Project Report

SDG pathfinding methodological framework: Participatory Approach to Localise the Sustainable Development Agenda

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Foreword

About the report: This report describes a methodological framework to support the localization of the 2030 Agenda at local scales in African contexts. The framework offers practical guidance for applying its methods to other projects, outlining the various steps and open-source participatory tools available. The report also reflects on the application of the approach in the two case studies in Africa—Fimela District (Senegal) and the Swarzkop River Basin (South Africa)—and concludes with lessons learned and recommendations for future endeavors.

About the project: This report has been developed within the framework of the Belmont Forum Collaborative Research Action (CRA) project *SDG Pathfinding: Co-creating Pathways for Sustainable Development in Africa*. The project is transdisciplinary research initiative conducted from 2021 to 2023. The project aimed to develop tools and build capacities to support the localization of the Sustainable Development Goals (SDG) agenda in African countries, employing participatory, bottom-up approaches. It brought together natural and social scientists from three leading institutions—Rhodes University (South Africa), Institut National de Recherche pour l'Agriculture, l'Alimentation et l'Environnement (France), and the International Institute for Applied Systems Analysis (Austria)—in collaboration with a prominent local NGO, Groupe d'Action et d'Initiative pour un Développement Alternatif (GAIA). These partners worked closely with a broad network of stakeholders, including local policymakers, NGOs, grassroots organizations, and the private sector in Fimela District (Senegal) and the Swarzkop River Basin (South Africa).

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1. Background

1.1 The challenge of localising the SDG Agenda

The world is at risk, facing many crises, including political instability, rising socio-economic inequalities, climate crisis, biodiversity extinction, and more recently global health crisis. Many of these crises are interlinked threatening to derail the achievement of the 2030 Agenda and its 17 Sustainable Development Goals (SDGs).

To stay on track, policy commitments need to translate faster into effective policy actions, sustainable financing needs to increase, governments' capacities for (long) term planning need to be boosted, innovative stakeholder engagement approaches promoted, and behaviours and mindsets need to match our ambitions for sustainability (Meadowcroft et al., 2009; OECD, 2019; Schmidt-Traub et al., 2019; SDSN and OECD, 2019; TWI2050, 2018; UNDESA, 2019). There is, however, no one-size-fits-all solution, and transformations will need to match countries' capacities and socioeconomic-physical-governance contexts (Satch et al., 2019). Regional and global cooperation also needs to be reinforced, but in ways that are context-sensitive to prevent the emergence of losers and create a 'win-win' package deals (Moomaw et al., 2012; Susskind et al., 1996).

The implementation of the 2030 Agenda is an enormous governance challenge for all countries, irrespective of levels of development and income. African countries stand among those with the greatest challenges ahead to get on the sustainability track. Demographic imbalance, ineffective governance arrangements, poor data and capacity challenges , limited resources, inequalities and poverty, and high exposure and vulnerability to climate variability and change have prevented African populations from advancing the implementation of the SDGs (SDG Center for Africa, 2020).

The sub-national level faces additional challenges since the implementation of the 2030 Agenda often follows a top-down approach neglecting much of the local needs and realities (Oosterhof, 2018). There is a clear need, thus, for "localising" the SDG agenda by not only through raising awareness, but active strengthening local capacities and institutions while enhancing the participation of local and regional actors in the development and implementation the SDGs at sub-national levels.

There are, however, multiple barriers to effectively localise the SDG agenda, in addition to the top-down approach and the limited vertical cooperation. Some of these barriers include (Moallemi et al., 2020): 1) goals that are insensitive to local contexts and therefore ambiguous or insignificant for measuring and monitoring the progress of the sustainability agenda at the local level, 2) limited evidence-based and understanding of the multiple trade-offs emerging when implementing sectorial policies and actions to enable the implementation of the SDG agenda, 3) existence of diverse and often competing views among local actors when it comes to sustainability priorities, and between local actors and national or global players, 4) lack of preparedness to deal with uncertainty and the development of contingency plans, and/or 5) limited institutional capacities, among other factors.

supporting the localization of the SDG agenda. To date, much of the scientific focus has been on developing analytical frameworks to better understand interactions among SDGs, including trade-offs and uncertainties. For instance, qualitative approaches such as social network analysis have been used to highlight the interlinkages between goals, showing how achieving some SDGs can negatively impact others, or how the realization of certain SDGs depends on progress in others (Le Blanc, 2015). Quantitative approaches, on the other hand, include computational models designed to optimize the physical links of resource flows and their connections to broader drivers like climate change. These quantitative tools have primarily supported planning efforts related to infrastructure and landscape investments (Gómez-Echevarri et al., 2020; Parkinson et al., 2019).

Nevertheless, while these approaches are valuable, they fail to adequately incorporate local knowledge, contextual priorities, and the governance dimension, all of which are crucial for effectively implementing any agenda on the ground. Therefore, if science is to support the localization of the SDG agenda, existing analytical tools must be complemented by innovative participatory and co-production processes. These processes are needed to: 1) support the downscaling of global goals to make the 2030 agenda relevant to local realities; 2) co-create adaptive action plans that account for uncertainties, ensuring they are not only scientifically credible and salient at national or global scales but also reflect the priorities of local communities, thereby fostering ownership and adherence to the process; and 3) promote greater collaboration and partnerships between stakeholders and scientists.

1.2 The role of transdisciplinary research in addressing sustainability challenges

Transdisciplinary research (TDR) seeks to enhance the societal impact of research by integrating diverse types of knowledge, practices, and worldviews to address complex challenges and explore pathways for overcoming them. As described by Langan et al. (2012), TDR: (i) emphasizes the investigation of societally relevant problems; (ii) fosters mutual learning by bringing together diverse knowledge sources, including researchers, practitioners, policymakers, traditional knowledge holders, and other knowledge domains; and (iii) aims to produce knowledge that is action-oriented, socially robust, and applicable to both scientific inquiry and societal practices. In the context of sustainability challenges, adopting a systems thinking perspective is essential to unravel the complexity and ambiguity that stakeholders face regarding the issue at hand.

Box 1 Key characteristics of transdisciplinarity in sustainability research.

- **Complexity:** TDR focuses on addressing highly complex, real-world issues that cannot be effectively resolved within the confines of a single discipline (Lang et al., 2012).
- **Inclusivity:** A core aspect of TDR is integrating knowledge across disciplines while incorporating non-academic insights from stakeholders, such as policymakers, community members, and industry leaders (Bergmann et al., 2005).
- **Systems thinking:** TDR employs systems thinking to analyze and address the interdependencies within complex problems (Lawrence et al., 2022).
- **Co-production:** TDR fosters collaboration among stakeholders from diverse disciplines and knowledge domains, including scientists, practitioners, policymakers, and local communities. This approach facilitates a shared understanding of the problem and the joint development of solutions, such as adaptive pathways (roadmaps that guide local actors over time, providing timelines, responsibilities, and contingency measures to address future uncertainties and instabilities).
- **Societal impact:** Unlike traditional disciplinary research, TDR explicitly aims to deliver actionable outcomes with tangible societal benefits, transcending academic boundaries (Belcher et al., 2019).
- **Integration:** TDR recognizes that the "whole" offers richer and deeper insights than its individual components. These components may include knowledge systems, stakeholder views, ideas, methods, data, and paradigms. Integration is pursued at various levels and throughout the research process (Bergmann et al., 2005).

- **Iterative and flexible:** TDR embraces iterative and flexible research methods, allowing objectives and strategies to evolve in response to new insights and stakeholder feedback.
- **Evaluation and reflexion:** TDR incorporates mechanisms for ongoing evaluation and reflexivity, ensuring that the research process remains aligned with its goals. Researchers critically assess their assumptions, roles, and impacts (Belcher et al., 2019).

There are an increasing number of projects where TDR and co-production approaches have been used to support the localization of the SDG agenda. Croese and Duminy (2022), in the context of the *Mistra Urban Futures Program*, reflected on the application of TDR approaches in supporting the localization of the SDG agenda in urban areas of South Africa. Their work highlights the co-production of urban expertise, which facilitated SDG localization by integrating diverse knowledge systems and engaging multiple stakeholders, including local authorities, researchers, and community representatives. Similarly, Jiménez-Aceituno (2020) described the lessons learned from the seed projects developed under the *Good Anthropocene Project* in Africa, which emphasized initiatives aimed at implementing various SDGs at the local level. These initiatives illustrate how co-produced, locally adapted interventions can drive transformative change in diverse African contexts.

Further examples of SDG localization in Africa include the work of Elias and de Albuquerque (2022), who applied TDR to localize SDG 11 (sustainable cities and communities) in Lagos and Accra. Their project employed participatory processes and systems thinking to co-create sustainable urban solutions that address the unique challenges of these rapidly growing cities. Shackleton et al. (2023) also demonstrated how equitable and sustainable development pathways across Africa have been fostered through TDR, emphasizing the importance of inclusivity, collaborative learning, and transformative governance. These projects underscore the importance of local adaptation and stakeholder involvement in bridging global SDG goals with actionable, context-specific strategies.

Collectively, these examples highlight the growing recognition of TDR and co-production as key methodologies for aligning global sustainability goals with local realities, fostering collaboration, and creating tailored solutions to address specific socio-environmental challenges.

However, beyond these successful cases, there are also important challenges when implementing TDR approaches overall, and for supporting the localisation of the SDG agenda in particular. As Moallemi et al. (2020) described, researchers can face a dilemma in terms of when to choose which tool to implement and how to apply them through effective facilitation. The choice of the tools and the extent of stakeholder engagement can be influenced by several local factors (e.g., data availability, type of stakeholder, willingness to participate, resources available, etc.). This requires a careful consideration of local conditions and customise a set of methods and approaches suited to the local context and project capacities. Participatory processes are also exposed to the risk of a premature judgment based on past experiences, values, and strategic motives of a dominating stakeholder group. This necessitates engagement with stakeholders across sectors and scales to capture the diversity of ideas before narrowing down on actions.

TDR approaches can be very diverse depending on the problem at stake and the local needs but as described by Lawrence et al (2022) a standard project can be structured along three main phases (see Figure 1). *Phase 1* also called “collaborative problem framing and research team building”, where the team (scientists and stakeholders) is set up, the problem is jointly identified as well as the objective of the research. The essence of this phase is to set up the collaborative team and translate a real-world problem (e.g. how to implement the SDG agenda at the local level) into a boundary object that is researchable (e.g. what are the top sustainability challenges in a given region, and how to link them to the broad SDG objectives). *Phase 2* also called "Co-creation of solution-oriented and transferable knowledge" is where the research is actually conducted, including the selection of the methods, its further development, and application of the different bodies of knowledge comes together (e.g. what methodological approach and process would make most sense given the challenges, capacities, and stakeholders, who to involve, how, when). During each step of the research project it needs to be clear who contributes, with what means, and for what purpose. Therefore, in this phase it is very important to define the level of engagement of the different stakeholders and to also manage expectations. *Phase 3* " Integration and application of the co-created knowledge" is where the research results are implemented both in social and scientific practice. The integration of results into social practice should ideally imply the implementation of the evidence-based strategies and action programs generated during the research. Although the TDR literature is not clear who should implement the results, at what scale (both in terms of space, time and jurisdiction) our collective reflection in the current project suggest that actions can be implemented by different actors such as community members, practitioners, and policy makers, among others. It is therefore important to pay attention to opportunity for implementation actions in the course of the TDR project. In other words, implementation should not be seen as something that always happen at the end of the research, by some "distant, often policy-oriented actors" but it can partly take place during the project. Likewise, the integration of scientific practice might involve the development of publications with research findings. It is important to acknowledge that TDR processes, other than the "tangible" outputs, might also lead to less tangible but equally important outcomes, such as enhanced capacities of the actors involved, support for the development and empowerment of social networks, and social learning, among others (Thiam et al 2022).

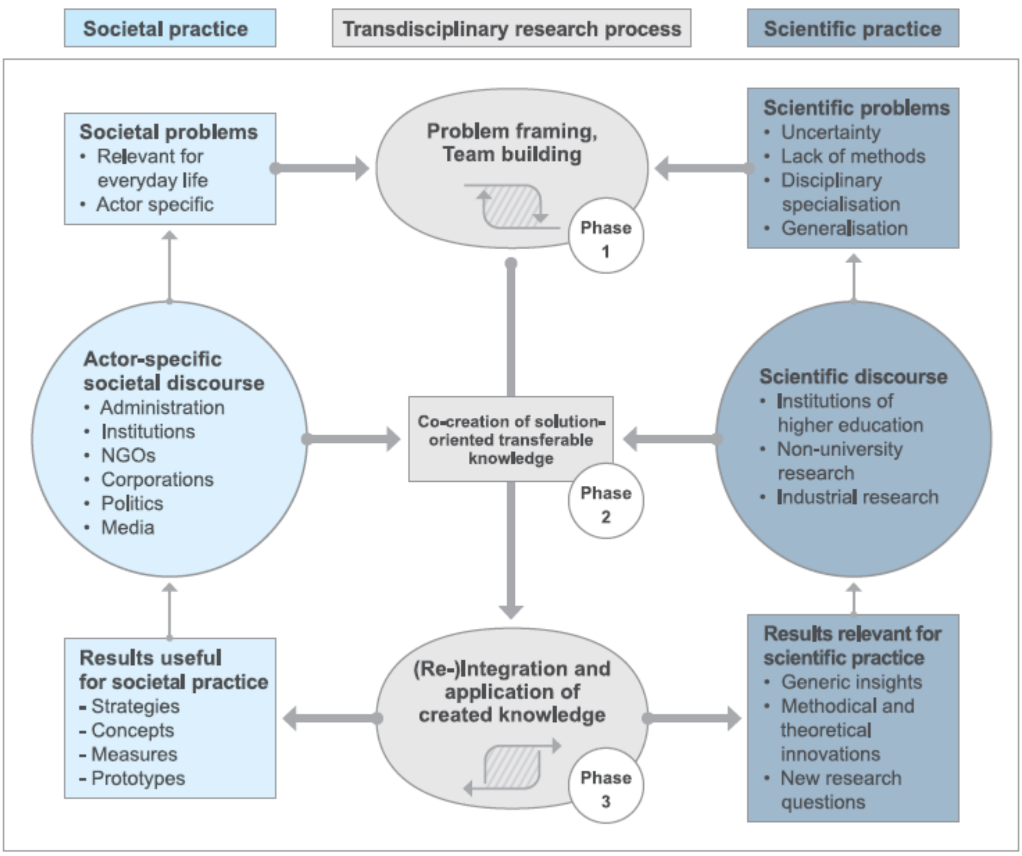

Figure 1Transdisciplinary research process. Source: Lawrence et al (2022)

TDR tools can be highly diverse and therefore difficult to cluster. One approach is to organize the tools on the basis of the phase and purpose they are meant to be used in a TDR project. The "td-net toolbox"[1] is one of the largest toolboxes available for TDR projects and it offers a wide range of possible tools to be used along the three above-referred phases. Furthermore, within each phase, tools are clustered depending on the question being addressed. For instance, within the *Phase 1* "Collaborative problem framing and research team building", the toolbox offers suggestions on tools that can be used to map stakeholders, develop a procedure for knowledge co-production process, or options to develop a rough idea of the project in a participatory setting. Overall, flexibility is required when developing a TRD project, and in the particular in the context of localising the SDG agenda, since the problems to be addressed are highly diverse, as well as the actors involved and the expected outcomes.

1.3 The SDG pathfinding project and purpose of these guidelines

The 'SDG-pathfinding: Co-creating pathways for sustainable development in Africa' project (*SDG-pathfinding* project hereafter) is a Belmont Forum-funded project under the call Pathways 2020[2]. The overarching goal of *SDG-pathfinding* is to develop tools and capacities that can help to localise the SDG agenda in African countries using participatory bottom-up approaches. The project takes a transdisciplinary approach and specifically aims to:

1. **Develop and test innovative tools** to lift local capacities for framing complex sustainability challenges using a system thinking approach and explore adaptative pathways to meet the SDG agenda at the local level,
2. **Foster multi-stakeholder collaboration** to promote social learning and innovation on how to implement the SDGs locally, and
3. **Support the institutionalisation of the sustainability agenda** beyond the lifetime of the project

The project brings together an interdisciplinary team of scientists from academic institutions and a local NGO, spanning Europe and Africa, with extensive expertise in systems thinking, stakeholder engagement, and participatory approaches to addressing complex sustainability challenges. The project aims to explore how various tools can be combined to support scientific and social innovations by providing a robust yet flexible framework for localizing the SDG agenda. This approach is tested and implemented in two archetypal SDG hotspots—regions where multiple SDG gaps intersect due to diverse drivers operating across different scales. The selected case studies are the Fimela district in Senegal and the Swartkops catchment in South Africa. This report describes the resulting methodological framework, reflects on its application in the two case studies, and highlights key lessons learned.

2. SDG Pathfinding Methodological Framework

2.1 The SDG Pathfinding Framework

The SDG pathfinding methodological framework (SDG Pathfinding Framework hereafter) builds upon the combination of existing participatory approaches developed by the scientific team in earlier projects. In particular, the SDG Pathfinding Framework integrates tools and methods from the Collaborative Systems Mapping of Sustainable Pathways-CoSMoS (Campos et al., 2023), the Adaptive Systemic

[1] https://naturalsciences.ch/co-producing-knowledge-explained

[2] https://www.belmontforum.org/archives/resources/pathways-2020-call-text

Approach-ASA (Palmer et al., 2024), the CoOPLAGE toolkit (Ferrand et al., 2017), and the participatory development of Causal Loop Diagrams (Clifford-Holmes et al., 2017). Each of these tools and toolkits, as well as relevant applications, are described in Section 2.2.

The main innovations of the SDG Pathfinding Framework are:

1) Coherent integration of existing participatory tools and yet very flexible, allowing the project team to integrate different sets of tools depending on the objective, stages and processes of the project, the type of participants, and resources available.
2) It integrates key characteristics of transdisciplinary methods: highly participatory, with a strong emphasis on co-production and integration of different types of knowledge, intended to build systems thinking capacities, with a prospective component exploring possible futures, and with a strong focus on generating outcomes and outputs that are scientifically relevant but also support social learning and action planning.
3) It places a strong focus on the use of methods supporting "experiential learning" and "learning-by-doing". Examples include hands-on of tools such as games, role plays, and simulation tools, among others.

The implementation of the SDG Pathfinding Framework follows a number of actionable steps that are closely linked to a standard decision-making process (Figure 2). The scope of the different steps is described briefly below.

Figure 2 The 5 steps of the SDG methodological framework

Step 1-Preparatory work and warm up. This step involves mapping the actors that will be part of the project and how, as well as an institutional mapping and political economy analysis (to analyse power dynamics and values), and desktop study to collect relevant information on SDGs at stake (e.g. map existing knowledge base on critical SDGs). The preparatory phase should also include preliminary engagement with actors and stakeholders, including the need for a system orientation to the problem.

Step 2-Diagnosis, contextual analysis and problem framing. The focus here is to share and gain an understanding of the current conditions, both in terms of the main concerns, values, actors, and the knowledge local stakeholders and actors have about sustainability, and the joint identification and assessment of the challenges to be addressed in the context of the project i.e. identification of the most pressing sustainability challenges, and how those connect with the SDG agenda. Such a diagnosis and contextual analysis will look not just into the present, but also into the historical context of the decisions made in the past, and then connect them to the challenges identified today to understand decision-making. The diagnosis should also help identify uncertainty factors (external, internal, cognitive) that need to be considered at a later stage in the decision-making process.

Step 3 -Visioning. This step is core to the SDG Pathfinding Framework as it intends to identify locally relevant collective vision which sets out the desired future and local aspirations. In a way, this step intends to shift the focus and narrative away from the unstainable path to the desired, sustainable path. The vision needs to be clear and agreed upon in terms of timescale when it should be realised. This could generally be categories into a short-, medium- and long-term vision, as this will determine not only the type of strategies that need to be designed but also the implementation timeline.

Step 4-Pathways, Scenarios and Action Planning. This step is intended to develop the strategies, or pathways (combinations of options/solutions) that can support achieving the proposed vision. This exercise goes beyond the identification of a long list of options/solutions but seeks to identify overall strategies to generate the maximum co-benefits and limit the unintended consequences of adopting single sectoral solutions. The focus is therefore on exploring combinations of options and how those can work out in an uncertain future to materialise the proposed vision. While the approach is intended to support long-term strategic planning it is acknowledged that there are limitations to anticipating long-term impacts of strategies planned today in a changing environment. Therefore, the development of the strategies is also adaptative and takes into account the need to establish short and medium-term interim goals that need to be revised and updated. Developing a timeline and mapping how strategies should be implemented and the identification of points in time for the review and update needs to be considered. Science-based climate and socio-economic scenarios are used also to support the development of robust pathways and anticipate changing conditions in the planning process. To support the operationalisation of the pathways, a prioritisation exercise should be undertaken. Criteria for the prioritisation are diverse, but it is important that in addition to standard criteria such as technical or economic feasibility, other relevant aspects related to social acceptance, equity considerations, and environmental sustainability aspects are taken into account. The prioritisation can help in the design of a roadmap that integrates measures that are socially, economically and environmentally more sustainable from the stakeholders' perspectives and values, and describes whom and when those should be implemented. It is also important that key indicators for monitoring action are co-developed, and resources required to implement the actions are co-produced or agreed upon.

