Climate Services 35 (2024) 100503

Contents lists available at ScienceDirect

Climate Services

journal homepage: www.elsevier.com/locate/cliser

Original research article

Co-designing in Tandem: Case study journeys to inspire and guide climate services

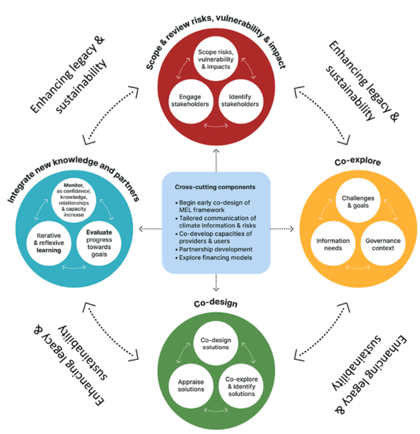
S. Bharwani [a,*], Å. Gerger Swartling [b], K. André [b], T.F. Santos Santos [c], A. Salamanca [d], N. Biskupska [d], T. Takama [e], L. Järnberg [b], A. Liu [a]

[a] SEI, Oxford Eco Centre, Roger House, Osney Mead, Oxford OX2 0ES, UK
[b] SEI Headquarters, Linnégatan 87D, Box 24218, 104 51 Stockholm, Sweden
[c] SEI, Calle 71, #11-10, Edificio Corecol, Oficina 801, Bogotá, Colombia
[d] SEI, Chulalongkorn University, 10th Floor, Kasem Uttayanin Building, 254, Henri Dunant Road, Pathumwan, Bangkok 10330, Thailand
[e] su-re.co, Jl. Dalem Gede No.25, Pererenan, Kec. Mengwi, Kabupaten Badung, Bali 80351, Indonesia

HIGHLIGHTS

- Tandem embraces pluralistic stakeholder goals and values whilst enhancing trust.
- The reflexive framework addresses multiple preferences, goals, capacities and power dynamics.
- Tandem tackles research, policy and practice gaps across temporal and spatial scales.
- The framework explores governance at appropriate decision-making levels.
- Tandem considers gender, social equity and local knowledge.

GRAPHICAL ABSTRACT



ARTICLE INFO

Keywords:
Capacity development
Climate services
Guidance
Climate change adaptation
Transdisciplinary
Co-design

ABSTRACT

This study tests, empirically validates and refines the Tandem framework for co-designing climate services (Daniels et al., 2019; 2020), to enhance its applicability and effectiveness. Intended as an inspirational guide for 'good practice', Tandem is practical and non-prescriptive and is designed to be tailored to context. We apply Tandem in three different geographic and socioeconomic settings: 1) a rural community in Indonesia, where smallholder farmers are confronting climate impacts on agriculture; 2) two cities in Sweden, where planners are addressing climate-related flooding and heat stress; and 3) communities and institutions in a Colombian river basin, where climate change is leading to water scarcity, raising questions about equitable use. We find that

Abbreviations: BMKG, Indonesian Meteorology, Climatology, and Geophysical Agency; TEK, traditional ecological knowledge; POMCA, Plan de Ordenación y Manejo de Cuencas Hidrográficas; SaLT, School of Climate *and* Living Tradition; CFS, Climate Field School; SMHI, Swedish Meteorological and Hydrological Institute; GI, green infrastructure.

* Corresponding author.
E-mail address: sukaina.bharwani@sei.org (S. Bharwani).

https://doi.org/10.1016/j.cliser.2024.100503
Received 28 July 2023; Received in revised form 10 June 2024; Accepted 19 June 2024
Available online 31 July 2024

Tandem was effective in these settings in: 1) moving from 'useful' to 'usable' information by building trust; 2) increasing institutional embedding through strengthened relationships and networks; 3) improving climate information uptake and use; 4) increasing capacity, confidence and a shared understanding of climate information by users, and the decision context by providers; and, 5) serving as a non-prescriptive guide for users, intermediaries and providers to co-design and structure an effective process for collaborative learning and action. We use insights from these case studies to enhance the original framework, enabling it to 1) scope and review climate and non-climate vulnerability and risks; 2) incorporate gender, social equity and power considerations; 3) acknowledge the value of local and traditional ecological knowledge; 4) co-explore horizontal and vertical governance at appropriate decision-making scales; and, 5) provide flexible starting points, with early identification of impact indicators.

Practical implications

The aim of this paper is to test, empirically validate and refine the Tandem framework for co-designing climate services (Daniels et al., 2019; 2020) to improve its application and effectiveness in different decision contexts globally. We use experiences and learning from application in three distinct geographical and developmental contexts to create a revised framework that aims to offer improved guidance. The goal is to support a wider community of climate service developers, users, researchers, practitioners and policymakers address climate change-related adaptation issues of growing attention and concern worldwide.

As the case studies demonstrate, Tandem fulfils key knowledge co-production principles (as suggested by Norström et al. (2020)) of being context-based, pluralistic, goal oriented, and interactive. We show that Tandem helps diverse users in varied contexts articulate their wide-ranging needs through a series of phases and guided questions to enable constructive conversations among climate information providers and stakeholders. These questions prompt other reflexive questions, and they are malleable and iterative enough to accommodate emerging insights and a shared understanding through open and agile conversations. Tandem's context-led approach ensures that user needs represent the pluralistic goals and values of stakeholders and that important sustainability concerns are addressed.

