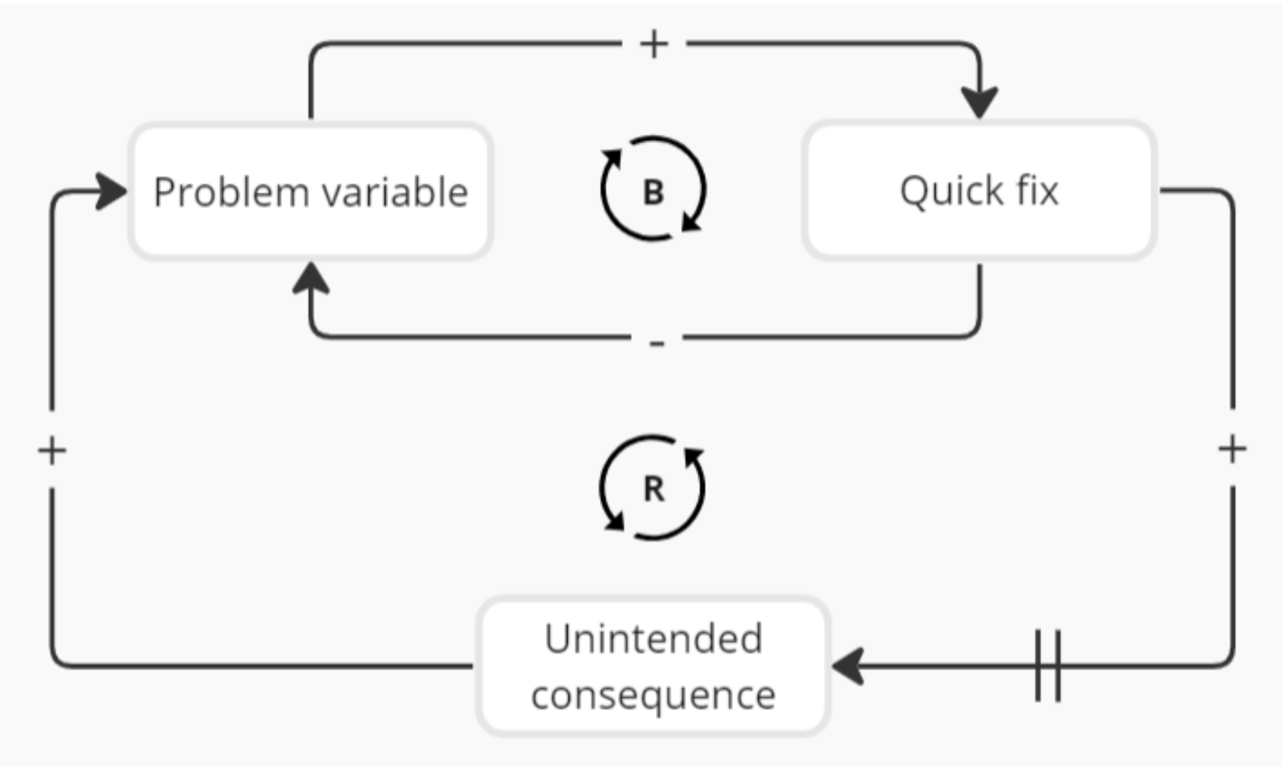


Figure 18 Structure of the archetype "Fixes that fail"

We can see two feedback loops, one balancing and other reinforcing. Balancing one doesn't have a delay which means its effects are manifested in a short term. On the other hand, the reinforcing loop has a delay which makes its effects manifest and influence the overall behavior of this part of the system in more of a long run.Furthermore, we notice the tendency of systems thinking to capture unintended consequences which give us the wider context. The story goes like this – as a problem is addressed by a quick fix, its symptoms are relieved. Therefore, in the short run, the problem is solved. However, the same fix causes an unintended consequence which is delayed and which manifests itself after some time, that is, after the balancing loop "went around" multiple times. In other words, we have a fix that works for a while but it causes the problem to get back to the initial level or even grow larger after a longer period of time. It is important to note that these short term / long term time frames are completely related to the context. In some context those could be measured in days, months, years or decades.

Let's describe a concrete example.