Step 5-Monitoring, evaluation, reflection and learning. A cross-cutting activity across all steps involves the monitoring of the process and outcomes. This is a critical step for reflecting on whether the process is delivering the expected outputs and outcomes and meets the expectations of the stakeholders. There are different ways in which this monitoring can be implemented, but in general can be done through the allocation of a specific time within each action, which for example may take a session within a co-production workshop to reflect on the lessons learned and aspects that can be improved from the participants' perspective, as well as through the use of evaluation surveys. Reflection should be seen as an integral part of every steps that enhances the learning process. The scientific team should draft at the beginning of a participatory process a validation approach that can help to improve and refine the process as it moves forward.

The steps described above summarize the main elements that should be developed when trying to replicate the SDG Pathfinding Framework making use of a participatory process to support the localisation of the SDG agenda. The SDG Pathfinding Framework is flexible, as it allows the use of different tools to address each of the steps, and in some cases, the tools are complementary.

Table 1 describes available methods that can be used along the different steps of the framework. As illustrated, several approaches can be implemented for specific steps, and the choice of the appropriate method and tools will be determined by the project team and/or in consultation with the stakeholders. As described in Section 4, the application of the SDG Pathfinding Framework in the two pilots integrates different sets of methods and tools at different steps in time. This shows the flexibility of the approach in practice.

Table 1The SDG Pathfinding Framework

Steps	Purpose / Ambition	Collaborative Systems Mapping of Sustainable Pathways	Adaptive Systemic Approach	CoOPLAge	Causal Loop Diagrams
STEP 1: Preparatory work and warming up	Preparatory work: Gather information to support the contextualization of the pilot area and participatory approach, including: • Data collection • Stakeholder mapping, • Co-design key research questions • Design of the participatory process/protocol	**METHOD:** • Desktop work • Design of the system mapping tool • Selected interviews **PROCESS:** • Defining the boundary conditions (pilot area) • Desktop review of available data • Stakeholder Mapping • Participatory framing of research questions • Design of the system mapping tool (pilot map + cards describing key physical, socio-economic, infrastructures, policies, and actors)	**METHOD:** • Desktop work • ½ day workshop **PROCESS:** • Desktop gathering of relevant data • Mapping stakeholders & Address influence and interest • Developing a common understanding of the research questions with stakeholders • Assess existing governance system for natural resource protection and use • Discuss with participants the meaning and practice of Participatory Monitoring Evaluation Reflection and Learning (PMERL).	**METHOD:** • **PREPAR**: Participatory design of the process • 1-day Workshop **PROCESS:** • Mapping stakeholders to be involved • Identify the main steps of the participatory process/protocol • Specify stakeholders' participation and role for each step (lead, observe, facilitate, etc.) • Define which participatory tools and methods will be mobilized for each step.	**METHOD:** • Desktop work • Selection of the software (e.g. VENSIM, STELLA, KUMU) **PROCESS:** • Defining the decision unit (pilot area) • Desktop review of available data • Stakeholder Mapping (snowball technique) Identification of the key variables that are going to be mapped

Steps	Purpose / Ambition	Collaborative Systems Mapping of Sustainable Pathways	Adaptive Systemic Approach	CoOPLAge	Causal Loop Diagrams
	Warm Up: Build awareness among stakeholders about the importance for adopting a systems approach to address complex sustainability challenges	**METHOD:** ● **NEXUS GAME** Simulation game ● 3-4 hours onsite play ● 8-24 participants ● 1 Moderator **PROCESS:** ● Participants take on roles of decision makers from the water, food, energy sectors, in two countries sharing same river (transboundary) ● Overall goal of decision makers is to match their increasing water demand with adequate supply ● Goals of both countries overlap, the game provides an opportunity for practising conflict resolution and cooperation at the international level.		**METHOD:** ● **IniWAG** Simulation game ● 3 hours onsite play ● 8-24 participants ● 1 Moderator **PROCESS:** ● Participants will gain an understanding of the common aspects related to water usage and availability using a simple and abstract game ● Over rounds, participants will manage economic activities related to the river and discuss common rules for the management of their territory and shared resources.	
	Joint understanding on what is are the main sustainability challenges in the pilot Identify what are the key physical, social, economic, and governance variables	**METHOD** ● **CoSMoS: Participatory systems mapping** ● 3-4 hours (onsite or online) ● Groups of 6-8 participants ● 1 overall moderator and one moderator per table	**METHOD** ● **Participatory VSTEEP-H approach + PMERL framework:** ● ½ day Workshop (onsite) ● Groups of 6-8 participants ● 1 overall moderator and one moderator per table.	**METHOD** ● **Self-Modelling for Assessing Governance (SMAG):** ½ day Workshop (onsite) ● **CREAWAG:** 1-2 days for model design + few weeks model se up and calibration +(at least) 1 day testing	**METHOD** ● **Participatory mapping of variables and causality** ● 2-3 hours (onsite or online) ● Groups of 6-8 participants ● 1 overall moderator and one moderator per table

Steps	Purpose / Ambition	Collaborative Systems Mapping of Sustainable Pathways	Adaptive Systemic Approach	CoOPLAge	Causal Loop Diagrams
Step 2- Diagnosis of current situation and problem framing	connected to the challenges identified and how Identify uncertainty factors (external, internal) that need to be considered for later action planning	**PROCESS:** • Participants work in groups developing a system mapping exercise • First, they identify the location and status of key physical variables and ongoing trends in the map of the pilot • Second, participants map the location of key infrastructures and socio-economic activities • Third, participants map the location key pressures • (Optional) participants collaborate in the development of a draft Casual Loop Diagram to establish connections between all variables • Lastly, participants draft a narrative describing main challenges, drivers and impacts	**PROCESS:** • Build a confident environment and record the immediate concerns (worries) that participants have with respect to the problem the project wants to address • Participants then start diving further into the problem context. First, by expressing their values i.e. aspects participants believe are important to the way they live and work (e.g. fairness, cooperation, etc.) • Participants also use the STEEP-H approach to diagnosis current concerns. This involves listing Social, Technological, Environmental Economic, and Political factors that help contextualise the current situation. The H applies to Historical factors, that are especially important in shaping current concerns, and may shape future realities. • After the exercise, participants work on using the PMERL	**PROCESS:** **SMAG:** • Participants will assess important decisions made in the past with significant impacts on the territory and related to the topic of interest, map who were the main actors, their causes and impacts, and use that as a basis to understand key factors influencing current governance regimes. **CREAWAG:** • Participants will identify the main issues of concern that want to be modelled • They will develop a conceptual model to map the main elements of the system and connect them (resources, actors, activities, space, etc.) that are connected to the selected issues of concern • Participants will work to develop a prototype of a game by specifying the roles of actors, as well as the natural and social processes that need to be accounted for; • Scientific team (possibly with stakeholders if time allow) will	**PROCESS:** • Participants work in groups • First, the facilitator can place a number of key variables of the system under investigation in a big board and facilitate the drawing of easy to understand causalities between variables (e.g. equivalent to the example in Figure 9) • Second, participants can start proposing new variables from the existing list or propose new ones if missing. An approach is to start with a goal (e.g. water security) and identify first the drivers enabling or preventing the achievement of the goal, and start selecting variables linked to impacts. • While placing the variables, it is important to draw the arrows, to establish causality. The question to establish the arrow and sign is ”an increase in variable A will lead to an increase/decrease in variable B?”

Steps	Purpose / Ambition	Collaborative Systems Mapping of Sustainable Pathways	Adaptive Systemic Approach	CoOPLAge	Causal Loop Diagrams
			framework to keep practising reflection and learning	calibrate the game by seeking for information to quantify activities, initial settings, scenarios, processes, etc • A testing session is organized to play the simulation game with participants to validate and refine the game and debrief.	• Once separated CLDs for specific goals (e.g. SDGs) have been developed, links can be established across different CLDs.
STEP 3: Visioning	Identify locally relevant goals to address identified challenges and put the pilot in the sustainability track	**METHOD** • **Cover Story** (ice-breaker to get familiar with what means developing a vision) • **CoSMoS-Participatory Systems Mapping** • ½ day workshop (onsite or online) • Groups of 6-8 participants • 1 overall moderator and one moderator per group **PROCESS:** • **Cover Story:** It is a creative method that enables participants to envision a sustainable future for their regions by designing the cover of a popular newspaper, journal, or magazine relevant to their context, imagining they are reflecting from a	**METHOD** • **Participatory hierarchy of objectives + PMERL framework** • ½ day workshop onsite • Groups of 6-8 participants • 1 overall moderator and one moderator per table. Again format may be different depending on the number of participants. **PROCESS:** • Building on the current context (STEEP-H), stakeholders are then encouraged to mentally 'jump into a desired future' and to collectively craft a vision for their desired future. This vision is a collective aspiration of the actors and stakeholders, reflecting want they would like to see and		

Steps	Purpose / Ambition	Collaborative Systems Mapping of Sustainable Pathways	Adaptive Systemic Approach	CoOPLAge	Causal Loop Diagrams
		future perspective (e.g., the year 2050). • Participants craft compelling headlines, images, and stories of success • **CoSMoS:** Participants work in groups envisioning how the mapped variables under the current situation are likely to evolve in the future (e.g., by 2050) under a BAU. Changes can be expressed by adding trends (increase, decrease) and adding new variables • Participants continue working on a sustainability vision. First, they identify the main goals underpinning the future sustainability vision. Different participants have different values, thus participants can split into groups and work on different visions. • Once goals are defined, a new system map is elaborated depicting the variables a sustainable future should include. • Supporting information is provided: future climate and socioeconomic scenarios	experience in their catchment in the long term. • The vision is a broad descriptive statement which includes goals along the different axis of the STEEP approach (social, technical, environmental, economic, political) • Each of these goals must be broken down into more detailed objectives using a hierarchy of objectives. This means that participants need to decide on what needs to be done first and in which way these goals will help meet other goals. • Indicators need to be defined to monitor progress towards meeting the proposed objectives • After the exercise, participants work on using the PMERL framework to keep practising reflection and learning		

Steps	Purpose / Ambition	Collaborative Systems Mapping of Sustainable Pathways	Adaptive Systemic Approach	CoOPLAge	Causal Loop Diagrams
		(external factors) and key development plans (internal factors) to address uncertainty ● Participants elaborate a narrative describing the main goals and underpinning elements the BAU and sustainability vision will include.			
STEP 4: Scenarios, Pathways and Action Planning	Co-development of pathways or strategies (combinations of options/solutions) that can support achieving the proposed vision and prioritization	**METHOD** ● Backcasting approach + Gradients of Agreement for Prioritization ● ½ day workshop (onsite or online) ● Groups of 6/8 participants ● 1 overall moderator and one moderator per table **PROCESS:** ● **CoSMoS:** Participants start by listing the main goals underpinning the vision and place them along a timeline (e.g., current up to 2050). ● Next, participants are requested to work on designing the pathways or strategies (combinations of grey, green, soft options) that are required to reach the proposed goals.	**METHOD** ● Objective hierarchy ● Prioritisation of objectives through agreed criteria ● May take up to ½ day of workshop with participants **PROCESS** ● Participants break the vision into a set of achievable objectives ● Each objective may have a set of smaller, objectives ● Objective are prioritised according to a set of criteria but must especially objectives that have positive externalities on other objectives are prioritised. ● Actions align to each objectives, including time	**METHOD** ● **Model-WAG:** ½ day workshop running different scenarios ● **CooPlan:** ½ day workshop running different scenarios **PROCESS:** ● Participants play the game designed with the CREAWAG process, assuming changing conditions (different scenarios). This helps anticipate the impacts of different strategies CooPlan: ● Participants define the objective of the action plan and brainstorm on a long list of actions required to address the issues of concern identified earlier ● Participants also list the resources, expected impacts	**METHOD** ● **Mapping actions along the CLD** ● 2-3 hours (onsite or online) ● Groups of 6/8 participants ● 1 overall moderator and one moderator per table **PROCESS:** ● Participants come in groups. Criteria is flexible e.g. each group works on a set of SDGs closely connected ● First, participants review the CLD developed in step 3 to get familiarized with what influences SDGs or sustainability goals (variables and causality) ● Second, participants start listing actions and placing them around the CLD to map

Steps	Purpose / Ambition	Collaborative Systems Mapping of Sustainable Pathways	Adaptive Systemic Approach	CoOPLAge	Causal Loop Diagrams
		• Participants check that proposed pathways/strategies are robust in the light of global scenarios (climate and socio-economic scenarios) • Resulting strategies are placed along the timeline • Participants present the proposed strategies and its implementation steps along a timeline • Participants are asked to prioritize the strategies according to different criteria. • Participants are also ask to map actors that need to support and/or directly responsible for its implementation	line for achieving each action and the responsible party(-ies) are identified. • Monitoring indicators are also agreed upon • The PMERL is used to keep practising reflection and learning	and implementation scale for the long list of actions • Participants also discuss the feasibility and coherency of the proposed list of actions • Validate the action plan and design an implementation strategy accordingly (i.e., whom, when, how).	and anticipate how actions could impact the system under investigation and whether they can create synergies and/or trade-offs. • Third, a discussion is facilitated to discuss what strategies will be needed to support the achievement of the goals (collection of actions aiming at creating change in different parts of the system and all together enabling the achievement of goals(s). • Through CLDs it is possible to discern "leverage points" i.e., actions which can trigger impact and cascading positive impacts on the entire system.
Step 5 Monitoring, Evaluation, & Learning		**METHOD:** • After Workshop Debriefing • Online Evaluation Surveys **PROCESS:** • Participants have the opportunity to debrief after each workshop on the main outcomes and the process itself. The main ambition is to	**METHOD** • **PMERL:** Participatory Monitoring, Evaluation, Reflection and Learning. **PROCESS:** • Participants define the relevant indicators and process (interviews, debriefings after participatory activities, etc)	**METHOD** • After Workshop debriefing • **ENCORE-MEPPP** participatory monitoring and evaluation of the participatory process and its outcomes **PROCESS:** • After each game session, a focused discussion is held to bring back from game to	

Steps	Purpose / Ambition	Collaborative Systems Mapping of Sustainable Pathways	Adaptive Systemic Approach	CoOPLAge	Causal Loop Diagrams
		promote social learning and support the refinement of the process • If this reflection can't take place during the workshop, it is possible as well to follow up through online surveys.	• Participants also agree on an implementation plan (i.e., who will take charge of what, when, and how) • Following every participatory activity, a session is dedicated to PMERL to identify lessons learned.	reality: jointly recognizing what is representative in the game, jointly identifying solution to stalemate, jointly elaborating on commitment for change • Participants define the objectives of the ME (e.g. process and outcomes) • Participants also define the relevant indicators and methods (interviews, debriefings after participatory activities) • Participants also agree on an implementation plan of M&E (i.e., who will take charge of what, when, and how)	

2.2 The toolkit

2.2.2 The Collaborative Systems Mapping of Sustainable Pathways-CoSMoS

Description: CoSMoS is an interactive system mapping tool intended to explore complex sustainability challenges and identify pathways to overcome those (Campos et al., 2023). It targets stakeholders concerned about the future of a region or an organization. Using CoSMoS allows them to develop strategic insights by building on selected representations of real-world structures and processes. By taking part in CoSMoS workshops, they can develop several alternative strategies, also called "pathways", that are robust sets of actions to a range of (external) scenarios (Notten 2006). This active and experiential process of co-creation helps them to develop systems thinking to understand both the key challenges on the way to their desired futures and sets of options required to overcome them.

CoSMoS builds on the scenario methodology through system mapping techniques. Scenarios are very useful to prepare ourselves for understanding better the implications of a wide range of future possibilities considering existing development plans, visions, strategies and global interdependencies. In a typical scenario-building process, scenario users jointly delineate their *internal sphere of influence* i.e., where they can effectively make decisions and develop policies, and an *external sphere of uncertainty* i.e., where they need to agree on most important but uncertain drivers, many of them global, which impinge on the decision-making space of national and sub-national actors. When integrating scenarios across sectors (e.g., water, food, and biodiversity) and scales (e.g., local, regional and/or global) such delineation of scenario space becomes far more complex due to overlapping spheres of influence and uncertainty.

Active engagement of stakeholders and knowledge exchange is therefore of critical importance to have a good understanding of the scales, sectors, and delimitation of spheres. Also, contributes to enriching the scenario development process by bringing different perspectives, values, and priorities, increasing their acceptability and legitimacy. The implementation of the CoSMoS is a 7-step process and is described next (Figure 3).

STEP 1: Defining system boundaries and problem framing. The very first step is to frame the system under investigation, the so-called "decision unit". This system can be a country, a city, a region or any geographical area. Once the physical boundaries are defined, another important step is the desktop review of available literature, to help the contextualization of the system. During this step, the team will carry out a stakeholder mapping. As explained by Varvasovszky and Brugha (2000) "stakeholders can be defined as actors who have an interest in the issue under consideration, who are affected by the issue, or who - because of their position - have or could have an active or passive influence on the decision-making and implementation processes". One of the commonly used methods in stakeholder analysis is the 'snowball technique', in which you start with identifying a few stakeholders at the beginning of the process and ask them to recognize new ones (either in terms of single individuals or entire categories of stakeholders). This method is usually supported by other methods and tools for stakeholder mapping. Lastly, during this step, the research team will define a number of research questions that can be informed by various types of consultations (e.g. scoping interviews, focus groups).

Figure 3 CoSMoS steps. Source: Campos et al (2023)

Step 2: "Understanding current situation" on the basis of the information collected in Step 1, the team will design a system mapping exercise. System mapping is a central part of CoSMoS and starts with characterizing the current situation of the system of focus of the workshop. This is done by representing the different important elements found in a region or city or by highlighting the current vulnerabilities found within a system. The system mapping approach uses a number of materials including a map with general information about the decision unit (administrative boundaries, main cities, rivers, land use types, etc.), and a set of cards that describe the main features (entities and processes). Entities include natural resources such as surface water, groundwater, forests, lakes, rivers, etc., along with socioeconomic activities, and main infrastructures (water, energy, transportation, agriculture, etc.). Processes can refer to ongoing trends, such as water scarcity, depopulation, energy demand, food insecurity, etc. In order to later describe how future scenarios can affect the decision unit, it is also important to define a number of indicators, that can describe inputs into the system as well as outputs (e.g. annual rainfall vs. surface runoff, wind potential versus carbon emissions, population versus jobs, etc.). These materials are provided to participants to collectively develop a mapping exercise to build a common understanding of the system in its current state. Such visual representation provides an opportunity for participants to have a broader and more systemic understanding of the system and facilitates deeper discussions of key issues among stakeholders within and across sectors and spatial scales. To represent changes over time and trends, additional elements can be included in the system mapping exercise, including attributes and trend tags. These increase the meaning and knowledge value of each card by adding information about its importance, general trend, state in the system, or location. Those tags come in the form of a small icon which can be added next to a card.

The card materials should be chosen to provide sufficient information without narrowing participants' scope of exploration and breadth of choices. Participants should mainly use the cards provided, but they can also use post-it notes to add information that they feel might be missing from the cards.

[Keep in mind] When dividing participants into smaller groups, it is important to consider their composition. Dividing participants into sectoral groups based on their expertise can be used to get specific information about a geographic or thematic area. On the other hand, using mixed groups will lead to a holistic view of the system, which can lead to further knowledge sharing. Both have advantages and drawbacks, but the decisions should be taken prior to the engagement with participants.

Step 3: Developing a "Business-as-usual" vision. Based on the assessment of the current situation made during the previous steps, participants develop a "business-as-usual (BAU)" vision of the future - i.e. how is the future of the system or decision unit looking in a given time from now if current trends continue, and what changes can we expect with respect to the current situation. The change is represented visually with markers such as "increase", "decrease", or by adding elements on the map. This step creates a baseline vision for the future that will happen unless action is taken to change the situation. "Business-as-usual" is an important step, as it invites stakeholders to be forward -looking and envision unwanted consequences linked to inaction. To support the development of the BAU vision, the participants are also offered supporting information such as global scenarios on climate and socioeconomic projects (external drivers). Likewise, they can also be supplied with information on ongoing and future development plans in the region with the potential to impact and transform the system (internal drivers).

Step 4: Developing a "Sustainable Future" vision. After developing a common understanding of the current situation with participants and having them create a "business-as-usual" future, it is time to start working on an alternative future vision and pathways (strategies or sets of actions) leading to them. Unlike the process of characterizing the current situation, which concerns the current state, existing policies, and directions of their system, the process of developing future pathways starts from a clear, simultaneously ambitious and realistic, vision of what can be achieved. Developing and mapping a shared future vision is an innovative process involving creative strategic thinking and decision-making. The future vision is developed on a new empty map, set to represent the region on a future date whose selection depends on the workshop's focus. It works in a similar way as the visioning exercise described in the previous steps, but this time participants are invited to interact directly on the map and place elements on their geographical location. The same cards as in the previous steps are to be used on a new map.