Case studies

In Indonesia, Tandem brought together coffee and cacao farmers, agricultural extension officers and climate scientists from the national meteorological office (BMKG) to recognize of the value of traditional ecological knowledge (TEK) used by farmers and integrate it with scientific forecasts through a School of Climate and Living Tradition (SaLT). The co-design process subsequently increased information sharing from BMKG and uptake by farmers with the delivery of regular weather bulletins. The government plans to hold similar field schools for 16 further crops. In Sweden, Tandem supported a continuous exchange of knowledge between climate and impact researchers and city officials with information that was highly trusted and deemed "good enough" for decision-making (André et al., 2021). In Stockholm, the results have been included in the city's climate adaptation plan (City of Stockholm, 2020). In Karlstad, construction of a flood defense wall at the centre of the co-design process is expected to begin in 2025. In Colombia, Tandem helped design a tool that translated "useful" hydrometeorological model results into language that made it "usable" and led to the formulation of a hydrographic basin management plan in its coffee producing regions.

The practical implications of applying Tandem are separated into the strengths and added value of the existing framework and new elements of the refined framework that have emerged directly or indirectly from case study findings:

Added value of the existing framework:

1. **Building trust and creating entry points** for new relationships, networks, and bridges across multiple domains and disciplines supporting the shift from 'useful' to 'usable' information.
2. **Understanding and embedding processes** within existing (formal and informal) institutional and policy contexts creates, building and strengthening relationships between users, producers and networks (e.g. public–private, institutional, associations, researchers), offering opportunities to enhance the sustainability and long-term legacy of climate-resilient decisions.
3. **Increasing the uptake of climate information** by tailoring the methods used to appraise adaptation options to the characteristics of the local communities and participants affected and involved.
4. **Purposefully focuses on processes, not products**, to leverage the convening power inherent in bringing together different actors and knowledge types to build the capacity of providers to understand the decision-making context, and users, the value, limits and applicability of climate information.
5. The **flexible yet semi-structured framework** relies on guiding questions that help initiate, structure and sustain conversations with stakeholders, starting from the very early stages of the process to identify shared goals (when it is also important to **identify impact indictors early** for monitoring progress towards achieving shared goals) and continuing into subsequent planning and implementation stages.

The refined elements of the Tandem framework:

1. A new 'scoping' and 'review' element **exploring both climate and non-climate vulnerability and risks** and the **multiple actors** that may need to be consulted on the same issue, due to their varying levels of vulnerability and adaptive capacity. This acknowledges that adaptation may be affected by **compound or cascading risks and siloed responses can exacerbate or create new vulnerabilities or lead to maladaptation** (see 4).
2. Identifying and addressing users' needs in a proactive, inclusive way that is **responsive to local dynamics, power imbalances, gender and social equity considerations and different knowledge types**.
3. **Enhancing trust in and the perceived value of different knowledge types** to encourage the **integration of local or Indigenous knowledge** throughout the co-design processes.
4. Co-exploring **horizontal and vertical governance at the appropriate decision-making scale (formal and informal)** to break down institutional silos, avoid potential maladaptation and recognize multiple, compound and cascading risks.
5. **Iterativity and reflexivity** as **learning, confidence and capacity** in the application and use of climate information increases among *both* producers and users of climate information. Based on this, early consideration of **impact indicators of both tangible and intangible outcomes** is important.

1. Introduction

1.1. Knowledge co-production approaches

To address the gap and speed at which climate change adaptation (hereafter adaptation) research impacts policy and practice (Klein and Juhola, 2014), collaboration and bridging efforts increase two-way knowledge exchange and dialogue between traditional climate information "provider" and "user" groups strengthen relationships, flexible partnerships and interaction (Jones et al., 2017, Brasseur and Gallardo, 2016; Lemos and Morehouse, 2005). There is increasing evidence that iterative stakeholder engagement and reflexive knowledge exchange, rather than the production of more, or "better" information, increases the likelihood that climate information will be used in decision-making (Bremer and Meisch, 2017; Djenontin and Meadow, 2018; McClure et al., 2024; Meadow et al., 2015; Steynor et al., 2016).

We conduct three diverse case studies to examine the effectiveness of a transdisciplinary framework to co-design climate services that includes many of these elements, Tandem (Daniels et al., 2019; 2020), and use the results to refine the framework to enhance its efficacy. Transdisciplinarity uses collaborative methods to bring scientists, policymakers and practitioners together to address societal problems and co-produce the necessary theoretical and practical knowledge to transition to a more just and sustainable society (Scott and Taylor, 2019). Transdisciplinary knowledge co-production has been applied as a method in a variety of sectors, geographies and scales from US agriculture (Prokopy et al., 2017) and Swedish forestry (Gerger Swartling et al., 2019), to urban planning in southern Africa (Daniels et al., 2020), Dutch marine resource management (Van der Molen et al., 2015) and conservation in north-western Australia (Cvitanovic et al., 2016). Recent work on what defines a successful climate service (Boon et al., 2024) is also pertinent to our examination of the degree to which Tandem (Fig. 1) adds value to climate information co-development, uptake and use in the case studies.

In recent years, the increased use of co-production as a methodology has spanned a spectrum that ranges from merely consultative to more deeply immersive processes (Carter et al., 2019). Depending on their application, these processes have the potential to strengthen individual and institutional capacities, collaboration, communication, and networks, and thus to accelerate climate-resilient decision-making and action (Daniels et al., 2020). Intermediaries such as embedded researchers (Taylor et al., 2021), knowledge brokers and boundary organizations (Cvitanovic et al., 2015) or policy entrepreneurs (Tanner et al., 2019), within research teams or institutions have connected different actors and knowledge types to help to tailor and customize decision support tools to fit specific contexts and needs (Fünfgeld et al., 2019). Such actors facilitate communication and knowledge exchange across diverse networks of stakeholders and provide insight into political contexts creating entry points for climate information, using both formal strategies and more tacit, informal strategies (Tanner et al., 2019).