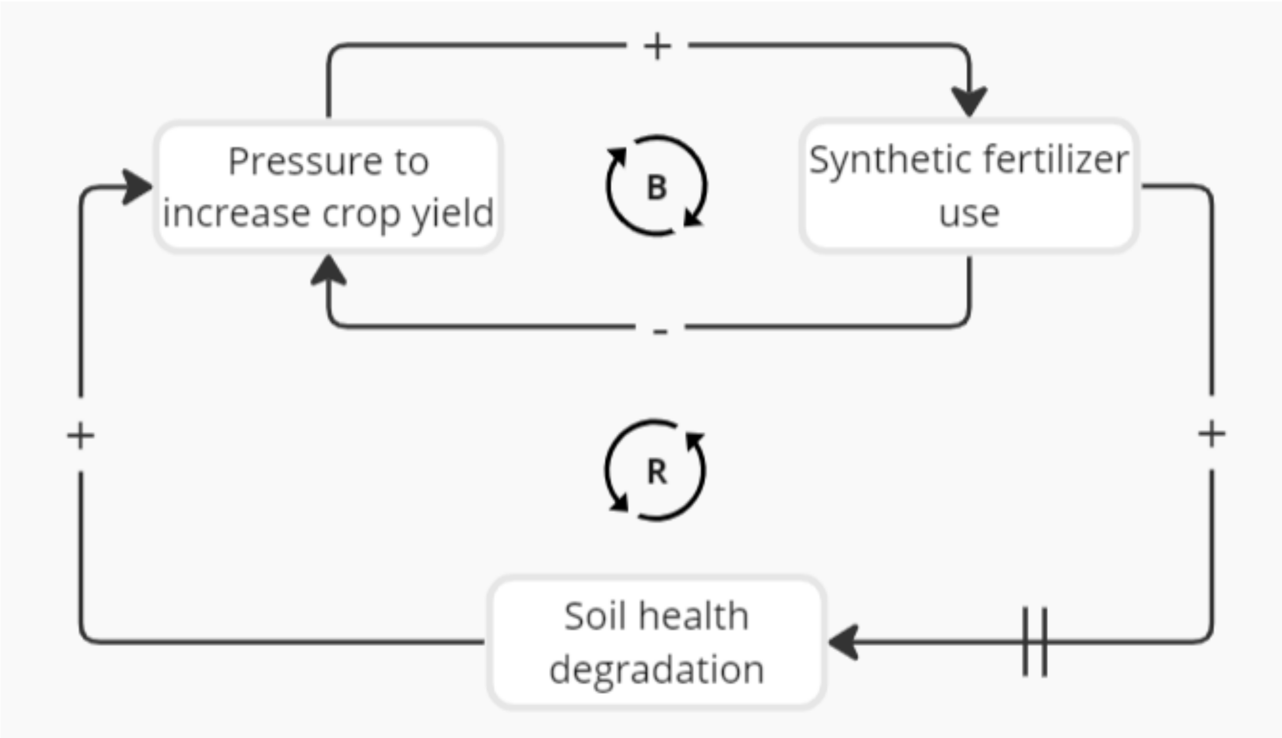


Figure 19 Example of an archetype "Fixes that fail"

If we assume that in our hypothetical context, there is some form of social pressure on farmers to increase crop yield (e.g., increased demand) and that they solely rely on the more intensive usage of synthetic fertilizers to deal with this pressure. That creates a balancing short term feedback loop within which the pressure to increase crop yield causes increase in usage of synthetic fertilizers, which relieve the pressure. The pressure then decreases the usage of synthetic fertilizers which increases pressure and so on.

Nevertheless, the increased usage of synthetic fertilizers increases soil health degradation in the long run which causes crop yield to decrease which increases the societal pressure to increase it once again. It is clear that the fix didn't manage to fix the issue although it seemed like that in the short run.