[Good to know]
This activity can be done as a plenary session or in breakout rooms depending on several factors:

- the size of the group. It is better not to have too many participants working on the same map. This will ensure that the process is a collaborative effort made through discussion and sharing of ideas.
- expected insights. If you want each vision to have a specific focus, assign participants to groups according to their specific expertise. This way, they can work in parallel on visions specific to the environment & water, economy and energy for example.
- sensitivity of the topic. If the topic is sensitive or controversial, it could lead participants to object or block proposals for the vision. Topics such as energy transition in some regions can be quite political and could lead to some sort of objections by certain participants.

If participants have worked in groups, it will be advisable that different visions are presented in a plenary, largely because different visions about a sustainable future might hold, since these will be largely driven by stakeholder values and their understanding on what sustainability means. Such discussion allows participants to develop a shared understanding of what others see as desired futures.

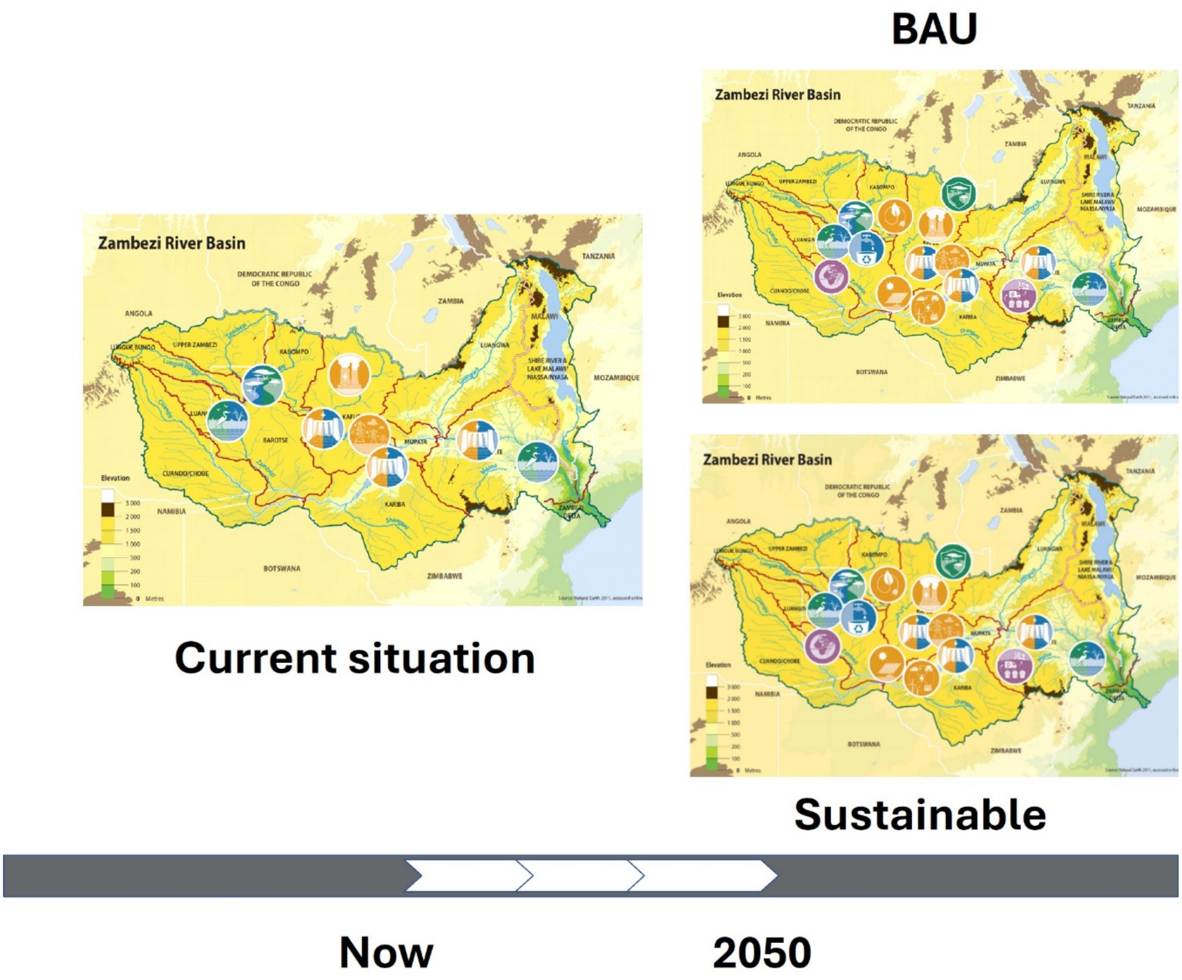

Figure 4 Developing future visions using CoSMoS tool. Source: Campos et al (2023)

Step 5: Developing pathways towards the future vision. After developing a future vision spatially on a map, pathways leading up to that future vision should be developed. In a collaborative effort, the many steps towards that future vision are discussed and placed on a timeline, which highlights the strategies, milestones, and decisions needed. Pathways can be developed in different ways and with different approaches, such as backcasting. Backcasting is a planning method that starts with defining a desirable future and then proceeding backwards from that future to the present in order to strategize and plan how it could be achieved (Vergragt and Quist 2011).

After sharing and discussing the different group visions that were developed leading to a shared common vision for the future, the main system elements (cards representing entities, processes, and indicators) should be arranged into a timeline to create pathways toward the shared future vision.

Participants first place major elements on a timeline template, indicating the desired time when each should be completed. From there, other, minor elements are laid out in between the major ones to map out the process of finalizing the vision. It should be remembered that this approach is about visioning, not forecasting. This is the start of a conversation about a future vision and the pathway should not be considered a hundred per cent accurate. It should be realistic without being limited by a lack of expert knowledge or uncertainty.

Step 6: Prioritization as the basis for action. After the timeline is filled, a prioritization of both the map and timeline elements should be done. This will highlight what participants feel are the key areas of action to focus on in order to reach the future vision and to take the discussion further.

The aim of the prioritization exercise is to highlight the most important elements that have been placed by the participants on the map and the timeline. It is achieved by way of voting. Each participant has a number of votes to use in the form of pre-prepared dots. You can decide on the number of votes per participant based on the number of attendees and the variety of elements to be voted on. Ask participants to vote on the most important elements on the map and the timeline. They should do it by placing the (voting) dots next to the cards located on the map and timeline. The next step is to enable attendees to rate their level of support for each priority on a scale. Gradients of Agreement is one of the methods that can be used for this purpose in order to move the discussion forward and reach the future vision. It is important to highlight that the aim of the tool is to stimulate the discussion and see where people are on the topic. It doesn't determine winners or losers.

Step 7: Debriefing. This is the time when we close the experiential learning cycle. Experiential learning requires us to experience a problem, reflect on its causes, brainstorm solutions and challenge them from different perspectives. CoSMoS leads participants from understanding their current situation to imagining desirable futures, and in the process, they construct sustainability pathways that include different solutions. The process helps them to navigate complexity, understand the diversity of underlying values, and attempt to define a shared ground for the future they all want. All these steps may require a look back and an additional round of reflection on the process itself.

Resources: This process requires at least a set of 1-2 in-person workshops (preferred) but there is a possibility of developing the exercise online (using boards such as Miro). The duration of each workshop is between 4-6 hours. In terms of materials, the team should develop the system mapping elements, including cards and maps. Graphical support is an advantage.

Relevant applications: This tool has been tested and further developed in the Integrated Solutions for Water, Energy, and Land project (ISWEL) and applied in the context of two large-scale transboundary basins: Indus and Zambezi.

Links and references to tool guidelines, publications and other resources:

- Campo, P., Willaarts, B., Magnuszewski, P., Giger, T.,Ksiazczak, A. M., Brychczynski, H.,& Kulakowska, M. (2023). *Collaborative Design of Pathways to Sustainability.* Centre for Systems Solutions and International Institute for Applied Systems Analysis. https://doi.org/10.5281/zenodo.8345513
- Wada et al., (2019). Co-designing Indus Water-Energy-Land Futures. One Earth 10.1016/j.oneear.2019.10.006.
- UNDRR (2022). Prospects and challenges of transdisciplinary research approaches for managing and communicating climate-related risks. United Nations Office for Disaster Risk Reduction

2.2.3 The Adaptive Systemic Approach

Description: The Adaptive Systemic Approach (ASA) is a participatory approach that is "future building" and intended for knowledge co-production between diverse and divergent stakeholders and researchers when dealing with complex sustainability challenges, and with a strong focus on supporting local benefit (Palmer et al., 2024). The ASA framework builds on three concepts:

1. Complexity and the need to build a systems thinking and promote transdisciplinarity and the integration of different types of knowledge (academia, practitioners, personal)
2. Explicit inclusion of epistemic justice i.e. promoting environments and habits of mutual respect and active breaching of knowledge barriers among different knowledge providers (e.g. academia, practitioners, practical)
3. Social learning as one of the main drivers of transformative change i.e., when individual participants show a clear change in understanding through the process (e.g. moving from "knowing about" to "knowing how to", and "knowing from experience") - and the change extends from participants into their social units.

The ASA framework was developed and tested in the African context in the framework of the project "Unlocking resilient benefits from African water resources" [3] led by Rhodes University, and motivated by the need to overcome persistent barriers that decrease the likelihood of research delivering outcomes to support a sustainable and justice transformative change, including: i) limited conceptual basis articulating the linkages between the three above-mentioned concepts to support the development of a methodology; ii) limited consideration of fairness aspects; iii) difficulties in funding a common language among the many different knowledge providers, iv) limited reflection on the process and resulting learning; and v) limited sustainability of project outcomes and learnings after the project ends.

From an operational perspective, ASA is a four-step process (Figure 5).

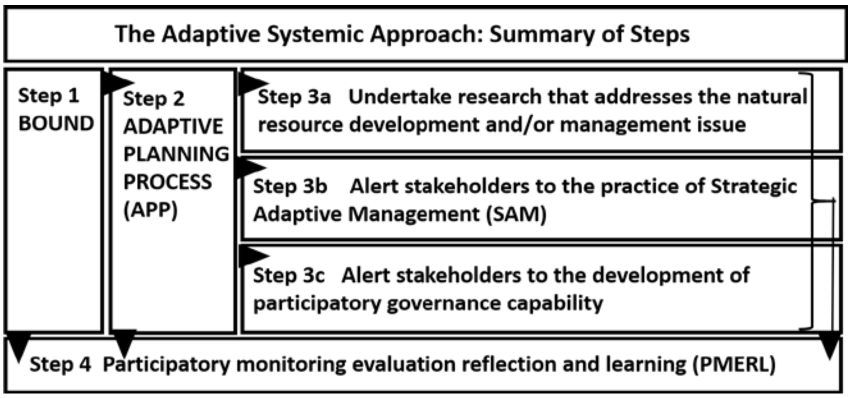

Figure 5 The four-step Adaptive Systemic Approach

[3] https://gtr.ukri.org/projects?ref=ES%2FT015330%2F1

Step 1. System Bounds. It involves identifying the boundaries i.e., biophysical and social dimensions of the research unit or system under investigation. This will include practical activities such as i) desk-top gathering of relevant data, ii) mapping stakeholders, and iii) developing a common understanding of the research questions to be addressed with stakeholders, as well as the existing governance system for natural resource protection and use, and the meaning and practice of Participatory Monitoring Evaluation Reflection and Learning (PMERL, see Step 4).

Step 2. Adaptive Planning Process. This step refers to the implementation of the Adaptive Planning Process (APP) component of Strategic Adaptive Management (SAM)[4] developed by Rogers and Luton (2011). APP is focused on the construction of a shared vision that is influenced by the values and context, and it provides accountability as it links the vision with specific objectives organized in a hierarchical manner, where high-order objectives capture intent and low-order detailed objectives link to "on-the-ground" interpretation of the desired condition. AAP is conducted as a facilitated, workshop-based activity with stakeholder participants, and is designed to be attentive to epistemic justice (Ralekhetla 2018). APP is implemented through at least one workshop, and the first activity is to build a confident environment and record the immediate concerns (worries) that each stakeholder has with regard to the problem the project is addressing. Stakeholders progress to share diverse perspectives on, and knowledge about, the problem context. The V-STEEP approach can be used to assist stakeholders while framing the context. This approach is meant to help stakeholders to map and discuss what are the main factors and characteristics of the system under investigation. The characteristics are (Palmer and Munnik, 2018):

- **Values** (also called 'principles') which are the beliefs that drive stakeholders when they are making choices and decisions. Examples of values are equity, transparency, etc. Values are held by individuals, by groups of people, by organizations, and even by society as a whole.
- **Social** characteristics, e.g. important relationships between people, organizations and the environment; age and gender distribution of the population; educational, recreational and health facilities, cultural sites, etc.
- **Technical** factors, e.g. pipes, pumps, dams, data bases, phones, computers, irrigation canals, water treatment plants, waste water treatment plants, infrastructure and maintenance
- **Economic** characteristics, e.g. size and distribution of income, size and distribution of the population; municipal finance management; ring-fencing of funds; procurement policies and implementation; the land-use patterns (farming, mining, recreation, industry, etc.); the number and prosperity of towns, cities, rural development areas; levels of employment; levels of industry ...
- **Environmental/Ecological** characteristics, e.g. rainfall patterns and frequency; groundwater; water availability and allocation; water quality, quantity and threats; people, birds, fish, insects, algae; etc
- **Political** factors, e.g. municipalities, district areas, international agreements, irrigation boards, river basin organizations, energy companies, farmers, etc.
- **Historical:** important historical factors that are particularly influential in shaping current lived realities, and may shape future realities. These factors are transversal and may include historical political systems, and structures, historical economic structures and systems. The relevance of history is to pay attention to the past, in the context of the current realities and

[4] SAM is a participatory approach that is "future building" oriented and used to achieve consensus and cooperation between diverse and divergent stakeholders when dealing with complex sustainability challenges. The assumption is that moving from the current state into a desired situation is not a linear process, and this is largely because many factors (value-driven) are affecting the trajectory towards the desired system. Further information can be found: Kingsford, R.T. and Biggs, H.C. (2012). Strategic adaptive management guidelines for effective conservation of freshwater ecosystems in and around protected areas of the world. IUCN WCPA Freshwater Taskforce, Australian Wetlands and Rivers Centre, Sydney.

how this may shape the future. Although history is not included in Palmer et al. (2023), the importance of explicitly reflecting on history has played out in our current case study and others (Odume et al 2022).

Building on the current context, stakeholders are then encouraged to mentally 'jump into a desired future' and to collectively craft a vision of their context with the project problem effectively addressed. This vision becomes the overarching goal of a hierarchical set of planning objectives. Stakeholders can break up into groups and develop their vision using the V-STEEP approach as a reference. On the basis of the vision developed, stakeholders will work to agree on a plan to achieve the vision i.e. sets of actions that need to be put in place.

Step 3. Concurrent Activities

*3a. Research – gathering appropriate data in the project context***.** By Step 3, research teams have engaged with stakeholders and their research context (Steps 1 and 2). Out of relationships built through Steps 1 and 2, researchers and stakeholders refine the research questions. It is likely that the specific research questions to be addressed require a range of knowledge, expertise, and different types of methods. This step will thus require researchers to reflect on both the data collected and the process for data collection as a research group and with the stakeholders.

Step 3b. Participatory governance development. The departure point here is the stakeholder mapping and governance analysis done as part of step 1 i.e. who (individuals and institutions) is involved and makes which decisions, about what, when, and with whom. This information will be used in this step to collaborative develop a governance map, using a range of methods that strengthen relationships among stakeholders. The relational focus of the ASA does not prevent conflict and contestation, rather it builds a foundation for negotiation and seeking consensus or at least a record of what stakeholders can all consent to. In many instances, and particularly in marginalized settings, stakeholders do not always have the skills and vocabulary to easily enter land and water governance spaces and institutions. The ASA provides occasions for those with formal governance responsibilities to meet and collaborate with those experiencing land and water issues. An example of how to achieve this in practice is provided by Palmer et al. (in press), who co-developed with stakeholders a participatory governance Capability Pathway. The Capability Pathway describes a set of skills, and the processes, that are required for local people to become more included and influential in the management of the landscapes where they live. The Capability Pathway focuses first on building equitable knowledge and vocabulary concerning the project. Learning the vocabulary of government officials, natural resource managers, a range of users, and different researchers takes time. If this "knowing" skills development is neglected, epistemic injustice is a likely consequence, because it is easier to exclude the knowledge of people who are less articulate. It is here that multi-lingual contexts may require effective translation and activities that are facilitated in a local language. The Capability Pathway focus moves to developing skills in both listening and speaking, with groups of people whose activities are conventionally separated (for example people in government and people who live in the catchment). These foundational steps facilitate institutional arrangements that allow for participation. The goal is for local people to become actively involved in planning and management decisions.

Step 3c. Strategic Adaptive Management (SAM). SAM is initiated by the APP Process in Step 2, where participants build an objectives hierarchy to reach the vision for the research project. Stakeholders can decide if they want the vision to describe aspirations for a future beyond the project. The objectives hierarchy is essentially "the plan" to achieve the vision. Step 3a supplies research results from different domains. Step 3b supports the understanding of the enabling environment. These inputs are used to i) support the knowledge co-production in the drafting of an action plan. Stakeholders who want to take SAM into their institutions are alerted to that possibility and can be supported to do so.

Step 4. Participatory Monitoring, Evaluation and Reflexive Learning (PMERL). Each Step in the ASA links to PMERL, which explicitly highlights participation, reflection and learning as functionally essential for monitoring and evaluation to become effective in delivering project outcomes (Cockburn et al. 2018). PMERL starts in the APP (Step 2) with stakeholders identifying indicators but becomes most real as active adaptation in how research results (Step 3a) can be used, with other stakeholder knowledge to progress towards the goals of the project (the vision co-derived in Step 2), including development of participatory governance (Step 3c), address the project natural resource management (Step 3c), particularly when local benefit is experienced. Researchers and stakeholders monitor the indicators; for example, the range of representation, expression of the power relations among stakeholders, and changes in bio-physical management. Regular stakeholder and research meetings enable reflection and learning from monitored results.

Resources: The implementation of the ASA framework requires 2-3 workshops other than desktop research (e.g. Step 1). The duration of each workshop is between 4-6 hours. In terms of materials, posters, post-its and markers are the only essential materials, and graphical materials are not required.

Relevant applications: The ASA framework was developed and tested in the context of the project RESBEN "Unlocking resilient benefits from African water resources" funded by the United Kingdom Research and Innovation (2020-2023). Further information can be found at ARUA Water Center of Excellence Hub.

Links and references to tool guidelines, publications and other resources:

- Kingsford, RT and Biggs, HC (2011). Adaptive management guidelines for effective conservation of freshwater ecosystems in and around protected areas of the world. IUCN WCPA Freshwater Taskforce, Australian Wetlands and Rivers Centre, Sydney.
- Kingsford, R.T. and Biggs, H.C. (2012). Strategic adaptive management guidelines for effective conservation of freshwater ecosystems in and around protected areas of the world. IUCN WCPA Freshwater Taskforce, Australian Wetlands and Rivers Centre, Sydney.
- Palmer, C., Tanner, J., Akanmu, J., Alamirew, T., Bamutaze, Y., Banadda, N., ... & Woldu, Z. (2024). The Adaptive Systemic Approach: Catalysing more just and sustainable outcomes from sustainability and natural resources development research. River Research and Applications, 40(9), 1732-1746.
- Palmer, C.G. and Munnik, V. (2018) "Practicing Adaptive IWRM. Integrated Water Resources Management (IWRM) in South Africa: Towards Practicing a New Paradigm"

2.2.4 Coupling innovative tools for sharing change in socio-environmental systems-CoOPLAGE

Description: CoOPLAGE is an integrated set of participatory methods, tools and protocols designed to support the effective transformation of socio-ecological systems using bottom-up approaches. CoOPLAGE offers a wide range of tools intended to support the different steps of a decision-making process (Figure 6).

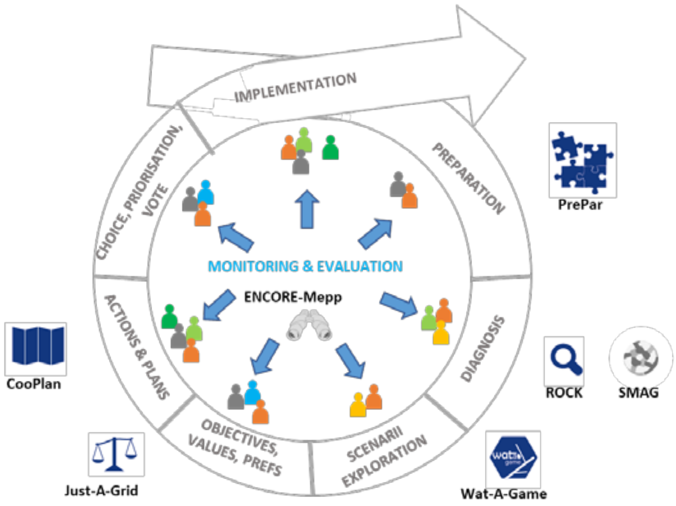

Figure 6 The CoOPLAGE toolkit

CoOPLAGE toolkit offers a wide range of tools and processes that can be used along the different steps of the SDG Pathfinding Framework, as described in Table 1.