It is by virtue of their independence and ability to represent different sides across the interface of science and decision-making spheres that intermediaries are key to facilitate effective knowledge exchange between providers and users. They have the potential to connect the different cultures of policy and of science that measure impact, value engagement activities, and incentivize knowledge exchange differently (Cvitanovic et al., 2015) using co-production to enhance the dialogue between users and providers.

1.2. Key enablers for effective and holistic decision-making

Key enablers of information uptake and use are a *deeper understanding of the needs of the decision-maker and of the decision-making context* by climate information providers, and a clearer understanding of the potential value and limitations of such information by users (Brasseur and Gallardo, 2016, Jack et al., 2020). However, transformational change in this context requires the space to reflect and deliberate on contested or 'pluralist' worldviews (Norström et al., 2020, Turnhout et al., 2020).

Enhancing the capacities of intermediaries in terms of their facilitation skills to enable co-exploration of stakeholder needs, can enable this space to reflect and deliberate to reduce the "usability gap" between climate science and information use in decision-making (Lemos et al., 2012) and the risk of a linear, supply-driven flow of climate information

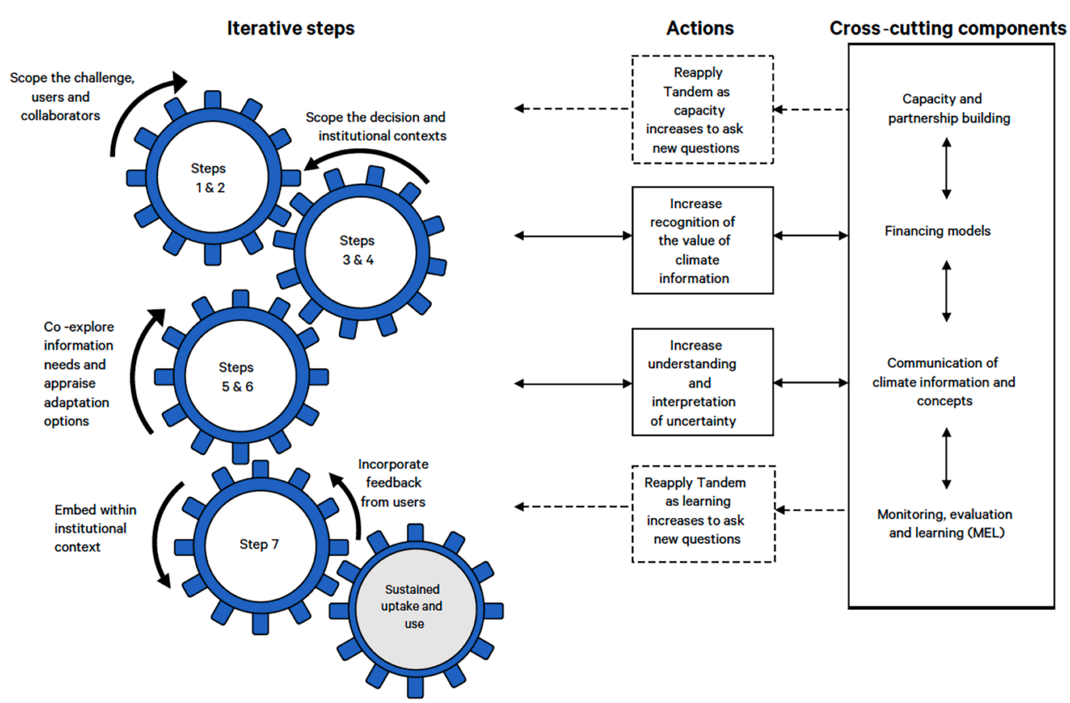


Fig. 1. Iterative steps presented in the original Tandem framework for co-designing climate services (Daniels et al., 2019). The gears in Fig. 1 highlight the co-dependent nature of each step, whilst acknowledging cross-cutting components with bi-directional arrows.

(Brasseur and Gallardo, 2016).

Further enablers of holistic decision-making are *increasing information access* and potential for use through *timely* and *tailored provision* of *decision-relevant* information, in *appropriate formats* and *language*, to create a shared understanding of, and *reduction in the use of technical terminology* (Briley et al., 2015, Adams et al., 2015, Djenontin and Meadow, 2018, Jones et al., 2017).

Context-led, or "decision-*first* and science-*informed*" (FCFA, 2015, *emphasis added*) engagement with decision-makers and other stakeholders by climate scientists through the knowledge co-production process is likely to enhance users' capacity and confidence to recognize both the potential and the limits of climate information, better interpret it, identify assumptions, understand uncertainty and thus better articulate information needs (Bruno Soares and Dessai, 2016; Cortekar et al., 2017; Jack et al., 2020).

Additionally, successful co-production relies not only on the *development of trust* and *sustained and early interaction* and but also *on the co-production process* itself and *ownership* of this (Daniels et al., 2020). For example, participatory monitoring, evaluation and learning (MEL), that actively involves participants can strengthen ownership and sustainability (Visman et al., 2022). Such enablers can be just as important for climate resilience and sustainability as the generation of knowledge products themselves (Norström et al., 2020). In our previous research we have argued that the emphasis should not be on the generation of an output *per se*, but on the process itself – which leads to enhanced learning, capacity, empowerment, relationships, and networks, and, thus, strengthened knowledge systems and decision processes (Daniels et al., 2020; McClure et al., 2024).