Notice that we are actually lacking one variable here. Therefore, we should insert a variable between soil health degradation and pressure to increase crop yield. So let's add the variable and name it "crop yield", as actual crop yield. We will get the more complete depiction and a variation of the archetype with the same logic applied. It will look like this:

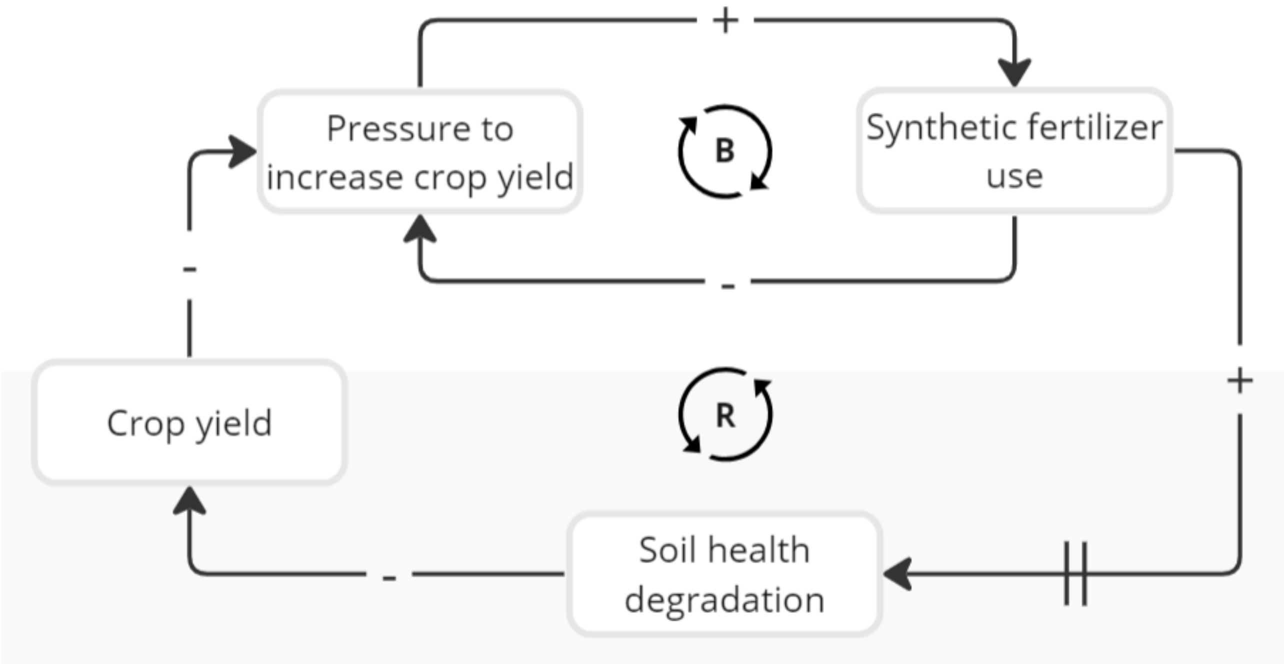


Figure 20 Example of an archetype "Fixes that fail" with an added missing variable

The causal value between the added variables and variables that are connected to it are both negative as they influence each other in opposite direction.

This archetype and our example can be projected through a BOT diagram like this:

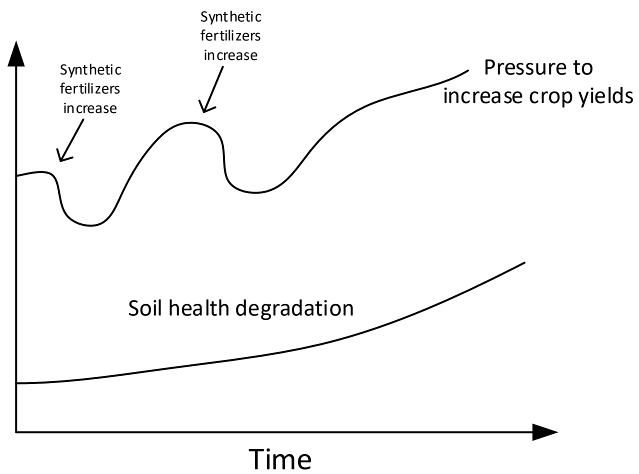


Figure 21 BOT diagram example for the archetype "Fixes that fail"

On the BOT diagram we can show how these variables manifest over time and how the fix variable triggers both intended and unintended consequences, One short and other long term. We have a drop in the problem variable after the usage of the fix (increased use of the synthetic fertilizer, but at the same time we clearly see an overall trend of the increase of the problem variable. As the unintended consequence (soil health degradation) gains momentum after its delay, the problem variable continues to grow.

We have shown just one, simplest archetype, but we encourage readers and future system thinkers to study other archetypes using the relevant literature listed in the "References" section.