Step 1: Preparation. This step is focused on defining jointly with participants the scope of the participatory exercise, plan and rules i.e., who will participate in which decision step, and how. By addressing openly the procedure and common rules early, it recouples participants with their own commitments, their roles and collaboration conditions. Open to all citizens it supports new forms of complementarity between representative and participatory democracy (e.g. Kohler-Koch, 2007; Trenz, 2009). A specific tool that can be used for this purpose is **PrePar** (preparing the participation). This tool allows participants to build jointly a participation protocol that will guide them later. It consists of four main steps: 1) list stakeholders to be involved, 2) Identify the main steps of the participatory process, 3) Specify stakeholders' participation and role for each step (lead, observe, facilitate, etc.), and 4) precise which participatory tools and methods will be mobilized for each step.

Step 2: Diagnosis. Governance is a key aspect to be addressed when dealing with the transformation of socio-ecological systems and the understanding of what are the barriers and enablers. Tools such as **SMAG** (Self-Modelling for Adaptive Governance) are designed to support participants to look into the past of management and governance as a way to enlighten the future. SMAG allow participants to assess the important decisions made in the past with significant impacts on the territory under investigation and related to the topic of interest, map who were the main actors, their causes and impacts, and use that as a basis to understand key factors influencing current governance regimes. Through SMAG, participants are able to build a transferable map of the history and infer key findings for current and future changes. Thereby it couples the past and the future. The use of SMAG entails fiver main steps: 1) Mapping major spatial changes that took place in a territory over the past 30 years; 2) Identifying the most significant governance decisions made in history affecting water and other natural resources (when relevant); 3) Map the dynamics which led to and were generated by these decisions; 4) tracking the decision process and identifying the roles of the stakeholders involved those, and 5) Analysing the governance process of the river basin by describing the model.

In the context of river basins, other relevant tools of the CoOPLAGE toolkit suitable to help citizens explore and understand their environment is **ROCK** (River observation and conservation kit). ROCK is a tool for participatory observation of water and rivers in a territory. It supports citizens in identifying the information they want to know and the relevant collection methods to get them on the field. It might be meaningful to associate it to collaborative walk along the river or across the catchment so that participants show artefacts they need information about. This tool was not used in the context of the SDG pathfinding project, but is nevertheless relevant to showcase the existence of other tools that focused on improving the understanding of the bio-physical environment. ROCK consists of 4 steps: 1) Get citizens to assess and discuss what they want or need to know about the river and its socio-ecological environment; 2) synthetize the proposals that came up from step 1 and organise the collection process (tools, logistics, protocols, etc); 3) go walking, observe nature, record, collect, etc, and 4) Share results and contribute to a joint diagnosis. This diagnosis is a prerequisite to the action plan phase.

A core feature of CoOPLAGE toolkit is the inclusion of participatory modelling approaches in the decision-making. This step is fundamental for coupling diverse issues: environment, society, governance, technologies, and current and future activities. CoOPLAGE has developed a number of modelling tools based on simulation games, broadly called WAT-a-GAME (WAG), but embracing different formats, including generic simulation games (**IniWAG**), or more advanced versions that include the development of context-specific models with stakeholders (**CREAWAG**).

- **Ini-WAG** is a simple abstract and quick game for the general audience, often used for initiation, dialogue and opening phase for future specialized modelling. It enables the participants to get familiar with the use of simulation gaming tools. It allows for the exploration of the general aspects of water usage and sharing. Over the rounds, the players will manage economic activities related to the river and discuss common rules for the management of their territory. Ini-WAG is played along 6 main steps: 1) Game settings: draw a river, place field plot, get money and pick activities; 2) Initialize 1st round: add activities to your field plot, pay your investment and discover water availability from the river this year; 3) Run 1st round: water flows and players pick and return water according to their activity, 4) Assess 1st round: water quantity and quality downstream; 5) Discuss potential changes & start 2nd round, and 6) After 5 or 6 rounds organize a general debriefing about the session. Ini-WAG toolkit involves a printed map, along with tokens, and a manual to inform participants on how to play the game.
- **CREAWAG** is a method that allows stakeholders to participate in the design of their own models. Likewise, the resulting model is later used for participatory simulations or role-playing games. This tool is developed in a 5 step process: 1) Framing: specify the main issue, the stakes and constraints; 2) Develop the conceptual mapping to identify and articulate the main components of the systems (resources, actors, activities, space, etc.) that are connected to the challenges and issues of concern identified in the earlier step; 3) on the basis of the conceptual mapping participants work to develop a prototype of the board game by specifying the roles of actors, as well as the natural and social processes that need to be accounted for; 4) the next step is the calibration, and requires seeking for information to quantify activities, initial settings, scenarios, processes, etc.; 5) lastly, a testing session is organized to play the simulation game with participants to validate and refine the game and debrief. CREAWAG game set involves a map of the system under investigation, along with tokens and other informative materials to support the gaming exercise, along with a manual for facilitating the exercise. This method might be used all participatory (ideally) or partially desk based. It can also be conducted in row or in fragmented steps, enabling considering time availability of participants, and delegating some technical actions such as calibration or data collection to a subset of participants (possibly the academics but not necessary)

Step 4. Scenario exploration. This step is closely related to step 3, in particular when using gaming tools such as those created with CREAWAG, as it allows participants to anticipate the implications of different scenarios. Use of simulation games is by design associated to a collective debriefing session right after the game simulation itself.

Step 5 Defining Objectives, Values and Preferences. Sharing resources requires coupling of various stakeholders' expectations, based on fundamental justice principles. By letting stakeholders express, share and recouple their justice principles before addressing the operational dilemmas, we help frame the "deep" social and policy orientations (Neal (Patrick), Lukasiewicz, & Syme, 2014; Venot & Clement, 2013). Understanding others' preferences and constraints is also a key factor for collaboration and for anticipating future blockages. **Just-A-Grid** is a simple adaptable protocol by which participants can formulate first individually then share collectively their distributive justice principles, and search for compromises. A debate is organized to share arguments. Later this farming can be referred to for assessing the final strategies. Controlled experiments have been used to assess the coupling with other participatory tools (Ferrand, Hassenforder, Abrami, & Daniell, 2014). Just-a-Grid implementation requires 5 steps: 1) Introduce the participants; 2) Allocate individually X resources (token) to pre-identified users; 3) Comment on the individual allocation; 4) Allocate collectively the same X resources (tokens with different colours) to pre-identified users; and 5) Identify and define the sharing principles applied during the common allocation.

Step 6-8 Action Planning, Prioritization, Choice and Implementation. Participatory planning is used to design a short, medium and long-term plan in a participatory manner, identifying the needs of each actor and proposing actions or measures to meet those needs. Measures or actions include technical, social or political options, which are listed, discussed and evaluated. Participants are encouraged to choose among them "strategic bricks or strategies" that can be used to build common action plans. These candidate strategies are assessed against a number of criteria, including coherency, feasibility and efficiency, and finally adapted and chosen. **CooPlan** is a protocol developed in 2004 that supports anyone in such a process using simple adaptable frameworks, but providing the capacity to recouple very diverse actions and visions, to get really integrated territorial strategies. CooPlan meta-models address needs, impacts and uncertainties. The implementation of CooPlan entails 7 steps: 1) Define the objective of the action plan; 2) Brainstorm on potential actions to reach that objective[5]; 3) Detail your actions by identifying needed resources, expected impacts and implementation scale; 4) Discuss and modify your detailed action in small group (market place); 5) Combine your actions in time and scale to build action plan, 6) Analyse your plan and discuss its feasibility and coherency, and 7) Validate your action plan and design an implementation plan accordingly.

Step 9. Monitoring and evaluation. Monitoring and evaluation (ME) is usually decoupled from the process' participants (externalization for neutrality)(Datta, 1999). We argue that for fair piloting and enlightened engagement of participants, it has to be recoupled, and taken as a reflexivity trigger, opening to adaptive management (Boyd et al., 2007). We especially focus on impact M&E to tackle the efficiency of the process (Williams, 2015). Meanwhile, most M&E are driven by an analytical disciplinary or political perspective. But processes are hybrid, complex and multi-dimensional. Hence M&E has also to recouple disciplines and change dimensions. CoOPLAGE includes ENCORE-MEPPP framework to support the continuous monitoring of evaluation of the process and outcomes along ENCORE- (External / Normative / Cognitive / Operational / Relational / Equity) dimensions in Monitoring and Evaluating Participatory Planning Processes. Each requires a different disciplinary perspective and the attached

[5] Calls for proposals may also be launched publicly outside a meeting. It will be a matter of allowing time for everyone to express themselves and organize the collection of these proposals.

tools. The entire procedural cost of such recoupled ME can be high, but it does provide a comprehensive assessment of what changes. It can be implemented either by external observers or led internally by the groups themselves (participatory ME).

Resources: The implementation of the CoOPLAGE tookit is foreseen to take place throughout various months when implemented in a full manner. The advantage of the toolkit is that tools and methods can also be applied separately. Approximately, the time required to run the different tools is the following: 1) PrePAR and ENCORE-ME, each up to 1-day workshop; 2) SMAG and CooPlan can take up to ½ day workshop, and 3) Just-a-Grid will require between 1-2 hours and Ini-WAG 3 up to hours. CREAWAG is the method that will take the longest time as it requires building the model and populating it with the corresponding data, for which significant engagements are required, and for a duration of up to 3 months (with heterogenous involvement of participants across the whole period).

Relevant applications: CoOPLAGE tools have been tested in many countries worldwide, ranging from Europe to Africa and South America. Likewise, it has been used to address a wide variety of socio-ecological problems (ecosystem preservation, irrigation management, poverty water allocation, water pollution, etc.) at a wide range of scales (municipality, city, basin, etc.).

Links and references to tool guidelines, publications and other resources:

- Wepgage for CoOPLAGE (in french): http://www.g-eau.fr/index.php/en/production/methods-and-tools/item/888-l-approche-cooplage
- CoOPLAGE tools and factsheets: https://sites.google.com/site/watagame2/cooplaage-tool
- Ferrand Nils, Abrami Géraldine, Hassenforder Emeline, Noury Benjamin, Ducrot Raphaèle, Farolfi Stefano, Garin Patrice, Bonte Bruno, Morardet Sylvie, L'Aot Delphine. 2017. Coupling for Coping, CoOPLAGE: an integrative strategy and toolbox fostering multi-level hydrosocial adaptation. In : Proceedings of the ACEWATER2 Scientific Workshop, Accra, Ghana, 31 oct - 3 nov 2016. Ronco P. (ed.), Crestaz E. (ed.), Carmona Moreno C. (ed.). Ispra : European Union, pp. 58-63. ISBN 978-92-79-71744-4 ACEWATER2 Scientific Workshop, Accra, Ghana, 31 October 2016/3 November 2016. https://op.europa.eu/en/publication-detail/-/publication/324b8fca-9f42-11e7-b92d-01aa75ed71a1
- Hassenforder, E., Ducrot, R., Ferrand, N., Barreteau, O., Daniell, K.A., Pittock, J. "Four methodological challenges in the monitoring and evaluation of environmental participatory processes: example from the Rwenzori Region, Uganda",*Journal of environmental management* 2016, 180, 504-516.

2.2.5 Causal Loop Diagrams

Description: CLD is a tool for mapping how elements of a situation relate to each other and for exploring non-linear relationships. At the broadest level, a systems diagram is "... a powerful means of communication because it distils the essence of a problem into a format that can be easily remembered, yet is rich in implications and insights" (Kim, 2000: 6). The eminent systems modeller, Donella Meadows (2011: 5), motivates for the use of systems diagrams and models by arguing that "...*words and sentences must, by necessity, come only one at a time in linear, logical order. Systems happen all at once. They are connected not just in one direction, but in many directions simultaneously. To discuss them properly, it is necessary somehow to use a language that shares some of the same properties as the phenomena under discussion.*" Likewise, Peter Senge notes, "... reality is made up of circles" but often arguments and explanations are linear, therefore, CLDs can provide "a language of interrelationships" to uncover deep patterns in systems" (cited in Baugh Littlejohns et al., 2021: 11).

Systems diagrams can be used for multiple purposes (Clifford-Holmes & Scholes, n.d.), including: 1) as a means of communicating systems complexity; 2) in order to co-create a shared view; and 3) as a way to conceptualise problems holistically.

These multiple purposes generally come together in the goal of tackling complex, seemingly intractable problems (sometimes framed as 'wicked problems'). Systems diagrams can also be boundary objects that help with finding common ground and clarifying between competing views (Black & Andersen, 2012). Systems diagrams achieve the broad objectives of communicating complexity, co-creating a shared view, and conceptualising problems by connecting diverse variables to one another in order to create systems pictures (sometimes called 'systems maps'). These pictures (or maps) are best developed by working iteratively, which creates better systems diagrams/maps that are more refined and appropriate for the problem and the problem context. Working iteratively is also the way in which high-leverage points in the system can be found. Given the interest that most stakeholders have in working on *improving* a situation, rather than just *understanding* it, these high leverage points are an important part of communicating complexity and systemicity as part of the broader objective of tackling wicked problems, which is also achieved by finding common ground and clarifying between competing views as means of co-creating a shared view.

Making mental models transparent, including exploring the assumptions underpinning these mental models, supports finding common ground and clarifying between competing views. In addition to making mental models transparent, systems diagrams can be used for conceptualising problems at different levels of granularity (i.e. detail) to have both a 'big picture' view and a detailed, operational view. This is sometimes referred to as 'seeing the forest and the trees', which both helps with conceptualising problems and communicating complexity. Maintaining perspective on both the big picture and the operational perspective is supported by using different systems diagramming techniques, which have varying diagrammatic conventions and come from different disciplinary traditions and fields but have the same broad goal of tackling 'wicked problems'.

From the CLD perspective, it aim to address the following questions:

- What are the key variables in the situation of interest?
- How do these variables link to one another?
- How do these variables affect each other?
- Does a variable have a reinforcing or balancing effect on the variables it is linked to?
- Where are possible intervention points (i.e. levers for change)?

The basic elements of CLDs are variables and arrows – which can be understood as factors and the links between these factors respectively (Maani & Cavana, 2007). Within the tradition of system dynamics modelling, CLDs are often used in the early stages of modelling to generate a 'dynamic hypothesis' (i.e. a causal explanation for how different variables influence one another).

As system diagrams, CLDs can be used both as analytical devices for modelling and reporting purposes and as tools to support "the co-construction of a common understanding" (Pollard, Biggs, & du Toit, 2008: 65). CLDs can therefore be used at both ends of engaged research: for purely analytical purposes and as part of stakeholder-engaged action research.

Summary of CLD conventions

The diagrammatic conventions used in CLDs are summarised in Figure 7, which includes simple line-drawing illustrations of each of the three variables, adapted from Clifford-Holmes et al. (2017). This simple population model shows three variables, with population at the centre of the diagram, which is causally impacted by births and deaths.

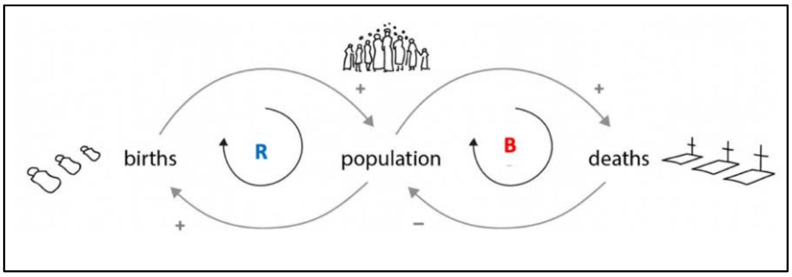

Figure 7 Example illustrates CLD, showing the diagrammatic conventions. Adapted from Clifford-Holmes et al., 2017, p.6-7

Births increase population (denoted by the positive ('+') polarity on the arrow); as the population increases, the number of childbearing women increases, which further drives the number of births, creating a reinforcing feedback effect (denoted by the R at the centre of the feedback arrow on the left-hand side). When the population increases, there is typically an increase in the number of deaths, which, in turn, decreases the population size (the negative relationship between 'births' and 'population' is shown in the diagram via the '–' polarity, i.e. the sign on the arrowhead). This effect is a balancing feedback loop, shown as 'B' in the feedback arrow on the right-hand side. Overall "+" and "-" signs between two variables represent causation (i.e. change in one variable causes a change in another variable) and not correlation (i.e. statistical association between variables, without necessarily implying causation).

CLDs can be used along several steps of a decision-making process including the SDG-pathfinding framework (Table 1).

Step 1: Preparation. In this step, the research team has to collect information about the system under investigation (i.e. main variables, preliminary causation between variables) and broadly a general understanding of the issues under investigation. Other than a desktop review, this step can also be complemented with a number of scoping interviews, where researchers will try to find more about the problems at stake, their level of importance, which are the critical variables related to the issues under investigation, and level of interlinkages among them. This preparatory stage can help a preliminary mapping of variables.

Step 2: Diagnosis of current situation and problem framing. During a workshop participants can be organized into groups to work towards the development of a CLD in a participatory manner, or even validate a preliminary version produced by the scientific team. This step is meant to support the development of the system boundaries and the exploration of the elements (variables) and causation (what influences what and in which way). This step is fundamental to developing the systems thinking perspective, and the resulting CLD will not only be useful to gain systems capacities but it can also be used to further inform the development of a model (e.g. Participatory Systems Dynamic Modelling).

Step 3-Action planning. Through the use of the CLD and the visualization of the different system elements and linkages, it is possible to facilitate the discussion of actions that can help to improve the problem at stake. Also, identify leverage points (i.e. actions that can trigger multiple benefits in the system, ranging from low-hanging fruits to deep transformational changes required).

Resources: This process requires at least 1 in-person workshop (preferred) but there is a possibility of developing the exercise online (using boards such as Miro and Zoom). The duration of each workshop is between 2-3 hours. In terms of materials, A0 or flipchart paper is required, along with markers and a list of the preliminary variables to be considered.

Relevant applications

Two South African projects, both funded by the Water Research Commission (WRC), applied systems thinking more generally, and systems diagramming more particularly, to water security challenges:

- Clifford-Holmes et al. (2017) is a handbook detailing how municipal government officials could be engaged using causal loop diagramming around the challenges facing water service delivery in rural municipalities.
- Pollard et al. (2008) provide an exploratory resilience analysis of the Sand River Catchment, using a social-ecological systems (SES) framework.

Links and references to tool guidelines, publications and other resources:

- Baugh Littlejohns, L., Hill, C., & Neudorf, C. (2021). Diverse Approaches to Creating and Using Causal Loop Diagrams in Public Health Research: Recommendations From a Scoping Review. Public Health Reviews, 42 (December), 1–13. https://doi.org/10.3389/phrs.2021.1604352
- Clifford-Holmes, J., Carnohan, S., Slinger, J., & Palmer, C. (2017). HOW TO... engage with the challenges facing Water and Sanitation Services (WSS) in small municipalities. Handbook No.5 (SP 120/18). Water Research Commission (WRC) project, K5/2248. WRC, Pretoria, Gezina.
- Hovmand, P. S., Rouwette, E. A. J. A., Andersen, D. F., Richardson, G. P., & Kraus, A. (2013). Scriptapedia 4.0.6 (Issue August). http://tools.systemdynamics.org/scrpda/scriptapedia_4.0.6.pdf
- Kim, D. (2000). Systems Thinking Tools: A User's Reference Guide. Pegasus Communications, Inc.
- Meadows, D. H. (2011). Thinking in Systems: A Primer (D. Wright (ed.)). Earthscan.
- Nguyen, N. C., & Bosch, O. J. H. (2013). A Systems Thinking Approach to identify Leverage Points for Sustainability: A Case Study in the Cat Ba Biosphere Reserve, Vietnam. Systems Research and Behavioral Science, 30, 104–115. https://doi.org/10.1002/sres
- Pollard, S., Biggs, H., & du Toit, D. (2008). Towards a Socio-Ecological Systems View of the Sand River Catchment, South Africa: An exploratory Resilience Analysis. Water Research Commission (WRC) Project No. K8/591. May 2008
- Williams, B. (2021). *Systems Diagrams: A practical guide*. https://gum.co/systemsdiagrams

3. Applications of the SDG Pathfinding Framework in Africa

3.1 The Swartkops catchment (South Africa)

3.1.1 Background

The SDG Pathfinding Framework in South Africa was implemented in the Swartkops catchment (Figure 8). The catchment is situated just north of Port Elizabeth in the Eastern Cape. The catchment is 120km long and 42km wide, with a total river length of about 155km and a total area of 1360km^2. The dominant topographical features in the catchment, are the Groot-Winterhoek, Elands and Zunga Mountains in the western part of the catchment, and the lower-lying Van Stadens Mountains in the southwest (DWAP, 1996). In the east, the mountain ranges are fringed by low-lying coastal plains, which are terraced around an extensive alluvial floodplain and the so-called "The Swartkops Estuary". The river system has two main tributaries, the KwaZunga and the Elands Rivers. The catchments of these two rivers form the major portion of the greater Swartkops Catchment. Both rivers have their source in the Groot Winterhoek Mountains and have numerous small tributaries that drain the steep valley side.

The KwaZungu River flows through a narrow, steep-sided valley, where development is unlikely and runoff potential is high, that is, the sub-catchment is and will in the future be less impacted than the lower catchment. The Elands River has a wide alluvial floodplain and has been extensively developed by farmers. As a result, much of the river has an ill-defined channel with disconnected rivulets and often only flows during, or immediately after, rainfall (DWAF, 1999).