1.3. The Tandem framework

To address the disconnect between scientific research, policy requirements and adaptation needs on the ground (Klein and Juhola, 2014; Palutikof et al., 2019), Tandem was created to offer a collaborative guidance framework for co-produced and process-led climate services. While there is a myriad of climate services related tools and frameworks available (see e.g. the Climate-ADAPT database), many with different features and content, including sector-specific, funding-related and geographically-oriented, some appear to have similarities with Tandem. For example, the Regional Adaptation Support Tool (RAST), which is being promoted under the EU Mission on Adaptation, provides a step-by-step approach and is intended to support local or regional authority's adaptation efforts. While iterative, flexible and comprehensive in nature, we propose that Tandem goes further by offering practical guidance in the form of co-exploratory questions for each stage of the co-design process.

More specifically, Tandem supports stakeholders to work together to create a shared understanding to co-design and co-develop adaptation solutions and climate services that promote long-term climate resilience and sustainability. The original Tandem framework (Daniels et al., (2019), Fig. 1 and Daniels et al. (2020), Fig. 2), was developed inductively primarily through experience in the Stockholm Environment Institute's (SEI) Climate Services Initiative,[1] a review of scientific literature, a survey of the international climate services community, an analysis of enablers and barriers to using climate information, and long-term engagement in sub-Saharan African urban planning contexts, and particularly through a climate services-related 'Learning Lab process' in Lusaka, Zambia.[2]

Tandem recognizes that key to collaborative processes is bringing together people with diverse expertise and experience (e.g., engineers, impact modelers, planners, community representatives, climate scientists and social scientists) to share insights and perspectives and to jointly develop new knowledge that represents multiple disciplines, knowledge types, decision-making levels, and practices. More specifically it provides a structure for i) understanding decision needs; ii) guiding actors in designing and delivering an effective transdisciplinary knowledge-integration process; and iii) enhancing individual and institutional capacities, working relationships, and networks necessary for longer-term change and action (Daniels et al., 2020).

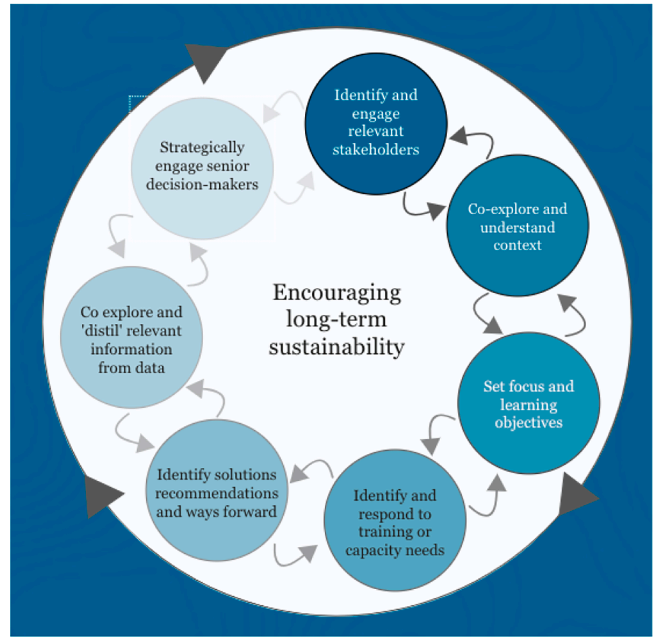


Fig. 2. This represents a move away from a possible linear interpretation of Fig. 1. Here, Tandem uses a circular presentation of 'elements', as opposed to the original 'steps' (Daniels et al., 2019). This highlights that the process can be embarked upon at any stage and feedback arrows further emphasize Tandem's iterative, reflexive and agile nature. While inspired by the original framework, this was created using data from Lusaka, Zambia (Daniels et al., 2020).

The Tandem framework initially proposed iterative steps (Fig. 1) that providers, intermediaries and users could collectively use to inform, guide, and structure their transdisciplinary interaction. As Tandem aims to embed the design of climate services within the policy, decision, and institutional contexts in which they will operate to enhance their relevance, usability and sustainability, it evolved into a circular framework to emphasize the iterative and reflexive nature of the process (Fig. 2). Recent empirical applications of Tandem in several diverse decision contexts (Table 1) have provided insights that further refine, improve and consolidate elements of both frameworks into an overarching approach. Fig. 3 illustrates this and emphasizes the non-linear, complex nature of these processes when applied in reality.

The rest of this paper is organized as follows: Section 2 outlines the application of Tandem in the case studies and the results from using the original framework (Fig. 1). Section 3 discusses the degree to which Tandem added value in each process. Section 4 shows how the framework was updated (Fig. 3) based on gaps identified or modifications made in applications in the case studies. Section 5 discusses the limitations and challenges of the study with concluding remarks and potential further applications in Section 6.

2. Application of Tandem and results

2.1. Methodology

We applied Tandem (Fig. 1) in three settings: at the rural scale in Southeast Asia, where smallholder farmers are confronted with climate

[1] https://www.sei.org/featured/collaboration-to-bridge-the-gap-between-climate-science-and-adaptation-policy/.

[2] https://www.fractal.org.za/.

Table 1
Case studies where Tandem was applied, their risks (climate and non-climate) and prioritized adaptation challenges.

Location	Climate Hazard	Other stressors (non-climate)	What shared adaptation challenge is prioritized?
Campoalegre River basin, Colombia	Water scarcity for human consumption, agriculture, hydropower generation. Landslides because of heavy rainfall on the high slopes of the Andean mountains.	Development of new activities such as tourism, which demands more water and increases contamination. Change of coffee crops for avocado, with a higher water demand.	Management by the Basin Council of natural resources to guarantee ecosystem services for local and regional communities.
Bali, Indonesia	Seasonal unpredictability; increased periods of precipitation, humidity, and drought; changes in the timing of rainy season; changes since the last El Nino.	Crop disease; geographical isolation and lack of support from agricultural agencies; limited funds to try new or improve existing techniques.	Supporting small-scale farmers and extension workers in improving crop yield and quality.
Karlstad municipality, Sweden	Multiple water hazards, and compound risks including fluvial flooding from the Klarälven River, heavy rains/storm surges and cloudbursts.	Increased pressure on land for housing, businesses, and other activities to meet expected increase in population and future development of a growing city.	Flood protection of the adjacent residential and industrial area, and critical infrastructure assets.
City of Stockholm, Sweden	Rising temperatures and increased risk of heatwaves.	Increasing population, growing demand for housing and densification of the city. Health impacts of heat stress on the vulnerable.	The role of green infrastructure to reduce heat stress experienced by residents in the city's dense and developing new residential areas.