Step 3 - Develop a narrative

As our CLD gets to the stage where we have pretty much exhausted our cognitive resources (group and individual) and data resources, and as it gets quite complex, it might be time to take a step back and develop a narrative around our model. What we mean by the narrative is simply, but systematically, converting the main points, insights, conclusions, summaries, and problematic elements of your CDLs into words and sentences.

This is useful for at least five reasons.

1. To get an overview of the work that has been done, highlight some important insights and summarize key points in a concise way to improve our understanding of the CLD.
2. To use these key points to identify what is lacking in your CLD, and to list key questions that are still pertinent and could improve/validate certain elements of the diagram.
3. To have a clearer idea of which type of social actors (e.g., experts, enthusiasts, public officials, etc.) you need to include in the following iteration (through group work, interviews, or some other method). In other words, it will guide you to find people who have the knowledge or experience to answer these questions.
4. To use the narrative as a tool that will help with presenting your CLD during the following iterations. Always remember that you and your initial group of participants have a great understanding of your diagrams as you have developed them over the course of time from low to high levels of complexity and have experienced the process as subjects. They are a byproduct of your efforts to increase your understanding of the system at hand. On the other hand, CLDs can be very daunting and confusing to people who see them for the first time. They look messy, they have no beginning/end, they are not linear/have no path you can follow as a first-time viewer. Therefore, it is very helpful, almost essential, to build and use the narrative as a sort of guidance through your CLDs to help people who are seeing it for the first time to catch up to your level of familiarity and to start contributing meaningfully rather than being discouraged at the face of complexity and stay passive or quit the process.
5. Narratives are mandatory for concise communication with a wider audience. Your diagrams are tools in the process of understanding complex reality. They are not great tools for wider communication of your insights. Narratives are more comprehensible by individuals and are essential for communicating complex issues effectively.

Example of a complex CLD related to family life and related sources of problems or happiness (Bureš 2017).