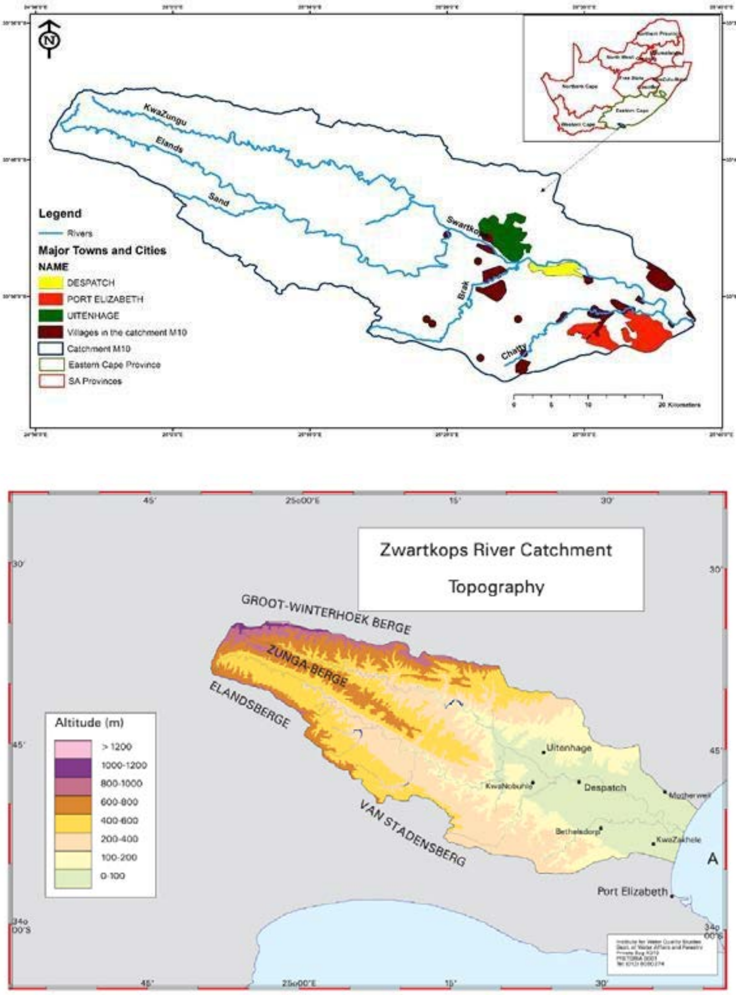

Figure 8 Location of the Swartkops catchment. Source: DWAP (1999)

The maximum rainfall occurs at the headwaters of the Swartkops River system and decreases towards the coast. The rainfall is not strongly seasonal, although the coastal area falls with a winter rainfall area and the upper regions have a spring maximum. Average annual rainfall varies between 1000mm in the upper regions to 500mm on the dry north-eastern area near the coast, while the annual average evaporation for the area is 1700mm with the highest evaporation rates occurring in the summer months (Ninham Shand, 1994).

The development within the Swartkops Catchment has been largely influenced by the topography and therefore largely concentrated in the floodplain and lower catchment. The majority of the population therefore occurs within the urban areas of Port Elizabeth, Despatch, KwaNobuhle and Uitenhage. The **headwaters** of the basin are protected and there is barely any agriculture or economic activity, which influences positively the quality and availability of water for downstream users.

In the **Upper section** below the headwaters of the basin, there are important settlements, but the most important trend is irrigation expansion, including horticulture products. This is on the one hand increasing water abstractions for irrigation, but at the same time, it represents a potential threat to water quality due to the use of fertilizers and pesticides.

In the **Middle section** the biggest challenges are related to the increasing water quality deterioration problem. This sections drains an important industrial town of Uitenhage and many informal settlements. Another important pressure is related to a growing population and the resulting increasing demand for water for drinking purposes. In fact, domestic water is the largest water demand in the basin and much of this demand concentrates in the lower section, as well as in the middle part.

In the **Lower section** and estuary – water quality continue to be an important driver of change due to mainly to upstream activities.

The catchment is experiencing a number of important sustainability challenges, with environmental, social and economic implications. Water scarcity is a major problem in the catchment, and is driven by both insufficient quantity and quality management, and this has been exacerbated in recent years by drought.

> ***Water quantity*.** The growing demand for drinking water has required to establish water transfers from nearby basins to satisfy basin demands. These demands are driven by the increase in population and growing industrial activities and irrigation. In terms of uses, the majority of domestic water users within the catchment are supplied by water supply schemes with most of the water sources outside of the catchment. The use of water directly from the Swartkops River and its tributaries only occurs on a very small scale by inhabitants in informal developments next to the river, while the use of borehole water in the upper catchment is on the rise, amplified by the recent drought.

> ***Water quality.*** There is also a serious water quality problem driven mainly by releases from wastewater treatment works , run-off from informal settlements, rail and road-networks. . The level of treatment is supposed to be secondary and, in some cases, tertiary, but in many instances wastewater treatments are not working properly due to the limited maintenance and power outages. Poor management of storm waters is also impacting the quality of the water in the river and its estuary.

Water challenges pose therefore important socio-economic but also environmental pressures within the catchment and downstream in the estuarine, including pollution and biodiversity loss. Such challenges overlap with other additional ones such as high levels of poverty and unemployment, rapid urbanization and development of informal settlements, crime, over-stretched public health services, and poor corporative governance within structures of government across jurisdictional and administrative scale. All of these local challenges are well aligned with relevant SDGs, including Goal 1 (no poverty), Goal 6 (clean water), Goal 11 (sustainable cities and communities), Goal 14 (life below water), Goal 15 (life above water), and Goal 17 (partnerships for sustainable development).

3.1.2 Application of the SDG Pathfinding Framework

The co-production process in the Swartkops is based on the main principles of TDR processes summarized in Box 1. It was designed to be **inclusive** in terms of the diversity of actors and types of knowledge, ranging from academia, local policymakers, NGOs, and grassroots movements, who brought their different expertise and values throughout the engagement process (Figure 9). The focus of the work was largely on developing **systems thinking** capacities since many of the challenges are known but solutions and actions are often discussed in isolation, preventing the development of an effective action plan. The process as per the request of the participants also had a strong focus on **action planning**, with a particular focus on water security as this is a high priority on the social and political agenda given the severe water crisis the catchment is facing due to the on-going drought. The process also supported the development of networks, which builds on on-going trusted relationships that has been developed over 10 years by the South African project team. Annex I provides further details on the stakeholder organizations participating in the co-production process.

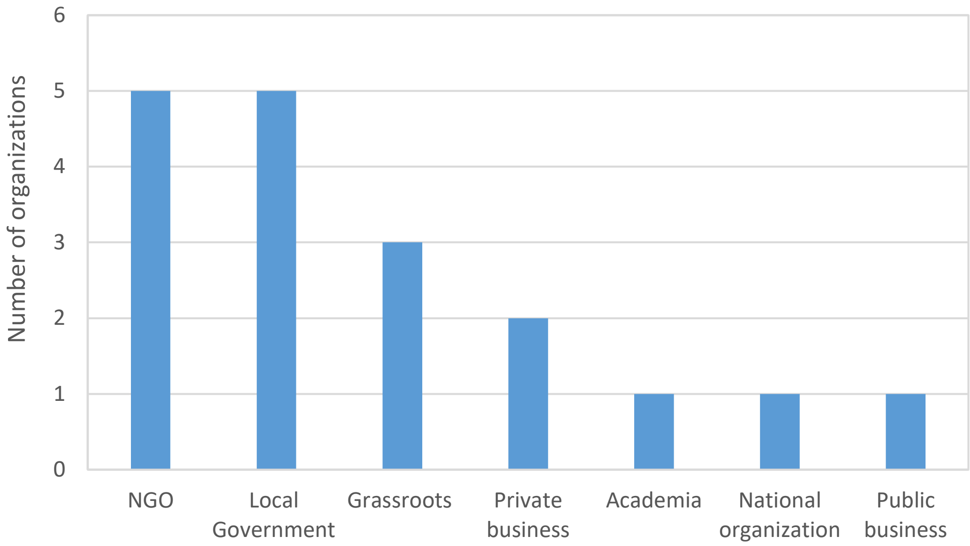

Figure 9 Groups of actors involved in the Swartkops process. Source: own elaboration

Next, a summary of the co-production process designed and implemented in Swartkops is provided using the SDG Pathfinding Framework.

Step 1	**Preparatory work**	
June - December 2021	Objectives	Carry out the stakeholder mapping, hiring the supporting staff, literature review and internal discussions with the consortium on the tools and process to be implemented (SDG Pathfinding Framework).
	Engagement format	Monthly meetings & online workshops with project consortium
	Tools	MIRO, ZOOM
	Outcomes/Outputs	• A general understanding of the participatory process steps, tools available and training needs within the consortium • Train-the-trainers in the use of SDG Pathfinding tools • Preliminary mapping of stakeholders to be invited to the process and definition of type of engagements (workshops, living lab sessions)
	Relevant reports	

This phase was mostly dedicated to exchange among consortium members on the different participatory tools and experiences in TD processes, and think broadly how the SDG Pathfinding Framework could be adapted to Swartkops bearing in mind the local conditions, team capacities and types of actors to be involved. Dedicated webinars were organized to train partners in the different tools. Likewise, the Rhodes team leading the co-production process in Swartkops carried out the stakeholder mapping and established the first contacts.

Photo: SDG-framework methodological Workshop

Step 2	**Diagnosis of current situation and problem framing**	
January2022	Objectives	Introduce the project: scope and goals Participatory identification of sustainability challenges and values Definition of the sustainability plan (format, frequency, purpose)
	Engagement format	1-day workshop
	Tools	ASA-APP, including STEEP-H: Collective identification of catchment sustainability challenges and value identification

	Outcomes/Outputs	• Stakeholder buy-in and endorsement of the project
		• Identification of the main sustainability challenges
		• Agreement on the stakeholder engagement plan
		  o Two type of in person engagements: 1) workshops involving the broader stakeholder group for knowledge exchange and co-production, and 2) Living Labs to design action plans
		  o Frequency: 3-4 workshops and living labs back-to-back
		• Shared values guiding the should be later reflected in the vision and guide the action planning.

	Relevant reports	Swartkops catchment workshop I

In this very first workshop, the Rhodes University team provided an introduction to the project and carried out some first exercises to identify stakeholders' perceptions about the main sustainability challenges using the ASA VSTEEP-H approach. Through this approach, stakeholders were organized into groups and requested to identify the main sustainability challenges along the STEEP-H dimensions (i.e. social, technological, economic, environmental, political and historical). Table 3 provides an overview of the main challenges identified by the different groups.

Photo: Working groups using the STEEP-H approach to discern key sustainability challenges

Acknowledging that different actors have different values and priorities, stakeholders also worked at the workshop to identify a number of shared values that should guide the co-production process in Swartkops (Table 2).

Table 2 Shared values agreed by participants that should guide the co-production process in Swartkops cathcment

Shared Values		
Accountability	Mutual respect	Communication
Teamwork	Adaptiveness	Dedication
Integrity	Innovation	Leadership

Table 3 Participatory mapping of sustainability challenges in Swartkops catchment using STEEP-H

Dimensions of STEEP-H	Key sustainability challenges
Social	Poverty
	Unemployment
	High levels of inequality
	High crime rate; safety and security concerns
	Infrastructure vandalism
	High rate of unwanted pregnancies, abortion, and disposal of foetus into Swartkops River/Estuary
	Growing human population
	Underserviced communities in terms of water and sanitation related services; poor sanitation-induced diseases
	Community release of solid wastes into River, impacting on spiritual use of water by the local tribes *Sangomas*
Technological	Maintenance of road networks
	Upgrade and maintenance of wastewater treatment works/technologies
	Upgrade and maintenance of urban storm water infrastructure
	Electronic waste management and the challenge of the electronic circular economy
	Old technologies being deployed in the agricultural sector and land management
Economic	Declining tourism potential of the Swartkops catchment due to pollution and reduction of the migratory bird population
	Declining property values in proximity of the Swartkops Estuary
	Industries support job creation, but are also major contributors to catchment pollution
Environmental	Climate change, drought, and flash floods in low-lying communities and in informal settlements
	Fear of the so called "Day Zero" in the catchment
	Water and air pollution emanating from various sources e.g., industries, informal settlements, road and rail networks
	Poor solid waste management e.g., plastics and electronic waste
	Discharges of occasionally poorly treated wastewater effluent from municipal wastewater treatment works into the Swartkops system
	Poor water quality from the Kat and Motherwell canals
	Invasive alien plants species in the catchment
	Biodiversity loss
Political	Governance failure - poor community participation, involvement and consultation in governance decision making
	Corruption and politics of exclusion
	Challenges with planning and implementation particularly of the Integrated Development Plan (IDP)
	Features heavily hierarchical and market-based governance, network governance not well entrenched
Historical	Legacies of historical apartheid spatial planning

Step 3	Visioning	
July - November 2022	Objectives	Map sustainability challenges over space and identify key variables affecting the challenges at stake. Develop a current and future vision Develop system thinking capacities Link locally identified sustainability challenges with relevant SDGs
	Engagement format	1-day workshop (July) 0.5 day Workshop (November)
	Tools	CoSMoS: Systems Mapping CLDs: Participatory Development of CLDs
	Outcomes/Outputs	• Customized CoSMoS tool (maps and cards) to facilitate sustainability discussions and co-production process in Swartkops catchment • Spatial representation of the current sustainability challenges across the catchment • Spatial representation of the sustainable vision for the catchment • Causal Loop Diagrams summarizing the interlinkages among sustainability challenges and associated variables. • Narrative summarizing the main sustainability challenges and its linkages to SDGs.
	Relevant reports	Swartkops catchment workshop II

The earlier step provided a preliminary overview of the Swartkops challenges through the lens of the STEEP-H dimensions. This information helped inform the design of the CoSMoS tool.

The purpose behind the use of the CoSMoS tool was twofold. One is to support the spatial representation of the main challenges identified and have a deeper understanding of what variables are connected to the issues at stake. Two, to develop a future vision for the catchment that can support the development of a sustainability action plan (pathways).

The customization of the CoSMoS tool to the Swartkops context involved the development of a map with key physical (rivers) and geographical features (cities, towns, key infrastructure) to allow stakeholders to locate themselves within the catchment. Also, the team developed a set of cards that are meant to represent the key variables that are linked to the challenges identified through the STEEP-H exercise. These cards represent three different types of variables: entities, processes, and indicators. Entities refer to distinctive elements with independent existence (e.g. water bodies, types of land use, infrastructures, cultural or spiritual sites, etc). Processes are a series of activities, motions or operations leading to some result (e.g., farming, water treatment, water pollution, land degradation, air pollution, etc.). Lastly, indicators are elements that can be used to monitor conditions or changes (runoff, precipitation, biodiversity index, energy efficiency, etc). Indicators are also suitable when trying to use this qualitative mapping exercise to support the development of quantitative scenarios, as it will allow monitoring e.g. improved or deteriorated conditions emerging from a given scenario and make comparisons. Annex II lists the cards that were selected by the team to describe entities, processes and indicators across the different STEEP-H dimensions.

To carry out the exercise, stakeholders were first placed into groups. Each group developed a systems map representing the current situation and in a second step the future vision. At the end of the exercise, eachgroup presented the main features in a plenary session.

Photo: Participants developing the Swartkops system mapping

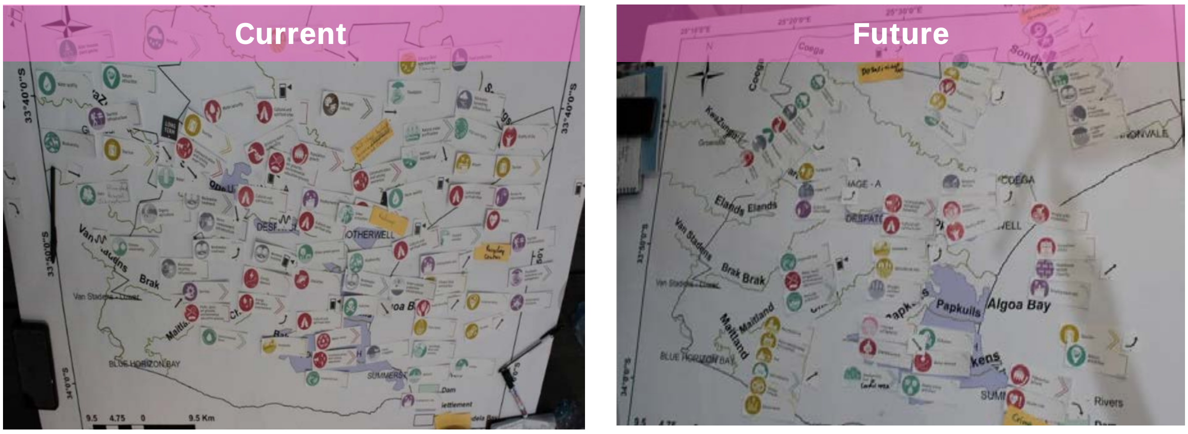

Photo: System Mapping Exercise current situation (left) and future vision (right) from one of the three groups.

<u>Summary of the system mapping exercise: current and future vision</u>

Social

Current condition: The most prevalent social challenges and concerns identified by participants were largely similar across the three participant groups. They include the increasing **unemployment** rate, leading to an increase in incidents of **vandalism and crime.** Also, there is **low awareness** and poor communication about **water** and the **environment**, largely due to often inequitable situation of public social spaces such as parks , arts centres and educational grounds that make them inaccessible to a large portion of the population especially those in historically under-serviced communities.. Furthermore, participants reported that there was an increase in **water and waste pollution** in the catchment. The pollution has led to a decrease in cultural sites in the catchment. Informal settlements are mushrooming in the catchment, including in ecologically sensitive areas such as floodplains and just a few meters from water courses. Yet a more critical challenge is that there is a growing increase in water demand, which over the past years, has escalated leading to a water crisis in the catchment.

Future Vision: The mapped vision for the Swartkops Catchment painted a healthier and sustainable catchment, as participants envisioned having a lower and declining unemployment rate, and associated decline of crime and vandalism. This envisaged future included having increased water security, and an increase in rainwater harvesting facilities. Rainwater harvesting and storage practices will be implemented to ensure water security in the catchment. Last but not least, the catchment will have more clinics that will provide timely and quality health services to residents.

Technology

Current condition: Technology plays a vital role in the sustainability of the catchment, especially to enhance water quality and storage. However, participants highlight there is overall a **shortage on infrastructure and technologies** related to wastewater treatment facilities, groundwater extraction, flood protection, water storage including reservoirs. This shortage of technologies impacts the quality and quantity of water and is responsible for the underservice of water in many communities within the Swartkops Catchment. Progressively, this is breeding a social-political challenges in the form of service- delivery demonstrations/protests.

Future Vision: The vison reported by participants is a catchment with sufficient and updated infrastructures to secure water services in sufficient quality and quantity.

Environment

Current condition: Stakeholders identified several key environmental concerns in the Swartkops Catchment such a **decrease in biodiversity**. One key indicator of this is the decrease of flamingo and other bird species in the Summerstrand area. This is also linked to the increase in habitat degradation within this area and the decrease in the environmental quality of Swartkops Rivers and estuary systems. Another environmental challenge is the **decrease in water levels** because of an increase in drought events within the area. The most critical environmental concern is a rampant increase in pollution including, biological and chemical **pollution**. This is caused by, among others, uncontrolled dumping and the mushrooming of informal settlements along water courses. Moreover, **ineffective communication** renders local residents unaware of appropriate strategies to prevent water pollution.

Future Vision: In light of these challenges, the vision of the catchment is a catchment with low levels of pollution, increased water levels through removal of alien plants from riparian zones, as well as increased number of green spaces and sanctuaries.

Economy

Current condition: The state of the economy directly affect the well-being, as well as sustainability of life in the catchment. The participants reported that the catchment was experiencing **awakening**

economy characterized by high food and energy prices, a **high unemployment rate**, as well as declining agricultural and tourism sectors.

Future Vision: Participants envisioned a future catchment with a healthy economy characterized by a buoyant tourism and agricultural sectors, high rates of employment, and proportionally lower prices of food and energy.

Politics and Governance

Current condition: limited public investments in the maintenance and **rehabilitation of public infrastructure** (water, roads, electricity, waste management, health care, among others). This limited investments are connected to budgetary issues but also politics, and are having multiple impacts on the social aspects (health, safety, service access and quality), but also economic (transportation, communications, limited attractiveness for important sectors such as tourism, unemployment).

Future Vision: Decision makers prioritize investments to support better infrastructures to secure access and adequate capacity to deliver services to its residents.

History

Current condition: The **legacies of apartheid spatial planning** remain a key historical concern within this catchment.

Future Vision: The vision was identified as a catchment with an increasingly thriving and improving Aloes Community[6] as well as an increased number of heritage and cultural sites.

Throughout the visioning exercise, variables describing the challenges across the STEEP-H dimensions were not just mapped but also it was possible to discern trends. A summary of the STEEP-H variables and trends is presented in Annex III.

The identification and mapping of the STEEP-H variables were further used to work collaboratively with stakeholders in the development of CLDs with two main objectives.