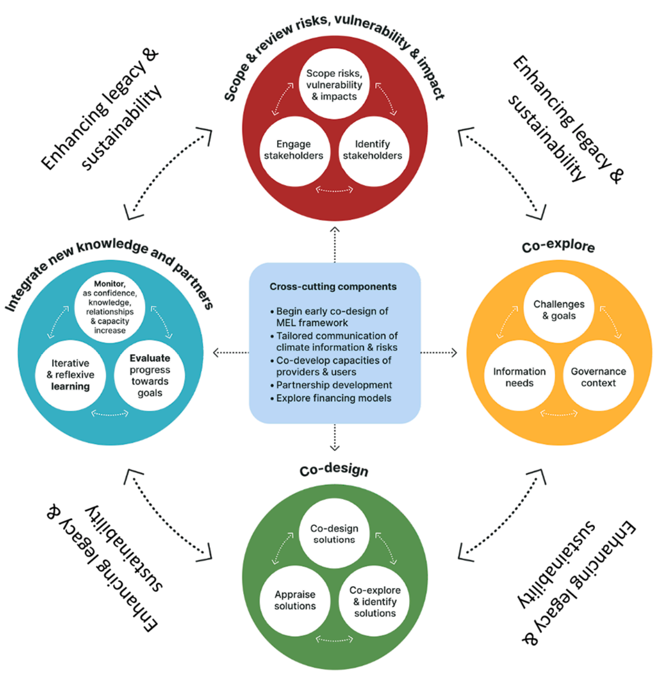


Fig. 3. The updated Tandem framework for co-designing climate services. The revised guidance continues the reframing of steps as iterative elements, that are further embedded within other iterative elements, to re-emphasize the non-linear, complex nature of many of these processes in reality. The stages in the original framework and the guiding questions, are now captured in nested circles, but simplified in the online guidance which is available in over 100 languages. (online guidance: https://weadapt.org/tandem/). The dark circles indicate the main framework element. The white circles show sub-elements. The white rectangles show the cross-cutting elements. The arrows again indicate the iterativity and reflexivity of the process.

impacts on agriculture (Biskupska & Salamanca, 2020), at the municipal scale in Northern Europe, specifically in Sweden where urban planners are addressing climate-related flooding and heat stress (André et al., 2021; André et al., 2020; Järnberg et al., 2020) and at the basin scale in Latin America, specifically in Colombia where climate change is leading to water scarcity, raising issues about access and equitable use of water (Santos Santos & Gerger Swartling, 2020). Insights from this range of applications show the key benefits of the framework (Section 3) and underpin refinements (Section 4) that include consideration of: 1) differentiated climate and non-climate vulnerability and risks; 2) gender, social equity and power considerations; 3) the value of local and traditional ecological knowledge; 4) horizontal and vertical governance at appropriate decision-making scales (formal and informal); and, 5) flexible starting points, with early identification of impact indicators.

An independent, external social scientist carried out a literature review and document analysis of 11 existing Tandem publications supported by a Tandem lead researcher (and author). Ex post meetings were then organized involving case study team leaders to discuss and compare case-level results, commonalities and differences resulting from tailoring Tandem to specific contexts, to improve our understanding of the benefits of using the guidance and how this could be refined to address any gaps or weaknesses. The literature review and document analysis were used to inform 5 in-depth semi-structured interviews between the external researcher, Tandem lead researcher and case-study team leaders in Indonesia, Colombia and Sweden. This combination of inputs provided rich insights into the added value of the existing framework, and enabling conditions, barriers and limitations to the co-production process. Elements for refinement were also identified through the literature review and interview process and were verified and validated with case study leaders in an ongoing iterative manner.

Data from the Tandem literature and interviews were inductively and iteratively coded in the qualitative analysis software, AtlasTi, to derive high-level concepts. Case study documents were reviewed, and a first inductive iteration of coding was carried out to correlate case study elements with Tandem steps (Fig. 1) and gather evidence on any ways in which Tandem added value to the case studies. The independent researcher then produced summaries of the case studies, which were verified with the case study leads for accuracy. Semi-structured interviews were held with the leads to gain further project details and post-hoc insight, and the interview transcriptions were added to Atlas TI for a second iteration of coding.

The codes were deductively refined and grouped into five conceptual groups and two methodological groups. The conceptual groups included the "Context" of the project, the 'Added value of Tandem', and 'Areas for improvement', which included 'limitations in applying Tandem' and 'barriers' and 'enablers' to the co-production process. The methodological groups included codes covering the general methods used in the projects and those identifying actions that linked to any steps of the Tandem framework.

Insights from the independent research, interviews and the coding exercise helped classify the lessons learned into discrete pieces of evidence regarding the added value of Tandem (Section 3) and areas for refinement (Section 4). Based on these inputs, new questions were developed, and existing questions refined and re-ordered where needed (Fig. 3). The 'added value' and 'refinements' were verified and validated through extensive discussion with case study leaders. In response to a recommendation from the interviews, the updated guidance also includes example exercises to help co-explore questions in the guidance (see Supplementary Material).