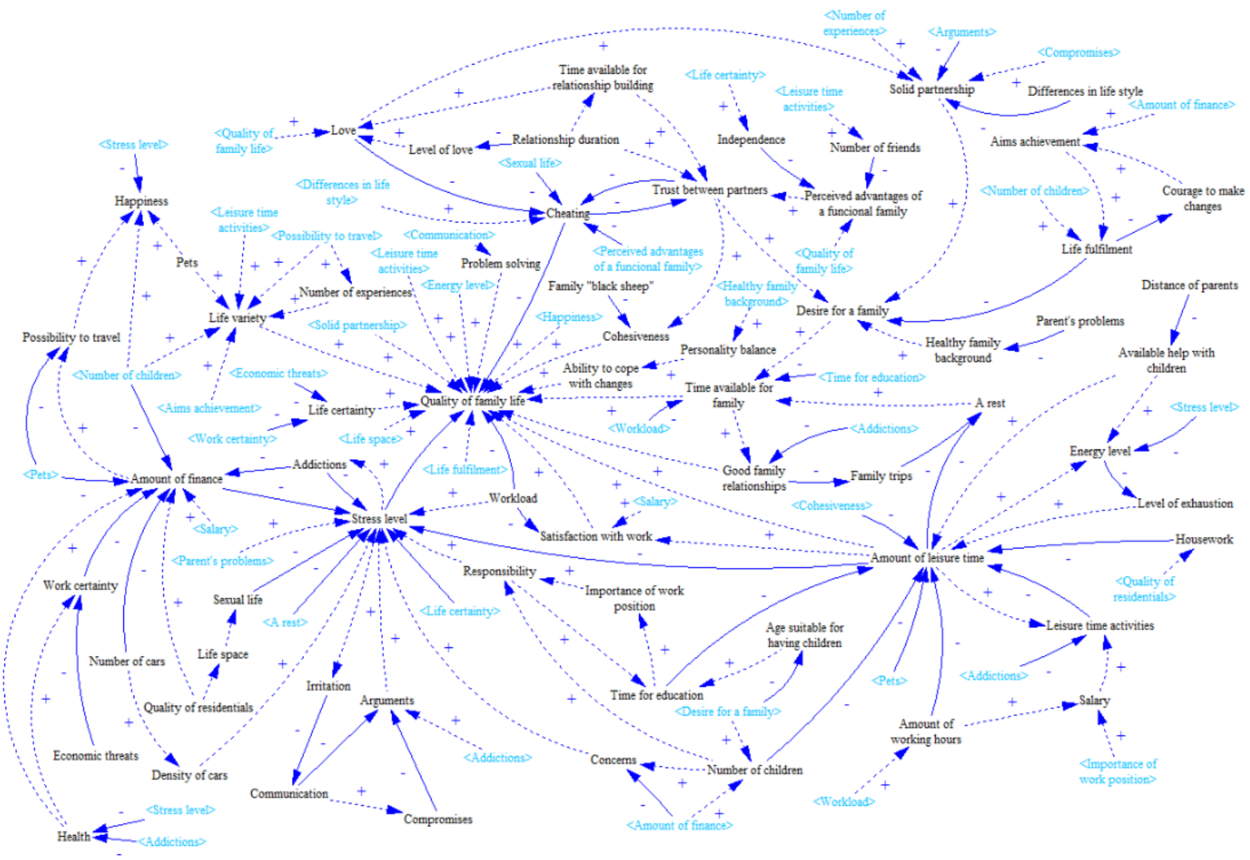


Figure 22 Example of a complex causal loop diagram

Here are some pragmatic tips on how to develop a narrative based on your mapping activities:

1. Write down the most important insights in the form of sentences or even stories. Keep it as short and concise as possible but don't leave out important aspects. Think about the feedback loops which are the most significant drivers, variables that turned out to be more impactful than you previously thought, controversial aspects, issues, etc.

2. Write a section that describes each category of variables in your CLD. Begin by dissecting individual categories of the system. Explore their functioning in isolation, and describe them shortly. Explain key variables, feedback loops, and the interaction with the system as a whole.

3. Once you grasp the dynamics of individual components, assemble the pieces to examine the system as a whole. Write the summary. What is the central story of the system and what are the major causal relationships? The summary encapsulates the system's current state and elucidates the primary drivers behind it.

4. Write down the main assumptions about your system. Remember that that there is no final version of your CLD so feel free to make bolder assumptions here as they are to be tested during future iterations. The stronger they are, the stronger feedback they will provoke. Of course, we need to stay in line with what can be inferred and be careful to not state something purely out to create a controversy or to cherry-pick what fits our personal agenda.

5. Write down the remaining questions about your CLD.

Identify categories within your CLD that may be underdeveloped, potential paradoxes, uncertainties, or unclear causal implications, etc. In addition, you can simply note down questions that are interesting, relevant to the topic, and open-ended ended like: "Are there any inaccuracies/discrepancies within the system that you've identified?" or "Do you see any crucial aspects missing, from your perspective?".

For each assumption and question, identify social actors who can help validate, question, or re-formulate assumptions, give good quality answers to remaining questions, and thus make your CLD better in future iterations.

Use this narrative to facilitate future iterations through group workshops and/or to design new data collection efforts (e.g., interviews, questionaries, etc.). Approach the process with patience and empathy, guiding your audience through the intricacies of systems thinking with clarity. By engaging in creating a narrative, you can facilitate meaningful discussions that not only validate your assumptions, improve your causal links, etc., but also deepen your understanding of the system while fostering collaboration and shared learning among different social actors.

Step 4 – Stock and flow diagrams

Stock and flow diagrams are the next step to better understand CLDs and therefore the system itself. They are also a step towards developing a computer model which can then be used to test different policies and predict system behavior. They are a foundation of system dynamics.

Causal loop diagrams (CLDs) and stock and flow diagrams are both essential tools in system dynamics, yet they serve distinct purposes and offer unique advantages.

CLDs are great for analyzing systemic issues due to their intuitive nature and simplicity, but stock and flow diagrams elevate our system mapping to a higher level in terms of precision and detail as they incorporate additional information not represented in CLDs. This depth of detail is crucial for a more comprehensive understanding of system dynamics.

Identifying stocks and flows

What exactly are stocks and flows and how to identify our variables according to this?

Stocks represent accumulations or depletions (e.g., the number of plants on a field. Conversely, flows influence the rates of change within stocks (e.g., planting or harvest).

We can look at the flow variables as variables that move, as subjects that are active, and "alive" in a way. On the other hand, we can look at stocks as objects of which the material reality is consisted of. The easiest way to distinguish between the stocks and flows is to do a simple thought experiment. If we simply close our eyes, imagine our CLD or one of its feedback loops, and imagine if the time stops. What would still exist in reality, what would you still be able to touch if you were passing by?