- Translate the locally defined sustainability challenges and variables obtained through the STEEP-H approach into SDG-relevant information.
- Build systems capacities to understand Swartkops catchment as a complex system and simulate how, in a real-life situation, decisions on one sector (increasing water storage capacity to secure water services) might impact negatively or otherwise, on other sectors (e.g. reducing flows downstream, impacting wetlands, and fisheries).

To support this exercise the scientific team worked with the results of the system mapping exercise and the STEEP-H variables identified carried out in July 2022 to produce a number of draft CLDs. In total, four drafts of CLDs were produced, linking the outcomes of the sustainability challenges and STEEP-H variables around four clusters of SDGs (Figure 12).

[6] The Aloes Community are led by a group of women (the so-called "*Gqeberha widows*") living in marginalized communities on the outskirts of Port Elizabeth, battling the devastating effects of having a toxic waste site set up on their land three decades ago, which led to the losing loved ones to the deadly scourges of tuberculosis and cancer. This community os also exposed to recurrent threats against their properties.

Figure 11 Clustering of the sustainability challenges mapped into SDGs

To complete and validate the four CLDs, a follow up workshop was organized in November 2022. At this workshop, participants were allocated into one of the four groups and requested to complete the draft CLDs.

<u>CLDs and SDG relevant narratives</u>

Water Security (SDG6)

The development of the CLD revealed that one of the core concerns is related to securing water availability, which is yet limited in both quantity and quality (see Figure 12). Infrastructural options that can help secure more resources include rainwater harvesting, increasing water storage and desalination. Participants cited two possible obstacles to efforts using the rainwater harvesting strategy. Firstly, it poses a health risk to households with asbestos roofs.. Secondly, excessive rainwater harvesting may disrupt some aspects of the hydrological system, especially groundwater and aquifer recharge. Regarding desalination, this option was also questioned by some participants as it will increase the energy demand and associated emissions. Moreover, from the 2017 Cape Town water crisis it was learned that it is also a very expensive solution. Additional non-grey infrastructural measures supporting higher water retention include floodplain restoration, and particularly in low-lying portion of the catchment . Such measures will also have a positive impact on increasing water quality. Promoting drainage infrastructure along with sanitation and wastewater treatment facilities, will have a positive effect on water quality and by extension on available water resources.

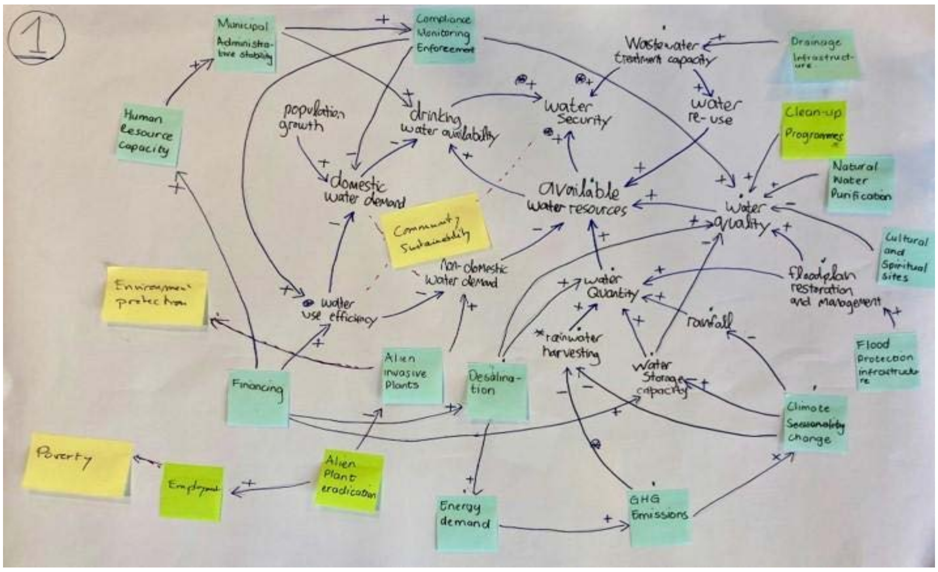

Figure 12 CLD describing water security challenges, drivers, and potential solutions

Demand management approaches are also seen as needed, especially increasing water use efficiency of both domestic and non-domestic water uses. Delivery of drinking water services is very inefficient due to the high water losses of the available network brought about by low investment in infrastructure. This is exacerbated by funnelling the available funds to the expansion of existing infrastructure to satisfy the demands of new users, while existing infrastructures are ill-maintained. Along these lines, the group discussed the need to strengthen reporting mechanisms so that residents can timeously report cases of water leakage to relevant municipal departments. Furthermore, the group explored strategies for capacitating the municipality's Water Division so that it can criminally charge people who cause leakages, vandalize water infrastructure and steal water.

Moreover, participants discussed the negative effects of invasive alien species such as black and white wattle that have colonized some riparian zones in the catchment. They recommended that the government needs to increase the budget to fund programs that clear alien invasive species such as the Working for Water program in which the NMBMM is an implementing agent.

Key to addressing the above-mentioned challenges is recognizing the existence of important drivers such as population growth, which will only increase water demands, especially for domestic use. In addition, the large number of informal settlements which are often unplanned, and hence sometimes established on or very close to riparian zones, is another very important driver of water pollution, and solutions here will require an integrated approach that goes beyond the water sector. Climate change was explicitly recognized as a major driver affecting rainfall and therefore water quantity.

These water-related challenges are closely connected to other socio-economic and key environmental challenges, particularly to poverty alleviation (SDG1), environmental conservation of the water bodies and the estuarine (SDG 14 and 15) and the development of sustainable communities (SDG11).

Poverty and Jobs (SDG1)

The discussion revolved around factors that make up the relationship between poverty and jobs, with the aim to craft strategies for increasing jobs as a means to eliminate poverty within the catchment (see Figure 13). One of the major factors that contribute to the configuration of the current job-poverty relationship is the legacy of the apartheid administration which was premised on racial segregation and the privileging system. In this administrative approach the people of the Nelson Mandela Bay Metropolitan Municipality (administrative unit embracing the Swartkops catchment), just as what happened elsewhere within South Africa, were grouped into races: black, coloured and white. Each racial group was allocated its residential area with its own services. The white race was the most privileged, followed by coloured and the black race was at the bottom end.

Participants said the apartheid segregation had multiple cascading effects that still significantly influence the nature of poverty and access to jobs, about three decades into democracy. The factors that influence poverty and access to jobs are education, availability of industries and employment or labour policy (see). All these factors were negatively affected by apartheid policies, and hence it is mainly blacks that are unemployed, while the whites are the most employed per capita. The majority of black communities continue to get poor education today, which in turn makes them not employable. In addition, because of racially skewed spatial planning inherited from apartheid, many black communities are situated far from employment opportunities such as industrial zones. All these factors contribute to the growing challenge of poverty in the metro.

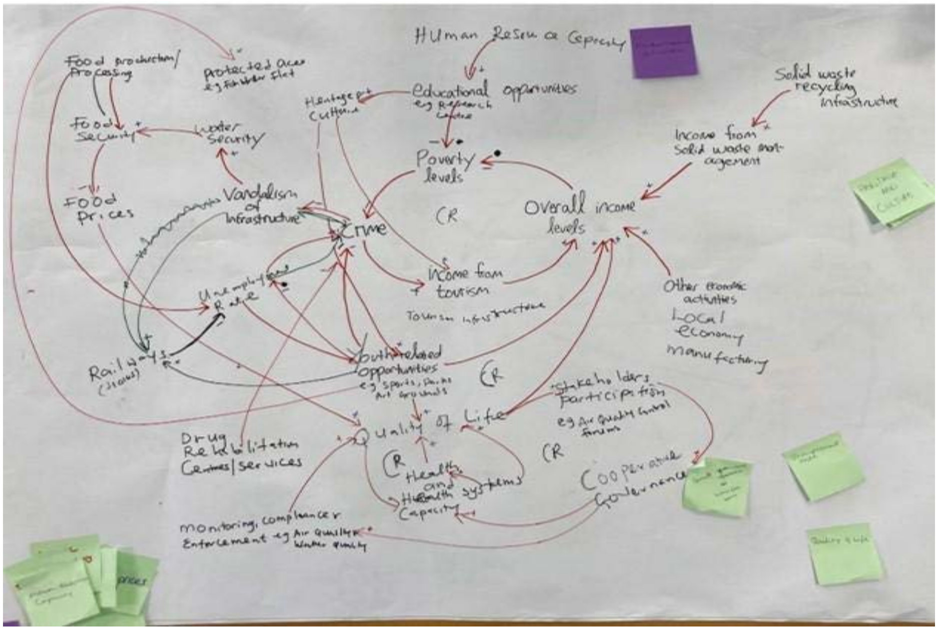

Figure 13 CLD describing poverty challenges, drivers, and potential solutions

Food and Sustainable Communities (SDG2 and SDG11)

Discussions on food and sustainable communities largely revolved around finding strategies to increase access to food within the catchment. Participants pointed out that agriculture with its allied components, including land, water and distribution form the central cog of food access and sustainable communities (). In pursuit of this argument, participants said that to increase food security, agricultural activities in the catchment must be expanded by, among others, promoting backyard gardening for the production of vegetables to support household consumption. To this end, the Department of Human Settlements must embed backyard gardening as an integral component of a residential plot when allocating land. In addition, the municipality needs to release agricultural land not only to large commercial farmers but to subsistence farmers as well. This land must be parcelled out on secure terms of land tenure.

Another critical factor of food security is water availability. Water of sufficient amounts and suitable quality must be available to farmers to practice irrigation. Growing challenges of water shortage and pollution constrain farmers' opportunities to grow agriculture and ultimately contribute to the achievement of food security in the catchment. Another major factor is the distribution of food from the point of production to the point of use, which is mainly the household unit. Participants argued that although food might be produced in big quantities by farmers at the catchment level, individuals and households can still be food insecure. The main cause of this irony is the lack of money by individuals and households to access the produced food. Shortage of money to buy food was explained by the growing high rate of unemployment especially in black low-income communities of the catchment.

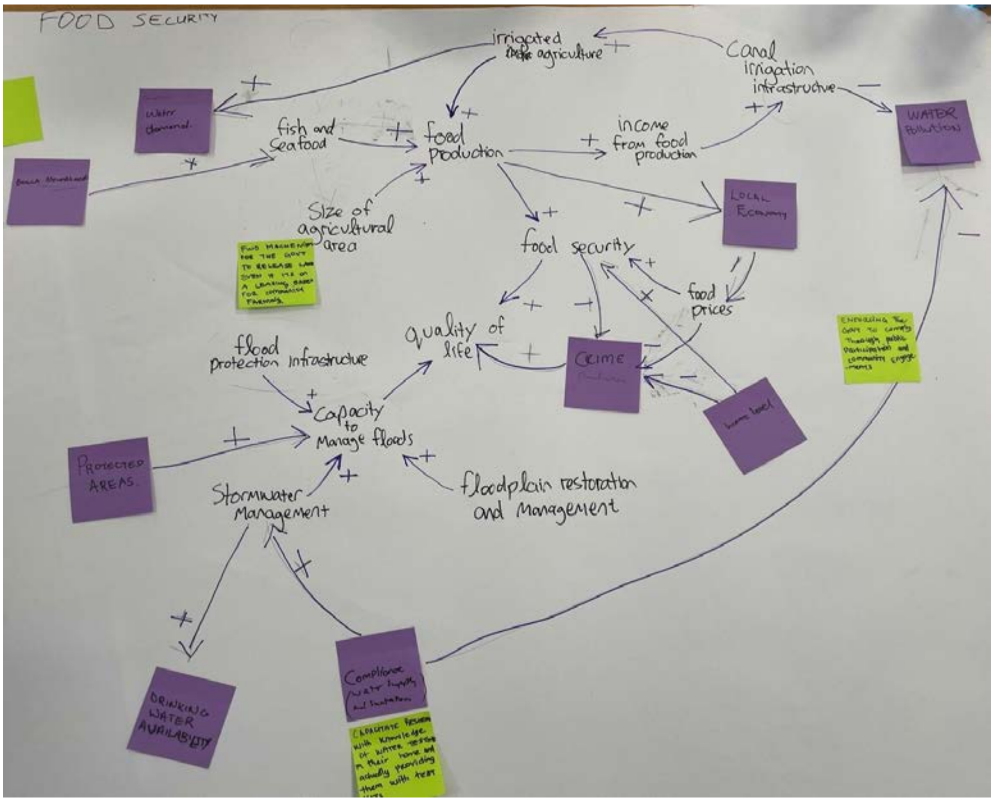

Figure 15 CLD describing food and sustainable communities challenges, drivers, and potential solutions

Protect, promote and restore ecosystems (SDG14 and SDG15)

Participants stated that well-functioning and healthy ecosystems are important for the well-being of residents of the catchment and their surrounding natural environment. They supply multiple services that communities in the catchment depend on. Such ecosystem services include provisional services such as fisheries and water (Figure 14). The participants noted that the increasing pollution of both fresh and marine water bodies is leading to the decreasing fish stocks from which the residents get food, and sometimes money through selling. Furthermore, pollution of water is progressively decreasing the amount of water available for human use including drinking, bathing and irrigation.

Participants also mentioned support services that the catchment gets from well-functioning ecosystems. Such services improve the quality of habitats, especially forests which in turn provide shelter to many faunal species such as birds and animals. The presence of these species attracts revenue through tourism and safari hunting. This in turn increases job opportunities and contributes to the alleviation of poverty within the catchment.

Because of the realized need to maintain well-functioning ecosystems, participants explored strategies for managing ecosystems. One such strategy is to increase the amount of protected areas, including game reserves, botanical gardens and parks. Another strategy is to strengthen the capacity of environmental non-governmental organizations

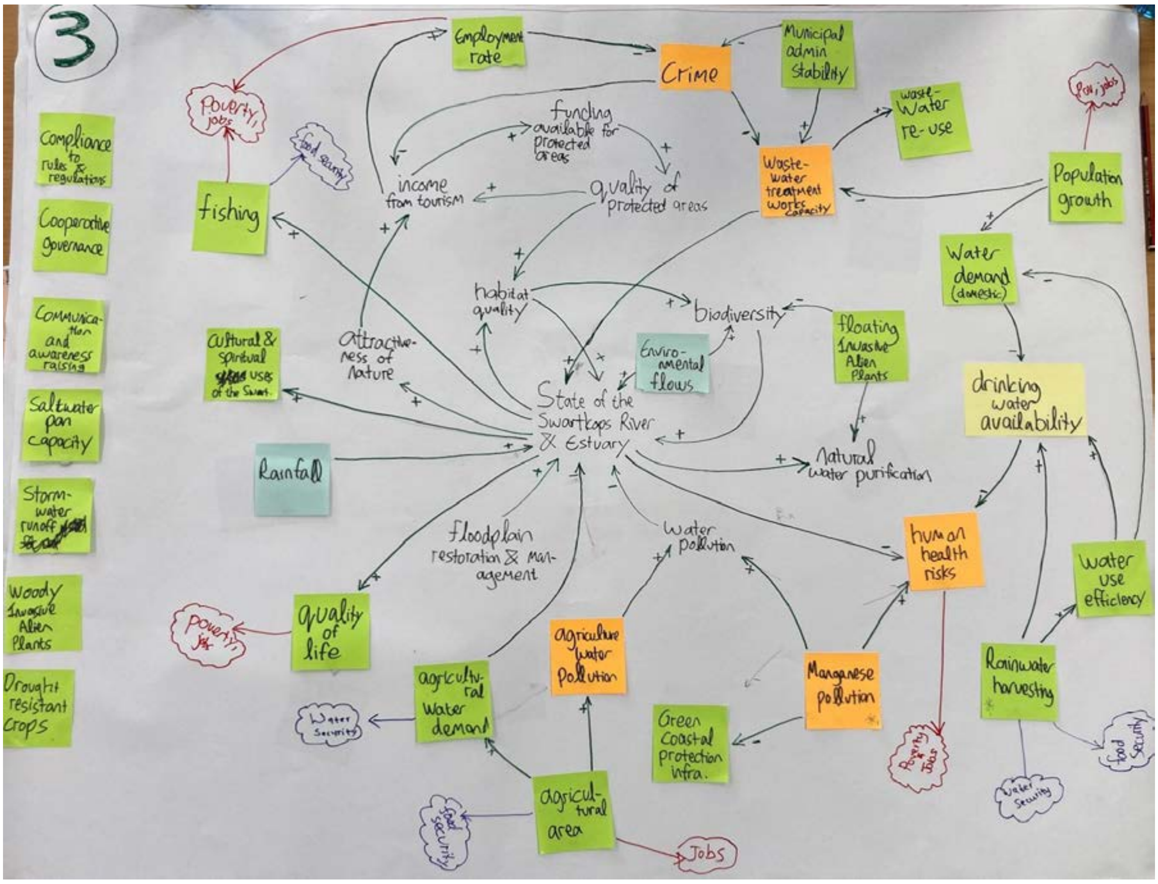

Figure 14 CLD describing ecosystem challenges, drivers, and potential solutions

Step 5	**Pathways and Action Planning**	
November 2022	Objectives	Identify pathways (sets of strategies) to achieve the desired vision and goals across the different SDGs. Develop an action planning Prioritization of measures
	Engagement format	½ Workshop 1 Living Lab Sessions
	Tools	CLDs CoSMoS prioritization of measures
	Outcomes/Outputs	• Action Planning to achieve the different SDGs goals • Empowered communities and willingness to lead community actions
	Relevant reports	Swartkops catchment workshop III

The action planning was carried out in a sequential manner and as part of the activities of the Living Lab. Such Labs include a subset of stakeholders participating in the workshops, and their mission is mostly focusing on trying to bring the knowledge gathered at the workshops into action, not only through the development of action plans, but also taking leade in carrying outn some of the proposed actions.

During the first Living Lab session (July 2022), it was agreed to prioritize the development of an action plan for water security, and a preliminary set of actions where discussed. However, the detailed identification of measures began after the CLDs were completed (November 2022), as such a tool was seen as very useful to support the identification of measures and explore their impacts throughout the CLD (positive and negative implications).

The second Living Lab session was therefore focused on continuing the drafting of the water security action plan and included a prioritization of actions according to two main criteria: Impact (size of the benefit such action can deliver) and Feasibility (capacity within the Living Lab team to take forward the action).

Given that water security embraces many subsectors (water supply and sanitation, water resources management, economic uses) and can require a comprehensive approach that includes both technical and governance measures, it was agreed to work on the development of an action plan structured across three main dimensions: water supply and sanitation, water resources management, and institutions and governance.

Photo: Results of the participatory identification and prioritization of water security actions

Table 3 summarizes the results of the water security action planning in the Swartkops catchment. For the prioritisation we used a simplified multi-criteria analysis. Participants from each of the three groups ranked each measure against the two criteria, with a minimum score 0 and a maximum of 5. The total ranking points given to each participant were limited to force prioritisation.

Table 3 Water Security Action Plan for Swartkops catchment. Note: Green dots (high), orange (medium) and red (low)

Water Security			
Dimension	**Actions**	**Feasibility**	**Impact**
Drinking water supply and wastewater related services	Wastewater-Work with the DEA and the municipal wastewater division to assist with putting the sludge management protocol in place	2.25 🟠	2.75 🟢
	Wastewater- DWS, DEA, DoH to strengthen their compliance and enforcement power	2.25 🟠	2.75 🟢
	Stormwater management- Improve and correct the litter traps in the Motherwell storm water canal system	3.75 🟢	2.5 🟢
	Eco-rangers/ Reporting of illegal dumping	3 🟢	2.5 🟢
Water Resources Management	Encourage industries to invest part of their corporate social responsibility budget on community rainwater harvesting	2.6 🟢	2.6 🟢
	Liaise with Department of Water and Sanitation (DWS) and Department of Agriculture, Land Reform and Rural Development (DALRRD) on activation of the policy of supplying water tanks (locally called *jojo* tanks) to communities for food and water security	1.5 🔴	3.8 🟢
	Awareness campaign on ways in which communities can diversify their water sources and reduce consumption	4.0 🟢	2.3 🟠
	Establish a citizen science network for testing water quality in the catchment; mini stream assessment scoring system (miniSASS) training	4.2 🟢	2.8 🟢
	Collaborate with DWS to fast track the development and roll out of the pollution incidence reporting system for the catchment	3.3 🟢	2.0 🟠
	Rainwater Harvesting	2.2 🟠	4.2 🟢
Governance and Institutions	Sustain and strengthening of Living Lab	4.3 🟢	3.9 🟢
	Living Labs collaborate with DWS as primary source of information dissemination about the Tsitsikamma Mvumbu Catchment Management Agency	3.6 🟢	3 🟢
	Joint investing between government agencies to ensure compliance (inter-government relationships IRG)	2.4 🟠	3.4 🟢

The results of the prioritization showed that for improving water supply and sanitation services surveillance and monitoring seem to be not just impactful but also most feasible actions that can be taken forward by the living lab members. Participants of the living lab argued that engagement of local water authorities is paramount to take forward some of the most critical actions, but due to a diversity of reasons, including high turnover and limited human capacities, they see the feasibility of the two additional proposed measures as medium to low.