2.2. Case studies and results

Here we describe the case studies in detail, their main challenges, the results in applying Tandem and the added value that this process provided. Tandem (Fig. 1) was applied in three locations: 1) in Indonesia, with smallholder farmers, agricultural extension officers and climate scientists from the national meteorological office; 2) in Sweden, with meteorological scenario modelers, hydroclimatologists and city officials in two cities; and 3) in Colombia, with river basin council members and representatives from the local and regional communities in the Campoalegre River basin. Table 1 summarizes the climate and non-climate risks in each case study as well as the adaptation challenge that was prioritized through the co-production process.

2.2.1. Coffee and cacao farming in Indonesia

Researchers worked with a well-established local intermediary and NGO in three locations in Bali (Fig. 4) to facilitate dialogue between the Indonesian Meteorology, Climatology, and Geophysical Agency (BMKG); agriculture extension workers; and coffee and cacao farmers on their individual needs and challenges (Fig. 1, Steps 1 & 2). The key adaptation challenge identified was a decline in the effectiveness of the traditional ecological calendar to support coffee and cacao farming decisions. Historically, weather forecasts had not been used by farmers, who lacked communication with BMKG, and questioned the accuracy of their forecasts (as the result of past incorrect forecasts), their relevance (due to the spatial and temporal scale of their information), and their own strong belief in using a traditional agriculture calendar (*Sasih*). BMKG staff had conducted many training workshops with farmers to support the use of their climate information and had participated in a Climate Field School established 10 years earlier to offer a series of activities and workshops to communicate seasonal climate information. Nonetheless, farmers still preferred to base their agricultural decisions on their traditional ecological knowledge (TEK) supported by the *Sasih*, and BMKG officials were not inclined to provide TEK-based climate information because they believed it incapable of keeping pace with rapidly changing climate trends. Farmers wanted short-term solutions to unpredictable weather events; by contrast, BMKG valued long-term information based on climatic trends.

Integrating traditional ecological knowledge (TEK)

While the climate field school was not a novel concept, the use of Tandem added value to the programme initially through scoping questions (Fig. 1, Steps 1–2) to identify the types of actors to engage, and later, in establishing a shared understanding of their respective objectives, pluralistic values, and knowledge systems. The process supported BMKG, a conventional producer of climate information, in recognizing the role and value of farmers' knowledge in the knowledge co-production process as potential providers of information as well as users (Table 2).

After the Tandem scoping exercise the school consisted of two rounds of workshops to assess the context, review existing work, and requisite needs from climate services. The first pilot workshop conducted in Indonesia still resembled much of the BMKG-led field schools and did not create a co-productive environment; however, the workshop was one of the first convening events that brought all the relevant actors together. The dialogues highlighted the importance of addressing the disconnect between the actors and identifying the underlying reasons for the slow uptake of climate information by farmers.

The co-productive process created trust and identified opportunities to bridge the gap between farmers and BMKG highlighting the overlooked value of TEK in climate services. Quickly recognizing the previous lack of progress and the potential value of local knowledge, BMKG introduced a TEK module that integrated *Sasih*, the traditional Balinese calendar, in the second field school. This showed how TEK aligned with BMKG's climate information and further increased trust and rapport with farmers.

Table 2
Enabling factors, barriers, and the added value of the Tandem process in Indonesia.

Location Tandem steps applied	Barriers and enablers of the co-production process	Added value of applying the Tandem approach
Bali, Indonesia Steps 1–2, 5–7	**Barriers:** Information was perceived to be quite generic and not at the spatial or temporal scale needed by farmers or extension workers (i.e., local-level information needed); existing information was difficult to apply to the local context.	Increased trust and rapport between farmers and BMKG. The fuller role of BMKG as a source of climate information in the field was introduced to farmers through the CFS. Previously, BMKG was restricted to certain 'less remote' regions only.
	Training was reported to be quite technical, using specialist terminology: such information was difficult for farmers and extension workers to understand.	The value of TEK was previously quite tokenistic. BMKG came to genuinely value TEK throughout the collaborative process. It was empowering for farmers to witness that their wisdom, rituals and practices were important elements in creating climate information.
	Enablers: BMKG sought to make language more accessible (e.g., by using traditional language, concepts, and daily observations).	Future CFS integrating TEK with climate information became a standard approach employed by BMKG.
	Work built on long-established relationships with local partners in the region and activities embedded within long-standing initiatives such as the climate field schools.	

Fig. 4. Location of three Climate Field Schools with coffee and cacao farmers in Bali, Indonesia.
Source: authors