If we take our example with crops, we can see how a certain number of plants would be there on the field while harvesting or planting stops. So, we can safely label plants as stock and harvest or planting as flows. This would happen because flows are the only type of variables that can change stocks.

These distinctions are crucial to enhance the dynamic accuracy of our models. While a CLD gives us great insights about system structure, it's dynamical aspects might be fallacious, which stock and flow diagrams efficiently expose.

We can take one of our previous examples of cow population reinforcing feedback loop.

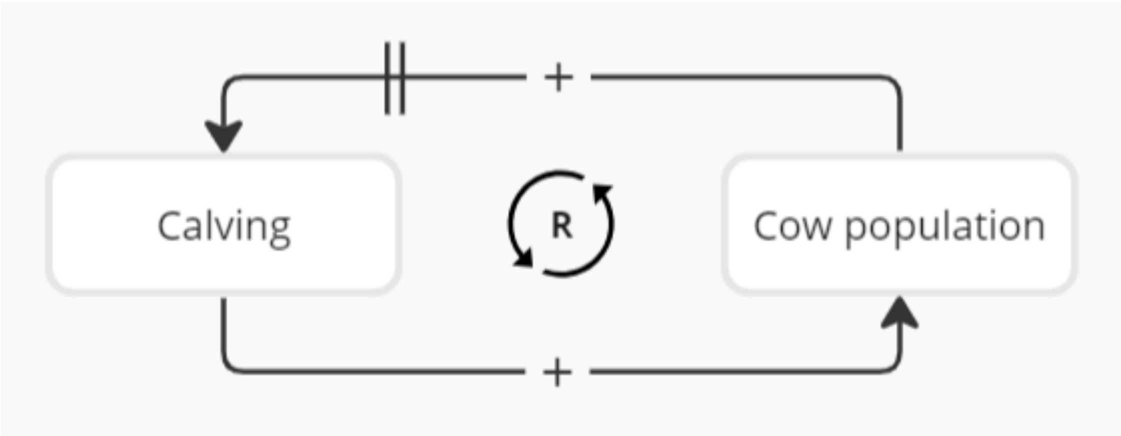


Figure 23 Cow population reinforcing feedback loop

Notice how the loop works if we increase the calving variable – cow population grows. This causes more calving which grows the population and so on. But what happens if the calving variable decreases? Cow population decreases, which leads to lower calving levels and so on. But does it really?

Let's convert this feedback loop into a stock and flow diagram:

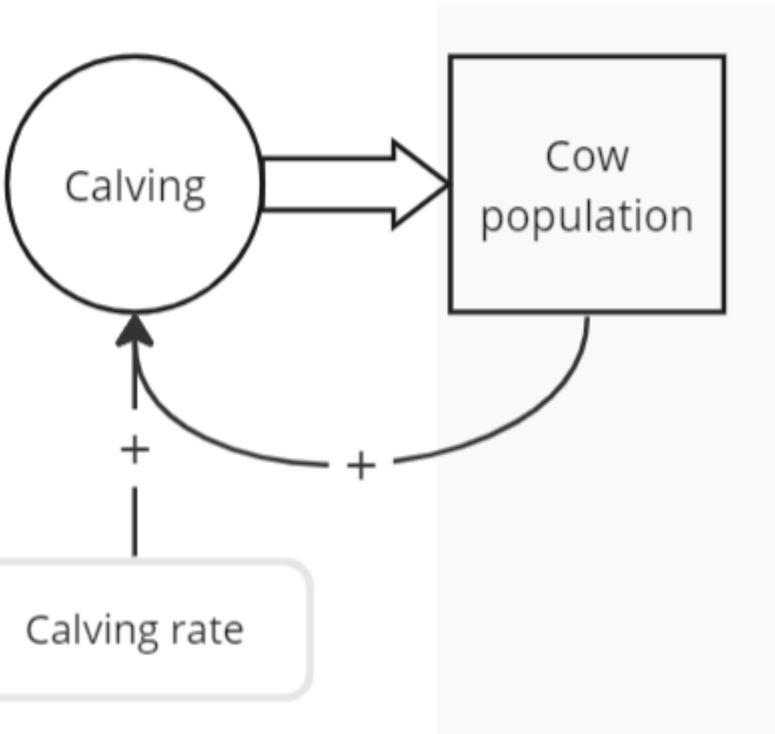


Figure 24 Conversion example, from CLD to a stock and flow diagram

Here, we present flows with circles and stocks with squares. We can notice that calving is a flow and cow population is a stock. Remember our thought experiment, if the time stops calving stops but there are still some cows around. Furthermore, it is visible that the flow variable (calving) has only one direction, and thus can only fill up a stock. If it increases, the population increases, if it decreases the population also increases, but at a slower rate. It cannot take away cows from the population as there cannot exist negative calving. In other words, if the calving rate reduces in our system, let's say there was an epidemy of some sort of disease, from 100 cows per year to 60 cows per year, the cow population still increases but at a slower pace than if the calving rate stayed the same or increased.

We can clearly see that the feedback loop (figure____) only works if the variables increase, but not the other way around. This cannot be confused when looking at the stock and flow diagram.

Converting CLDs into stock and flow diagrams

Now, we will outline a few major steps on how to create stock and flow diagrams based on CLDs.

Identify Units of each Variable in your CLD:

Start by examining each variable in your CLD and determining its units. This can be done during the preparatory work that we have described in Step 1, but it can be more efficient after the CLD is at least somewhat developed as some variables will come and go during the iteration process.

Assign appropriate units of measurement (e.g., number, volume, currency, etc.) depending on the nature of the variable. Pay close attention to interactions between variables, refining unit definitions as needed to ensure logical alignment with causal relationships depicted in the CLD. Continuously update unit specifications as the CLD evolves.

This process also enhances the rigor of CLDs and it helps with recognizing missing variables that we need to include as well so that the dynamic logic makes sense. This way we lay the groundwork for a transition from qualitative systems thinking to quantitative modeling, fostering a more comprehensive understanding of system dynamics.

Identify Stocks:

Now we have to see which variables in the CLD serve as stocks. Variables in your CLD that represent accumulations over time are most likely stocks.

"Stocks represent entities which accumulate or dissipate over time, characterize the state of the system, and drive decision-making and action" (Sterman, 2000)

Identify Flows:

Once you've identified stocks, look for variables that contribute to or draw from these accumulations. In other words, they change stocks – add or subtract from them. These are your flows, representing the rates of change within the system. The information provided by specifying units aids in this process by indicating variables involving time, which can be most likely identified as flows. However, it's essential to note that the presence of a time factor does not automatically classify a variable as a flow.

Identify Links between Flows and Stocks:

Establish connections between flows and the stocks they influence. If a stock also influences flow, create a link between them as well.

If a flow exerts a negative effect on a stock, it constitutes an outflow. On the other hand, if it has a positive effect, it represents an inflow.

Once all flows have been linked to their respective stocks, it may be necessary to draw links between certain stocks and flows, the other way around. These links occur when a stock influences one or more flows. One more difference between CLDs and stock and flow diagrams is in the differentiating the links between certain types of variables. We don't distinguish between a material and immaterial (information) variable when mapping links in CLDs. On the other hand, these links are different in stock and flow diagrams.

This meticulous connection of flows to stocks and stocks to flows ensures the accurate representation of system dynamics, facilitating a comprehensive understanding of causal relationships and feedback loops within the system.

Identify and Link other CLD Variables:

Incorporate any additional CLD variables that were not initially identified as stocks or flows. These auxiliary variables could be constants or calculations based on existing stocks and flows. Connect them as needed.

Step 4: Add and Link Remaining CLD Variables:

Now, we have to incorporate all CLD variables that are identified neither as stocks nor flows. These are called "auxiliary" variables, and they are divided into two main categories:

1. Constants – variables whose values remain the same over the timeline that we have identified as relevant.
2. Calculations - variables that are calculated in relation to stocks and flows.

Connect these new variables to the variables they influence and those that influence them. Note that stocks can impact auxiliary variables, but these variables cannot affect stocks directly. Always remember that stocks cannot be changed by any other variable other than a flow. If you assess, while analyzing your model, that some other variable is changing a stock (adding to it / reducing it), then you need to assess it again as it might be a flow or something else is wrong.