To improve the management of water resources in quantity and quality, citizen and private sector-led actions are seen as most feasible apart from being impactful. Awareness-raising is seen as an important and highly feasible action but its impact might be limited in the short term in preventing important pressures such as waste disposal, which ultimately is responsible for much of the pollution in the stormwater canals. Development of rainwater harvesting and installation of water tanks are regarded as highly impactful measures to increase available resources for household needs, but their feasibility is questioned since participants feel that water departments will not engage due to financial constraints.

Photo: Motherwell storm water canal

Governance, or the lack thereof, is seen as a key challenge in the catchment. Actions to address the limited capacities of actual water authorities include self-organization and cooperation, supporting the living lab beyond the project lifetime, and stronger citizen cooperation of the living lab members with local governments to support the dissemination of local and scientific data.

3.1.3 Next steps

Throughout the project an enabling environment for implementation in the form of a Living Lab was created. Certain actions were identified as implementable by members of the Living Lab. For example, sustaining the Living Lab, meant that the project team and members of the Living Lab had to work to secure other funding sources to keep the Living Lab going. Also the correction of the Litter trap which had been taken up by an NGO within the Living Lab as well as DWS which has begun further strengthening of its water quality compliance and enforcement monitoring within the catchment. All these had been possible through the Living Lab, as an enabling environment that brings together diverse actors from different sector of society.

3.2 The Fimela district (Senegal)

3.2.1 Background

Geographical Context. Fimela is located in the northern part of the Sine Saloum region, in Senegal (Figure 10). It is located in a delta where the Sine and Saloum rivers flow into the Atlantic Ocean. Its western part is a flat savannah, while the eastern area comprises mangroves, islands, and saltwater channels influenced by tides. Covering 1,115 km², Fimela lies about 2.5 hours from Dakar, accessible by relatively good road infrastructure.

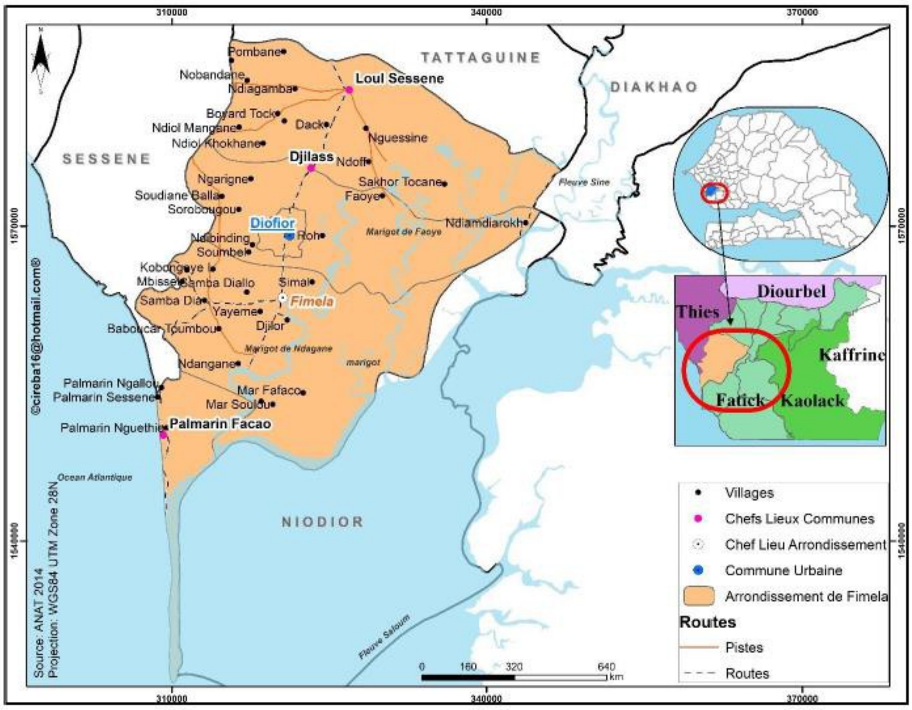

Figure 10 Fimela district, Senegal

Climate. Fimela experiences a Sudanian climate, with a dry season (November–June) and a rainy season (June–October). Rainfall varies significantly, averaging 717.9 mm over 42 days annually between 2006 and 2015. Seasonal changes transform its landscape from dry and barren to lush and green but often lead to severe flooding.

Administration. The district is administratively managed by a sub-prefecture in Fimela and consists of five municipalities: Diofior, Djilasse, Fimela, Loul Sessene, and Palmarin. These municipalities include numerous villages, except Diofior, which has a single village due to its earlier administrative emancipation. A recently formed intercommunal organization, ICSO (Intercommunalité du Sine Occidental), aims to foster regional collaboration but is still in its nascent stages.

Socio-Economic. The district's economy revolves around subsistence agriculture, dominated by millet, sorghum, peanuts, and rice during the rainy season, along with growing mango and other fruit production. Fishing, both inland and maritime, plays a significant role, particularly around Palmarin's fishing port. Livestock farming, especially cattle, goats, and sheep, is prominent during the dry season. Tourism is growing due to Fimela's proximity to the Saloum Delta National Park, renowned for its avian biodiversity and scenic beauty, and its relative accessibility from Dakar.

Environmental Challenges. Fimela faces several environmental issues:

- **Coastal Erosion:** Particularly severe in Palmarin, alongside rising water levels.
- **Deforestation:** Driven by soil salinization and human activity.
- **Mangrove Degradation:** Caused by salinity increases and anthropogenic pressures.
- **Soil Salinization:** Exacerbated by mangrove loss, rising water levels, and deforestation.

Major events include the 1987 rupture of the Sangomar barrier, which accelerated salt intrusion, and the Sahelian droughts of the 1970s and 1980s, which significantly impacted freshwater availability and mangrove health.

Cultural and politics. Fimela is in the Sérère heartland, with a blend of Catholic and Muslim communities. Sérère traditions coexist alongside Islamic and Christian practices. The district holds historical importance as the birthplace of Senegal's first president, Léopold Senghor, and is closely associated with the fomer country's leadership, given its proximity to Fatick, the hometown of fomer President Macky Sall.

3.2.2 Application of the SDG Pathfinding Framework

The co-production process in Fimela is based on the main principles of TDR processes summarized in Box 1. It was designed to be **inclusive** in terms of the diversity of actors and types of knowledge, ranging from NGOs and grassroots movements, to local and national government organizations, academia and business, who brought their different expertise and values throughout the engagement process (Figure 11). As in the Swartkops catchment, a strong focus of the participatory process was oriented towards developing **systems thinking** capacities since many of the socio-economic and environmental challenges are closely intertwined, and issues are often discussed in isolation and without bringing the different actors together. As opposed to Swartkops, the efforts of the GAIA team and leader of the design and implementation of project activities in Fimela were very much focused on developing tools and capacities for **problem framing, visioning and exploration of different scenarios,** and with a strong focus on addressing the issue of soils salinization, which is multi-driver and has cascading impacts on the environment and community livelihoods. GAIA is an NGO itself working in the region for many years, and that facilitated the engagement and trust on projects partners from the onset. Annex I provides further details on the stakeholder organizations participating in the co-production process.

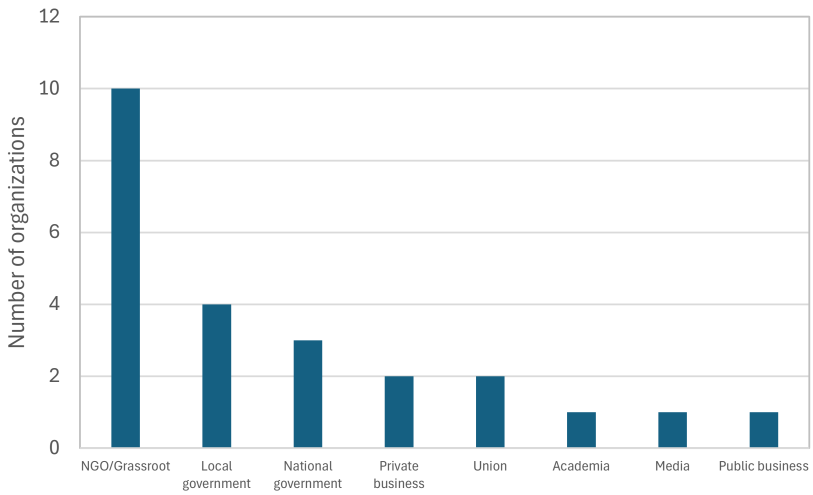

Figure 11 Groups of actors involved in the Fimela process. Source: own elaboration

Step 1	Preparatory work and warming up	
June - December 2021	Objectives	Carry out the stakeholder mapping, hiring the supporting staff, literature review and internal discussions with the consortium on the tools and process to be implemented (SDG Pathfinding Framework).
	Engagement format	Monthly meetings & online workshops with project consortium
	Tools	MIRO, ZOOM
	Outcomes/Outputs	• A general understanding of the participatory process steps, tools available and training needs within the consortium • Train-the-trainers in the use of SDG Pathfinding tools and • Preliminary mapping of stakeholders to be invited to the process and definition of type of engagements (workshops, living lab sessions)
	Relevant reports	

Equivalent to the process in Swartkops, this phase was dedicated to exchange with the project team and get some understanding on the tools we could use and reflection on their use for different purposes and contexts. Dedicated webinars were organized to train partners in the different tools (e.g., with the use of CoSMoS) but likewise a Master Student from INRAE spent 3 months (between March and June 2022) collecting information to co-design some of the tools and providing hands-on sessions for tools like Prepar and IniWAG. During this phase, GAIA team also did the stakeholder mapping and organized the first stakeholder workshop (December 2021) to introduce the project and establish the Living Lab framework, including the establishment of its foundational structure, roles, and objectives.

Step 2	Diagnosis of current situation and problem exploration	
December-March 2022	Objectives	Introduce the project: scope and goals Participatory identification of sustainability challenges and values Definition of the Living Lab plan (purpose, structure, organization, frequency,)
	Engagement format	1-day workshop (December 2021) 1-day Living Lab Session (March 2022) Half-day session for SMAG testing (March-June 2022)
	Tools	Prepar, SMAG (Self-Modelling for Assessive Governance), INIWAG and CoSMoS

	Outcomes/Outputs	• Stakeholder buy-in and endorsement of the project
		• Identification of the main sustainability challenges, drivers, consequences, and linkages to SDGs
		• Stakeholder engagement plan
		  o Two type of in person engagements: 1) workshops involving the broader stakeholder group for communication and broader knowledge exchange, and 2) Living Labs for experimental learning
		  o Frequency: Living Labs session organized every 2-3 months

	Relevant reports	Fimela Stakeholder Workshop I Fimela Living Lab Session I

The large majority of the efforts in Fimela case study were focused on this phase. It was considered crucial to dive further into a collective understanding of what are the key sustainability challenges, what drives them, causes, and consequences. Therefore, several tools have been tested and adapted during this phase. Broadly, the first workshop (held on December 2021, in Ndangane, Fimela District), , served as an informational and launch event to initiate the project's activities. Organized by GAIA in collaboration with Rhodes University, IIASA, and INRAE**,** the workshop's main purpose was to inform stakeholders about the project, align local priorities with the SDG framework, and create a foundation for the Living Lab.

Relevant activities taking place during this workshop included other than a general introduction to the project, some insights about the current implementation of the 2030 Agenda, explicitly main challenges in Senegal and importance to overcome them. This broad overview, was complemented with a system mapping exercise, where participants using a modified version of **CoSMoS**, collective map the main challenges they identified in the Fimela district (see Box 2). These activities together helped prioritizing the main SDGs the group collective wanted to work further. Priority SDGs linked to local sustainability challenges, including climate action (SDG 13), clean water and sanitation (SDG 6), and life on land (SDG 15).


Photos: Territorial mapping of challenges (left) and prioritization of sustainability challenges (right)

Box 2 Sustainability Challenges identified by stakeholders in Fimela District and its linkage to relevant SDGs

One of the foremost concerns is ongoing **water scarcity and quality** (linked to SDG 6 on Clean Water and Sanitation). Participants noted limited access to clean water for drinking and agriculture, exacerbated by salinization of both water sources and soil. This **soil salinization**, was identified as a major challenge tied to SDG 15 (Life on Land), has significantly reduced agricultural productivity, threatening local food security and livelihoods. Drivers are both natural and human-induced, and linked to the intrusion of saltwater from the ocean into groundwater and surface water bodies, ongoing unsustainable irrigation practices, and deforestation.

Waste management was another pressing issue (SDG 11: Sustainable Cities and Communities). Inadequate systems for waste collection and disposal have led to environmental degradation and health concerns. This challenge, compounded by growing urbanization, requires immediate action to improve infrastructure and community practices.

Stakeholders also expressed deep concerns about **climate change impacts**, directly related to SDG 13 (Climate Action). Erratic rainfall, rising temperatures, and other climate-related disruptions are increasingly threatening agricultural activities, water availability, and ecosystem resilience. These issues are intertwined with the ongoing **loss of biodiversity** (SDG 15: Life on Land), as unsustainable resource use and habitat destruction continue to degrade the region's rich natural environment.

Finally, stakeholders highlighted weaknesses in **governance and resource management**, noting the lack of coordinated efforts among local actors to manage shared resources and address these challenges collectively. Strengthening governance frameworks was recognized as crucial for implementing sustainable solutions and achieving the SDG agenda.

Another important outcome of this first workshop was the establishment of the guiding principles of the Living Lab. In the context of Fimela, the Living Lab is understood as a space for systemic reflection and experimentation, empowering local actors to take ownership of the SDG localization process while ensuring inclusivity and adaptability. During this meeting, GAIA along with participants also drafted the Living Lab charter, outlining the roles, responsibilities, and decision-making processes. In fact, the Living Lab charter was signed by the sub-prefect (local government official) to secure its legal recognition.

The first Living Lab session was devoted to draft the stakeholder engagement plan, as well as validating and exploring further the sustainability challenges identified during Workshop I, and with a strong focus on understanding the governance dimension linked to these issues. To co-produce the stakeholder engagement plan, participants used **Prepar tool** (see Section 2.2), and came up with a list of stakeholders, a clustering of actors based on their roles during the different steps of the project: 1) Active (participants directly involved in decision-making and implementation , for instance GAIA, local municipalities), 2) Advisors (providing guidance and expertise, for instance technical services and research institutions) and 3) Observers (keeping informed and supporting indirectly). Also, the charter included a shared agreement of the frequency of the meetings and overall plan of activities.

Photo: Stakeholder mapping in Fimela and their roles in the project.

Another important goal of this first Living Lab session was to expose participants to the complexity underpinning the sustainability challenges identified. To this end, participants were invited to play the **INIWAG** game. INIGAW is a fictional simulation set in an imaginary hydrological basin designed to explore conflicts over water quantity and quality. Participants assume the roles of various stakeholders, such as farmers, community leaders, NGO representatives, and policymakers, to navigate realistic scenarios involving competing water demands, governance challenges, and environmental pressures. Using symbolic tools like maps and tokens, players negotiate resource-sharing agreements, make decisions on infrastructure and policies, and experience the impacts of their choices through simulated feedback.

Photo: INIWAG role play session during Fimela First Living Lab Session

INIWAG game was a powerful tool for fostering systems thinking and collaborative governance. Participants gained insights into the complexities of water resource management, emphasizing the need for coordinated governance structures, such as committees, to manage shared resources effectively. The simulation highlighted the critical role of institutional frameworks and financial mechanisms, such as public budgets, in ensuring sustainable management outcomes. By actively engaging diverse stakeholders, the game fostered social learning and collective decision-making, providing a low-risk environment to experiment with adaptive governance strategies and strengthen local capacity for sustainable development.

One aspect that emerged from the Living Lab session and also remarked during the first workshop, was the importance of governance as a enabler but also a driver of the current sustainability challenges listed in Box 2.

As a result, the project team decided to elaborate a modified version of the **SMAG** tool, to specifically look into the issue of governance i.e. who are the actors, where is the power, how are actors linked and how this links to the SDGs. This adapted version of SMAG was not tested in the Living Lab but in smaller groups within five villages within the Fimela district. A protocol was tested in the five municipalities (see example Figure 12), and overall it helped stakeholders to first map a comprehensive list of historical decisions and events that have significantly impacted their territories. Some of the events referred included the construction of dikes to manage water flow and prevent flooding, the building of roads, such as the Fimela-Ndiosmone route, and reforestation projects aimed at combating soil erosion. Additionally, the management of the Kolou Ndig community forest, which dates back to the 1800s, and the rupture of the Sangomar land bridge in 1987, a natural event that altered salinity dynamics in the region, were highlighted.

From this long list, participants narrowed their focus to decisions that had the most profound and lasting impacts on governance and sustainability, such as the dike construction, land use and agricultural practices, and the Sangomar rupture. These decisions were directly connected to the issue of **soil and water salinization**, among others, which emerged as a central challenge for the district. The dikes, while managing water levels, inadvertently disrupted natural water flow, exacerbating soil salinity. Similarly, unsustainable agricultural practices and the Sangomar rupture intensified saltwater intrusion into the delta.

Causes	- Lutte contre la salinisation - Retenir l'eau pluviale pour la riziculture et l'abreuvage du bétail *La première digue datait de 1958, il s'agit ici d'une amélioration de l'infrastructure*	- Évacuation pénible et dangereuse des malades, notamment durant l'hivernage. - Surcharge du poste de santé privé de Djilasse - Faible couverture vaccinale - Accouchement à domicile dangereux - Différentiel de qualité entre public et privé (privé meilleur)	- Eau des puits non potable - Manque d'eau, notamment durant les derniers mois de la saison sèche (la soudure) - Alléger les taches ménagères pour les femmes (corvées d'eau) - Eau saumâtre/salée - Projet de l'Etat	- Réduire le taux d'abandon - Permettre aux jeunes qui souhaitent poursuivre de le faire dans de bonnes conditions (moins de déplacement) - Attractivité du territoire - Demande de la population
Décisions	**1999 & 2000** **Rénovation et amélioration des digues et des retenues d'eau de Ndindy et Diawando**	**2012:** **Création d'un poste de santé à Soudiane**	**2017:** **Adduction d'eau potable gérée par Azefor puis par SEOH**	**2017:** **Création du Lycée de Djilasse**
Conséquences	- Permet la limitation de la salinisation des terres sur le territoire de Djilasse - Favorise les herbes fourragères - Favorise la pêche - Gestion des vannes par la commune est difficile (quelques inondations) - Le territoire voisin (hors arrondissement de Fimela) se voit impacté. La salinisation s'accentue.	- Amélioration des conditions d'accès à la santé - Déplacement plus courts - N'a pas suffit à désengorger Djilasse - Baisse de la mortalité due aux accouchements dans de mauvaises conditions.	- Eau de qualité - Eau disponible pratiquement tout le temps - Tous les villages sont raccordés, pas toutes les habitations - Allègement des taches ménagères - Bénéfique pour les infrastructures de santé - Favorise le maraichage - Nouveau coût	- Diminution du taux d'abandon scolaire - Plus de monde à Djilasse (attractivité) - Moins de fatigue des élèves (pas de longues marches)

Acteurs/Décisions	**1999 & 2000 : Rénovation et amélioration des digues et des retenues d'eau de Ndindy et Diawando**	**2012 : Création d'un poste de Santé à Soudiane**	**2017 Adduction d'eau potable gérée par puis Azefor SEOH**	**2017 : Création d'un Lycée à Djilasse**
Etat déconcentré	I +validation	PI	PI	PA Acte la décision
Administration décentralisée (élus locaux	PI	PA demande	PA	PI Moteur
Agriculteurs/coopérative agricole	PA/X			
Eleveurs	PA			
Femmes productrices de sel	PA			
tourisme				
Acteurs du secteur médical (privé et public)		PA demande	I	
OCB/groupement de femmes/jeunes ASC		I	I	PA Manifestations
Appui pédagogique (CODEC & enseignant)			I	PA
Citoyens	I	PA : soutien travaux	I	PA demande
ONG (Océanium, World Vision, IRHA)	I & PA	I	I	PA

Figure 12 Examples of outcomes from testing SMAG in one of the Fimela municipalities

Key insights revealed a governance landscape marked by coordination gaps and decision bottlenecks. Stakeholders often struggled with fragmented collaboration between local communities and institutional actors, resulting in limited capacity to implement collective decisions effectively. The tool also exposed systemic power imbalances, such as the dominance of certain groups, including men in mixed forums, and tensions between technical services and local communities. These dynamics frequently led to suppressed discussions on contentious issues and hindered progress toward equitable governance.

Box 3 Development of Fim-WAAGA simulation game

Background: The Fim-WAAGA (Fimela Water and Agriculture Governance Analysis) game was developed in response to a critical challenge identified in the Fimela district: the widespread issue of **soil salinization** and its impact on agriculture and water resources. This problem, which undermines agricultural productivity and local livelihoods, was a central focus of territorial diagnostics conducted in December 2021 and March 2022. The game offered an opportunity to explore governance and management options through scenario analysis to address salinization collaboratively.