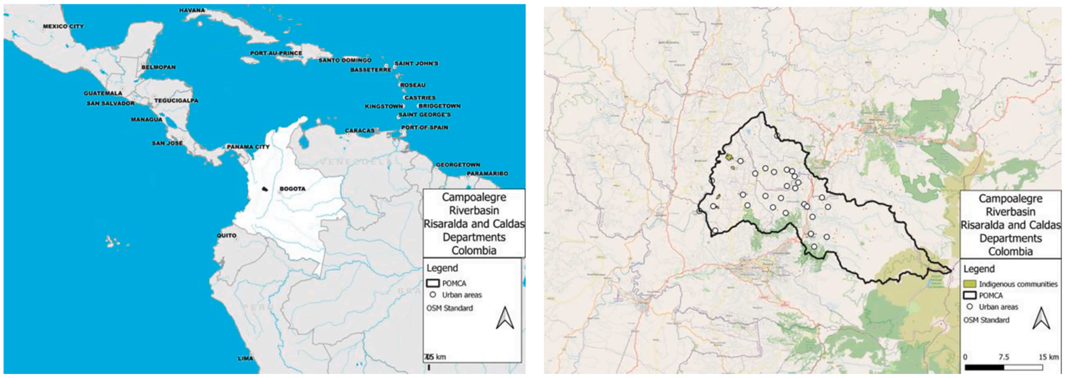


Fig. 5. Campoalegre River basin area in Colombia.
Source: authors

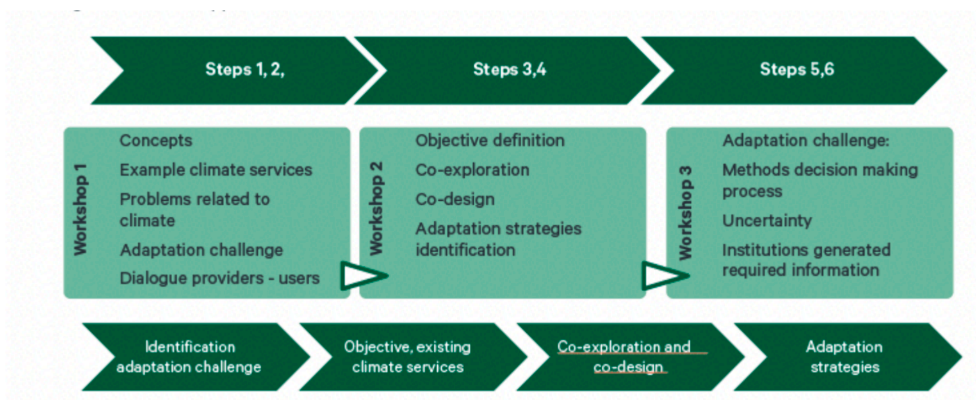


Fig. 6. Application of the Tandem process in Colombia. Each workshop was designed to provide insights and contextualized knowledge on steps described in the framework. Where appropriate, iterations were carried out, underscoring the non-linear character of this methodology.
Source: Santos Santos & Gerger Swartling (2020)

Formalizing the inclusion of TEK provided opportunities for the local community to articulate its needs and make better informed agricultural decisions. It was recognized by BMKG and the government that this could have wider implications across the region. A key outcome was that subsequent field schools began to integrate TEK with climate information as a standard approach, and this has become known as the School of climate and Living Tradition (SaLT).

2.2.2. River basin management in Colombia

In Colombia, Tandem was integrated into the formulation of the hydrographic basin management plan (*Plan de Ordenación y Manejo de Cuencas Hidrográficas,* identified by its Spanish acronym, POMCA) to ensure inclusive and adaptive land management and foster climate education and behavioural change in the coffee producing region of the Campoalegre River basin (Fig. 5). These plans were created with the involvement of a basin council, a participatory group that included representatives from local and regional communities and institutions that aimed to level up income and land inequality in the region. This participation takes place via a democratic process, in which each basin group – including farmers, municipalities, NGOs, indigenous populations, and the private sector – appoint two representatives to serve as members of the basin council (Santos Santos & Gerger Swartling, 2020).

A series of interviews with stakeholders and several workshops took place with the Basin Council. The first workshop focused on scoping (Figs. 1 & 6, Steps 1–2), with the basin council identifying the adaptation challenge, climate and non-climate risks, and reviewing existing climate services. It revealed that users found it hard to access information that they needed and even if they did find it, it was hard to use. For example, they struggled to translate rainfall forecast data into basin water flow and to understand the impact on community vulnerability. Further workshops focused on co-designing adaptation strategies (Figs. 1 & 6, Steps 5–6) using many different forms of engagement e.g. a social mapping process; drawing exercises to identify the usefulness of different kinds of climate information; individual questionnaires to validate proposed adaptation strategies; and group questionnaires to examine different roles in the council.

Considering gender and social equity in river basin management

Through participatory processes and iterative trust-building dialogues Tandem addressed underlying power dynamics at play among actors (Table 3). Factors to enable more sustainable and long-term outcomes included participatory co-productive exercises and building upon strong existing local partnerships, policies, initiatives, and networks. For example, a survey focusing on gender and social equity revealed challenges in climate information co-production due to an unequal valuation of knowledge (also apparent in the Indonesia case). This manifested in power dynamics in meetings and workshops where certain voices often dominated conversations, particularly at the start of the process. Representatives from institutions with more political, economic, or technical power (or expertise) were able to vocalize their needs to a greater degree. To address this, a subsequent workshop employed individual questionnaires to provide more opportunities to those who were dominated in group dialogues to provide input. A mapping process also allowed a better understanding of marginalized groups, such as women in the basin, and their differential experiences of

Table 3
Enabling factors, barriers, and the added value of the Tandem process in Colombia.

Location Tandem steps applied	Barriers and enablers of the co-production process	Added value of applying the Tandem approach
Campoalegre River basin, Colombia Steps 1–7	**Barriers:** Actors with greater responsibilities and tasks related to water management participated more in workshops. The challenge was to achieve dynamic and balanced participation of all groups. **Enablers:** Participatory co-productive processes, good existing local partnerships and building on existing policies, initiatives, and networks.	Strengthened relationships between stakeholders, basin councilors and entities responsible for environmental planning of the territory, leading to long-term engagement. Development of a new tool that "translated" model results and data into language that made the climate information "usable". Focusing on gender and social equity revealed challenges in climate information co-production.

vulnerability.

Through creative drawing exercises, workshop participants collaboratively designed a new graphical interface[3] for a climate service for the basin. This made available climate information more accessible and relevant to them. Stakeholders framed the objective of the climate service: 'To manage climate information to maintain the provision of ecosystem services in the Campoalegre River Basin'. Strategies identified together to reach this objective (Tandem Step 5) were:

- Restoring ecosystems
- Adopting better land-use practices
- Using water more efficiently
- Diversifying energy sources
- Cultivating alternative crops
- Gaining greater knowledge about climate, threats, vulnerabilities and adaptation strategies

The new tool "translated" model results and data into language that made the climate information "usable". This was seen as significant added value for water management and the basin council has continued to use this tool as a channel for obtaining climate information. The tool can be used by basin council members and institutions at no cost. While this tool is replicable in other places, it is dependent on a local co-production process for its design.