Making sure that variables are calculable:

The information contained in the diagram must be set up to calculate the value of each stock and flow. A CLD clarifies the connections between variables, but it is not as detailed as what is needed for these kinds of computations. A stock and flow diagram, on the other hand, offers a calculable depiction of the system. In order to achieve calculability, each variable must be precisely defined and assigned a unit of measurement. This frequently necessitates the addition of new variables.

Provide formulas that let you figure out each variable's value depending on its starting value and the values of the other variables in the diagram. To keep accuracy, make sure all of the variables have the same units. It is crucial to guarantee unit consistency between flows and stocks.

Final checks and iterations:

You might discover that more variables are required to finish the model and make sure it can be computed when you describe the variables and equations. As needed, introduce these variables and make links to the current system. After determining the appropriate units for stocks and flows, the focus turns to the remaining factors. You might discover from this analysis that more variables are required, in which case you would have to define them again and check the units. Once all required variables have been defined and unit consistency has been verified, the CLD can be converted into a stock and flow diagram.

While these instructions are designed to be operative and doable with a pen and paper or a Miro board, the best is to use some of the computer-based modeling software. This offers the advantage of having a computer model at the end of the conversion process. This model enables you to explore various policies and visualize the potential responses of the system. Nonetheless, this requires more training which is out of the scope of this handbook.

Step 6 - Leverage points

At this point, all our hard work hopefully has increased our individual and collective understanding of the system in question and should start paying dividends. Identifying leverage points means characterizing solutions, measures, and pathways to answer identified challenges. This process should be also easier by the fact that you have undergone the systems thinking process with other social actors as well so each of them got a chance to broaden their perspective and meet important drivers of change and influential system elements that they have been neglecting. These neglected elements aren't the same for every person who participated. This means that the understanding of relevant issues is now more homogenous and discussions can be more fruitful and relevant as you have "put everything" out on the table in previous iterations, so disagreements and latent beliefs about the system are chased out in the open and reduced to a minimum.

Leverage points are defined as places in the system where small manipulations could have significant impacts on system behavior (Meadows 2008). In other words, we want to find spots in the system that would give us the "best value for our money", if we decide to change them. During this step, the team that has undergone the process of system mapping should identify the leverage points. The team can choose whether to involve a wider group of participants (e.g., interviewees from previous steps) or not.

There are some principles of systems thinking that will help you identify and deal with the leverage points:

1. Analyze your diagrams by focusing on the variables that have the most connections with other variables. These often turn out to be leverage points as they have a wide range of influence and impact which translates highly to the behavior of the system as a whole. We call this a ripple effect. Such effects usually have the potential to set off numerous (more or less potent) effects on a bigger number of feedback loops.

2. Take a look at how could particular variables create effects that influence your central variable the most. What is their potential to change the behavior of the central variable through a ripple effect?

3. Assess the feasibility of each leverage point. Think about what is your ability to manipulate a particular leverage point and change it in the desired direction. Do you or your team possess the necessary resources? Which social actors have the power to do the same? Can you get to them? How likely is that they will engage and collaborate? The most feasible leverage points are obviously the go-to points but don't neglect the challenging ones as well. Note them down as you might find solutions down the line to switch these into feasible ones if circumstances change.

4. Develop a strategy that encapsulates your strategic insights to manipulate identified leverage points with a multi-actor engagement strategy that should help you mobilize necessary social actors, create synergies, and act in the most optimal way to change the system structure in a desired direction which should change patterns and events on the surface level. Explore the ways you can pull the leverage points in the desired directions.

Conclusion – Battle with Complexity

In the enthusiastic pursuit of understanding and navigating complex systems, we unavoidably embark on a perpetual battle with complexity. Nonetheless, this handbook provides the initial arsenal of system dynamics and system thinking methodology, to equip the users with the tools necessary to confront and conquer the intricate web of interdependencies that characterize our reality and therefore our issues.

We have explored the world of systems, uncovering how variables, feedback loops, and stocks and flows shape how systems behave, and how leverage points can have transformative power. We've accented the need to accept that things can be uncertain, ever-changing, and that although we may not know everything, we're determined to keep learning and understanding more, together, through numerous iterations. We know that dealing with complex issues isn't about solving problems once and for all, or legitimizing our pre-conceived agendas, but about continuing to learn and explore in a deeper way.

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