Game design process: The development of Fim-WAAGA followed an iterative and participatory approach, based on the CREAWAG methodology. The process unfolded in four phases:

1. **Conceptualization and Framing:** The initial phase involved workshops with local stakeholders to identify the key governance and ecological challenges associated with salinization. Participants mapped relationships between actors, activities, and infrastructures, forming the conceptual foundation for the game.
2. **Game Design:** Based on the conceptual framework, the game's core elements were developed, including roles, available resources, and decision-making scenarios. These elements mirrored the real-life governance dynamics of the arrondissement, ensuring relevance and applicability.
3. **Prototyping:** A preliminary version of the game was created, complete with a board and rules. It included scenarios reflecting common governance challenges, such as allocating resources for reforestation or constructing anti-salt dikes. The prototype emphasized the trade-offs between individual gains and collective benefits
4. **Testing and Refinement**: In June 2022 (II Living Lab Session), the game was tested and the feedback was informed adjustments to the gameplay, such as refining the costs of activities and balancing the representation of governance constraints. This phase ensured the game's realism and usability for future sessions

Main Outcomes and Future Use: The Fim-WAAGA game generated significant insights and contributions:

1. **Governance and Coordination**: t demonstrated the importance of intercommunal collaboration in addressing salinization. Participants observed that isolated actions by individual communes were insufficient, underscoring the need for systemic solutions
2. **Stakeholder Empowerment**: The game engaged stakeholders in an interactive and participatory process, helping them understand governance dynamics and identify practical solutions for shared challenges. It fostered dialogue and collective problem-solving
3. **Social and strategic learning**: By simulating real-world scenarios, the game provided a platform for testing innovative governance and management strategies in a safe environment. This allowed stakeholders to experiment with different approaches and evaluate their effectiveness.

The Fim-WAAGA game is set to remain an integral tool for governance capacity-building in Fimela. Its success in fostering collaboration and addressing systemic issues like salinization makes it a versatile resource for tackling other sustainability challenges in the region. As part of the project activities, in addition to the co-development of the game between project partners and stakeholders, several train-the-trainers courses have been organized to lift local capacities on the use of the tool to ensure transferability and ownership.


Photo: Fim-WAAGA simulation game testing

Step 3	Visioning	
June 2022	Objectives	Validate and enrich the current sustainability challenges Develop a future vision for the region
	Engagement format	1-day workshop (June)
	Tools	CoSMoS: Systems Mapping
	Outcomes/Outputs	• Customized CoSMoS tool (maps and cards) to facilitate sustainability discussions and co-production process in Swartkops catchment • Spatial validation of the current sustainability challenges across the catchment • Spatial representation of the sustainable vision for the catchment • Vision narrative
	Relevant reports	Fimela Living Lab Session II

The earlier step provided a preliminary overview of the main sustainability challenges in Fimela. This information was key to design and customize the **CoSMoS** tool. As in Swartkops, different sets of cards where developed to best represent the entities and processes in the region, as well as a map including the main geographical elements, allowing participants to place themselves on it.

The purpose behind the use of the CoSMoS tool was twofold. One, to validate and refine available knowledge on current sustainability challenges co-produced in earlier engagements. Also, gain a deeper understanding of what variables are connected to the issues at stake. Two, to develop a future vision for the catchment that can support the development of a sustainability action plan (pathways).

The validated map of the current situation provided a visual framework to explore interdependencies among governance issues, such as salinization, waste management, and water supply, and underscored the necessity of intercommunal coordination to tackle these systemic problems. The exercise set the stage for visioning and strategic planning, enabling stakeholders to align on future priorities.

Photo: Fimela participants of the Living Lab validating and refining the visual representation of the key sustainability challenges

This exercise also set the pave for the development of the future vision. One important aspect that came out when using CoSMoS for crafting the future vision is that different actors belonging to different villages and municipalities had different priorities. Recognizing this challenge, participants were encouraged to share their perceptions and reflect on a collective vision for the whole district of Fimela.

At the end of this exercise, the following vision was defined: *"By 2035, we want the district of Fimela to be a model of social, economic, and environmental development based on a motivated and engaged population united through intercommunality."*

Intercommunality in Fimela is very important and comprises multiple communes that have established intercommunal structures to collaboratively address shared challenges and promote sustainable development. This formalized cooperation was created with the purpose of enabling the pooling of resources and coordinated efforts to tackle issues such as environmental management, economic development, and public service delivery. The institutionalization of intercommunality in Fimela reflected a commitment to collective governance and regional integration, aiming to enhance the effectiveness of local development initiatives. However, Intercommunality in Fimela faces several challenges that limit its effectiveness, including the absence of a unified action plan to align efforts across communes and institutional weaknesses that hinder its functionality as a governance body. Many communes prioritize individual needs over collective goals, making it difficult to address systemic issues like salinization, among others. Additionally, capacity constraints in resources and human capital, coupled with governance challenges such as power imbalances and exclusionary decision-making, undermine its collaborative potential. Strengthening institutional support, creating a clear roadmap, and fostering trust and cooperation among communes are essential steps to enhance the effectiveness of intercommunality in Fimela. This is the reason why the vision placed such a strong emphasis on intercommunality.

Step 4	**Pathways and Action Planning**	
November 2022	Objectives	Identify pathways (sets of strategies) to achieve the desired vision and goals across the different SDGs. Develop an action planning Prioritization of measures
	Engagement format	½ Workshop 1 Living Lab Sessions
	Tools	CoSMoS prioritization of measures
	Outcomes/Outputs	• Action Planning to achieve the different SDGs goals • Empowered communities and willingness to lead community actions
	Relevant reports	Fimela Living Lab Session III

The earlier Living Lab sessions have pointed out a number of important sustainability challenges, namely soil salinization, waste management and water supply. Likewise, the visioning process also stressed that the drivers of many of these challenges are rooted in poor governance mechanisms and capacities. A intercommunality body has been created and establish to align local efforts and resources but it currently is falling to deliver the social, economic and environmental outcomes promised. One important aspect mentioned is related with the non existence of a intercommunality action plan.

Accordingly, participants of the Living Lab conducted a preliminary mapping of actions, actors and tentative timeline to overcome identified challenges (Table 4). Likewise, a more strategic plan was also co-designed in order to operationalize the intercommunality institution (Table 5).

Photo: Group work developing the Intercommunal action plan

The intercommunal action plan serves as the overarching framework that aligns and integrates the detailed actions outlined for addressing the three sustainability challenges: soil salinization, waste management, and water supply. While the intercommunal action plan focuses on establishing legal recognition, strategic diagnostics, and resource mobilization to strengthen intercommunal governance, the specific actions targeting these challenges—such as constructing anti-salt dikes, developing waste treatment centers, and improving water distribution systems—are embedded within this broader strategy. The intercommunal plan ensures that these targeted actions are implemented cohesively and equitably across communes, leveraging collective resources and capacities. By addressing systemic governance issues and fostering collaboration, the intercommunal framework not only facilitates the execution of these specific actions but also sustains their impact over time.

Table 4 Action Plan to address sustainability and governance challenges in Fimela

Challenge	Actions	Actors	Timeline
Soil salinization (SDG15)	Construct anti-salt dikes; reforest with adaptive species; raise awareness of salinization causes and effects.	Local communities, decentralized authorities, technical services, NGOs, government programs.	Short-term (dikes, awareness); medium-term (reforestation); long-term (monitoring).
Waste management (SDG12)	Develop waste treatment centers; promote recycling programs; implement waste collection services.	Local governments, NGOs, private sector partners, intercommunal organizations.	Short-term (collection services); medium-term (waste centers); long-term (recycling systems).
Water supply (SDG6)	Enhance rainwater harvesting systems; improve water distribution networks; explore desalination options.	Local communities, water authorities, NGOs, technical services, government programs.	Short-term (rainwater harvesting); medium-term (distribution improvements); long-term (desalination)

Table 5 Intercommunality Strategic Action Plan

Element	Description
Formalization and Legal Recognition	Establishing the intercommunal structure as a legally recognized entity to enhance governance capabilities.
Strategic Diagnostics and Planning	Conducting comprehensive diagnostics to identify critical issues and using insights to develop a robust intercommunal action plan.
Community Engagement	Designing and implementing strategies to ensure meaningful participation from all community stakeholders in both planning and execution.
Priority Areas	Focusing on systemic challenges such as water supply, soil salinization, and waste management, with targeted actions for each.
Capacity Building and Resource Mobilization	Identifying technical and financial partners to support the implementation of the action plan while strengthening local capacity.

3.2.3 Next steps

On the basis of what has been achieved in Fimela, the GAIA team in coordination with the local stakeholders have agreed upon the next steps:

- Finalizing the Intercommunal Action Plan: Consolidating the insights from pathways exercises, system mapping, and role-playing sessions into a comprehensive intercommunal action plan. Securing formal legal recognition for the intercommunal governance structure.
- Implementation of Identified Actions: Acting on priority areas such as constructing anti-salt dikes, improving waste management infrastructure, and enhancing water distribution systems. Mobilizing financial and technical resources to implement these actions.
- Capacity Building and Training: Organizing workshops and training programs to strengthen the governance and operational capacity of the Comité Restreint and other stakeholders.
- Community Engagement and Awareness: Launching awareness campaigns to involve local communities in sustainable practices and intercommunal initiatives. Engaging marginalized groups to ensure inclusivity in governance processes.
- Monitoring and Evaluation Framework: Developing mechanisms to monitor the progress of implemented actions and evaluate their impact. Regularly updating stakeholders on achievements and challenges.
- Exploration of Additional Challenges: Expanding the use of participatory tools like Fim-WAAGA to address other systemic challenges beyond soil salinization.

3.3 Lessons learned from the application of the SDG pathfinding framework

The experiences gathered from the co-design of tools and knowledge co-production and implementation of project activities revealed a number if important lessons learned emerging from the project.

- **Context-Specific Participatory Tools**: The tailoring of tools while taking important amount of resources and time to adapt to local realities has proven to be really useful and enabled stakeholders to collaboratively simulate and address governance challenges, making complex sustainability issues tangible and actionable.
- **Under resourced institutions and limited institutional capacities:** While institutions aiming at supporting the localization of SDg at the local level might be in place, they are not well resourced and have insufficient capacities. Either there no formal mechanisms for cooperation across local institutions, unclear roles, and limited institutional capacity. Strengthening these frameworks is essential for enabling coordinated and sustainable collective action.
- **Balancing Specific and Systemic Challenges**: While tools like Fim-WAAGA focused on targeted challenges (e.g., soil salinization), broader exercises, such as CoSMoS pathways development and visioning, ensured alignment with a shared vision. This dual focus ensured both actionable and strategic outcomes.
- **System Mapping as a Strategic Tool**: System mapping tools such as SMAG or CoSMoS provided a structured approach to identifying governance gaps and interdependencies. This tool was essential for diagnosing root causes and pinpointing actionable leverage points to address systemic challenges.
- **Inclusive Stakeholder Engagement**: Co-creation processes were vital for fostering ownership and inclusivity in planning and decision-making. However, ongoing efforts are needed to address power imbalances and ensure that marginalized groups are adequately represented in governance processes.
- **Localized Framing of Sustainability**: Experiences from Swartkops revealed that while SDGs are globally recognized, local actors often resonate more with terms and concepts reflecting their lived realities. Mapping local experiences onto the SDG framework proved to be an effective way to bridge global goals with local priorities.
- **Iterative and Adaptive Planning**: Regular reflection and adjustment of tools and strategies based on stakeholder feedback ensured relevance and effectiveness. The iterative nature of planning enabled projects to remain responsive to emerging challenges and opportunities.

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5. Annexes

5.1 Annex I

Stakeholder organisations involved in the co-production process in the Swartkops Catchment

Type of stakeholder	Organizations participating
Academia	Nelson Mandela University (NMU)
Environmental NGO	Benguela Current Conservancy
	Eastern Cape Enviro Forum
	GANESHA
	Zwartkops Conservancy
Food Security NGO	Siyabonga Feeding Scheme
Grassroot movements	#LetsLiveGreen
	Aloes Community
	Hlumani Nande
Local government	Eastern Cape Department of Economic Development, Environmental Affairs and Tourism (DEDEAT)
	Department of Forestry, Fisheries and the Environment (DFFE)
	Department of Mineral Resources and Energy (DMRE)
	Department of Water and Sanitation (DWS)
Municipal government	Nelson Mandela Metro Municipality
National organization	South African National Civic Organisation (SANCO)
Private company	EnviroServ
	Aspen
Public company	Coega Development Corporation

Stakeholder organisations involved in the co-production process in the Fimela District

Fimela actors and organizations involved in the process	Type
Association des éleveurs	Union
Syndicat du tourisme	
Société d'Exploitation des Eaux Hydroliques (SEOH)	Public business
Fédération des exploitantes de sel de Palmarin	Private business
Ferme agroécologique « Keur yakkar »	
Coordination des Actions pour la Restauration des Ecosystèmes Mangroves (CAREM)	NGO/Grassroot
ONG Jeunesse et Développement de Fimela (JED)	
ONG Nebeday	
Réseaux d'Organisation pour la Protection des Ecosystèmes Mangroves (ROPEM)	
Terre et Culture Solidaires	
Observatoire de Veille et de Plaidoyer	
Association des chefs de village	
Enda graf Sahel	
CODEC	
Collectif pour la défense des intérêts des citoyens (CDC)	
Direction des Aires Marines Communautaires Protégées (DAMCP)	National government
Direction régionale de la Statistique (ANSD)	
Inspection Régionale des Eaux et Forêts (IREF)	
Médias locaux	Media

Fimela actors and organizations involved in the process	Type
Collectivités territoriales/ intercommunalité	Local government
Agence régionale de développement de Fatick (ARD)	
Centre d'Appui au Dévéloppement Local (CADL)	
Conseil Local de Pêche Artisanale (CLPA)	
Université du Sine Saloum Elhadji Ibrahima Niass (USSEIN)	Academia

5.2 Annex II

List of cards developed for system mapping exercise in Swartkops (CoSMoS tool)

STEEP-H dimension	Entity	Process	Indicator
Society	Hospitals Older people Schools, universities Children Cultural and spiritual sites Cultural centres Cultural objects Informal settlements Outpatient clinics Parks, sport, art grounds, environmental education grounds People with disabilities Recreational sites Social sanctuaries in the catchment Community	Communicating and raising awareness Depopulation Energy efficiency improvement Fishing Population growth Rainwater harvesting Urbanization Water reuse Water use/consumption	Death rate Drinking water availability Education Energy demand Energy efficiency Food demand Food security Health Health risk Inequalities Loss of life risk Population level Property damage Unemployment Water demand Water use efficiency Energy consumption Quality of life Water security Crime Vandalism
Technology	Drought resilient crops Flood protection infrastructure Green coastal protection infrastructure Grey coastal protection infrastructure Groundwater (pumps) Irrigated area Irrigation water storage Organic agriculture Power grid Research centres Wastewater recycling infrastructure Water storage/reservoir Canal irrigation Drainage infrastructure Drip irrigation Electronic waste	Drought early warning system Fertilization Floods early warning system Food processing Groundwater extraction Wastewater treatment Water efficient irrigation management	Food production

STEEP-H dimension	Entity	Process	Indicator
	Sprinkler irrigation Water measurement infrastructure Rainwater harvesting infrastructure Solid waste recycling infrastructure		
Environment	Ecosystems Fauna Floodplain Flora Grassland Habitats Levees Nature attraction Protected area River Soil Urban green spaces Wetland Alien invasive plant species Fish sanctuary Flood polders Groundwater (aquifer) Parasites Swartkops River and Estuary Urban ecosystem	Agricultural drought Anthropogenic pressure on wetlands Aridifcation Beach nourishment Biodiversity loss Climate seasonality Coastal erosion Drought Environmental flows Erosion Evaporation Evapo-transpiration Flood GHG emissions Groundwater recharge Habitat degradation Land loss (due to sea level rise) Loss of arable land Loss of beaches Nutrients leaching Plant disease and pest Rainfall Recultivation of lands Runoff Salinization Salt water intrusion Sea level rise Sedimentation Soil conservation Waste management Water contamination Wetlands protection Desalination Natural water purification Pest outbreak Plants disease Precipitation (rainfall, snow) Waterlogging Wildlife migration	Air temperature Biodiversity Groudnwater level Pollution Seasonality Water quality Water stress Water temperature Biological pollution Chemical pollution Heavy metal pollution Noise pollution Nutrient pollution Organic pollution Pollution Water level Inter-annual variability

STEEP-H dimension	Entity	Process	Indicator
Economy	Agricultural area Airport Animal husbandry Fish & seafood Fish stocks Fruits Grains Manufacturing Meat Oil seeds Pastures Port Shellfish farms Vegetables Estuary (bird sanctuaries) Farmlands Food processing business Motor manufacturing and assembly factories Quarries River sites for sand mining	Circular economy Cultivation Disaster insurance Food export Food import Industrial production Services Tourism Trade - export	Development in flood zone Energy price Flood damage and losses Food prices GDP Income level Income Local economy Low income households Age restriction for employment
Politics and governance	Decentralized power grid Toursim infrastructure Drinking water supply infrastructure Government structures Transoportation infrastructure Wastewater treatment infrastructure	Flood restoration and management Sustainable mobility	Access to clean energy Employment rate Healthcare system capacity Infrastructure damage
Historical	Aloe community Historical spatial Apartheid plan		Heritage/culture

5.3 Annex III

Variables describing the sustainability challenges across the STEEP-H dimensions and trends in the current situation in the Swartkops Catchment

Swartkops Catchment Challenges

Society	Technology	Environment	Economy	Politics & Governance	History
Communication and raising awareness ?	Wastewater treatment ?	Water quality ?	Tourism ?	Tourism infrastructure ?	Historical Spatial apartheid planning
Drinking water availability ?	Wastewater measurement infrastructure ?	Biodiversity ?	Local economy ?	Infrastructure Damage ?	
Culture and Spiritual Sites ?	Ground water extraction ?	Drought ?	Estuary (bird sanctuaries) ?	Employment rate ?	
Unemployment Rate ?	Power grid ?	Climate Seasonality ?	Motor manufacture and Assemble factories ⇔	Health care system capacity ?	
Population Growth ?	Flood protection Infrastructure ?	Water level ?	Income level ?		
Energy demand ?	Water Storage/ reservoir ?	Pollution ?	Energy Prices ?		
Park, art ground, educational ?	Underserviced Communities ?	Water Contamination ?	Food Prices ?		
Vandalism ?		Biological Pollution ?	Agricultural Area ?		
Crime ?		Chemical Pollution ?	Manufacturing ⇔		
Health Risk ?		Habitat Degradation ?	Port ⇔		
Food Security ?		Heavy metal Pollution ?			
School, Universities		Wetland ?			
Water demand ?		Saltwater intrusion (summer strand) ?			
Informal Settlements ?		Biodiversity loss in coastal area			
Energy Consumption ?		Swartkop River and estuary ?			
		Flood Plain ?			
		Anthropogenic Pressure on wetland ?			
		Fish sanctuary ?			
		GHG emissions ?			

Increase	Decline	Stable
?	?	⇔

Variables describing the sustainability challenges across the STEEP-H dimensions and trends in the future vision in the Swartkops Catchment

Swartkops Catchment Future Vision

Society	Trend	Technology	Trend	Environment	Trend	Economy	Trend	Politics & Governance	Trend	History	Trend
Drinking water availability	?	Organic agriculture	?	Alien invasive plants		Energy price	?	Tourism infrastructure	?	Aloe community	?
Water use efficiency	?	Water measurement infrastructure	?	Water quality	?	Manufacturing	?	Services	?	Heritage and culture	?
Parks, sport, art grounds, environment and education grounds	?	Wastewater treatment	?	Nature attraction	?	Motor manufacturing and assembly	?	Employment rate	?		
Unemployment rate	?	Wastewater recycling infrastructure	?	Biodiversity	?	Port		Government Structure	?		
Water demand	?	Canal irrigation	?	Rainfall	?	Circular economy	?	Floodplain restoration and management	?		
Quality of Life	?	Green coastal protection infrastructure	?	Flora (alien plants –removal-job creation)	?	Income level	?	Access to clean water	?		
Schools, universities		Rainwater harvesting infrastructure	?	Climate seasonality		Farmlands	?	Healthcare System capacity	?		
Cultural and spiritual sites	?	Food Production	?	Water level –drop		Agricultural area	?				
Communication and raising awareness	?	Water storage	?	Environmental flow	?	Fish and Seafood	?				
Health Risk		Research centres	?	Protected area	?	Food prices	?				
Crime	?	Flood protection infrastructure	?	Pollution (biological)		Tourism	?				
Population Growth	⇔	Solid waste recycling infrastructure	?	Urban green spaces	?	Food Processing					
People with disability		Power Grid	?	Railways	?	Local economy	?				
Outpatient Clinics	?	Drought resistant crops	?	Habitat degradation		Estuary (Bird Sanctuaries)	?				
Food security	?	Irrigation water storage	?	Natural water purification	?						
Water reuse	?	Flood protection infrastructure	?	Flood plain							
Fishing	?	Drainage infrastructure	?	Fish Sanctuary	?						
Rain water harvesting	?	Desalination	?	Wetland and protection	?						
Water Security	?			Coast erosion							
Energy demand	?			Nature Attraction	?						
Energy efficiency improvement	?			Water management	?						
Health	?			Grassland							
				Ecosystem							
				Rainfall	?						

		GHG emissions **Beach nourishment**			