2.2.3. *Urban municipal planning, Sweden*

In Sweden, Tandem was applied in an urban-planning context in the cities of Karlstad and Stockholm (Fig. 7) through the HazardSupport project[4] – a collaboration with the Swedish Meteorological and Hydrological Institute (SMHI) and municipal officers from Karlstad and Stockholm in technical services, property management, environmental administration, and urban planning, building and development. The project aimed to address adaptation challenges related to increased flood risk in Karlstad and rising temperatures in Stockholm.

Set on the Klarälven River delta, Karlstad municipality sought to evaluate the potential effects of building a flood defense wall, to meet the demand for housing in the residential area of Skåre, while addressing risks of multiple water hazards in a changing climate from cloudburst events and spring floods. Stockholm sought to evaluate options to address heat stress in infrastructure planning while meeting the housing demands of a rapidly growing population. The focus for city officials (climate information users) in both cities was to enhance their understanding of adaptation challenges, evaluate different adaptation solutions (Fig. 1, Steps 5–6) and embed co-produced solutions in institutional contexts (Fig. 1, Step 7).

After co-exploring the adaptation challenges, SMHI conducted a series of scenario modeling and impact assessment exercises and identified climate services for both municipalities. For Karlstad, tailored climate impact information informed the municipality on the hydrological effects of building a flood defense wall (Berg, 2021). In Stockholm, two planning scenarios combining future summer temperatures and different distributions of green spaces at the regional level provided input to the future development of the city (Segersson and Amorim, 2020).

Understanding motivations, preferences, capacities and options

In the two Swedish urban cases there was a lack of scientific knowledge related to the identified adaptation challenges meaning that

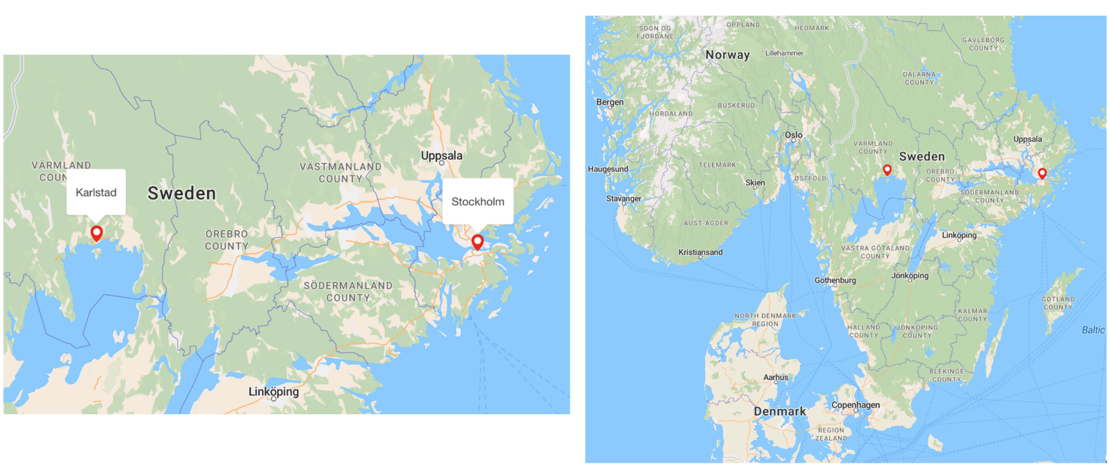


Fig. 7. The cities of Karlstad and Stockholm in Sweden.
Source: authors

[3] Graphical interface: https://latinoamericasei.shinyapps.io/Juego_Serio_POMCA_Campoalegre/.

[4] https://www.smhi.se/en/research/research-departments/meteorology/hazardsupport-1.96217.

it was sometimes hard to deliver exactly what stakeholders were asking for. Moreover, the long co-production-based process faced challenges such as staff turnover and a lack of continuity which negatively affected the process. Although HazardSupport had previously worked with stakeholders in Karlstad and Stockholm, Tandem helped to apply a structured co-production approach to identifying and exploring adaptation solutions resulting in rich and fertile discussions. The structure of the collaboration process – beyond workshops and other interim meetings – included regular meetings with a reference group engaging case study stakeholders, researchers and experts representing national agencies and consultancies. The reference group provided important feedback and reflected upon results from a wider societal relevance perspective.

The project benefited from the initial Tandem steps to scope the challenge and identify stakeholders and decision contexts (Fig. 1, Steps 1–4), especially in Stockholm where the adaptation challenge was a more recent phenomenon, where efforts focused on co-exploring information needs and embedding co-produced solutions in existing institutional contexts (Fig. 1, Steps 5–6). Stakeholders wanted to further co-explore previously proposed solutions (green infrastructure and a flood defense wall) that the municipalities had identified and assessed based on scientific data from SMHI and other knowledge providers. In both cases, this resulted in an iterative dialogue between SMHI and local stakeholders to co-develop credible, trusted and tailored data-driven scenarios. Thus, Tandem enabled a co-exploration of different motivations and capacities and in turn a deeper understanding of how different actors arrived at preferred solutions.

The Tandem approach revealed various enabling conditions for improving climate services co-production. It helped structure the project and emphasized an iteration of steps to identify and consolidate different understandings of the adaptation challenge and the data needs for modelling. This continuous, reflexive exchange allowed the co-developed technical models to remain usable and relevant in planning processes (Step 5). The iterative exchange of data and local experiential knowledge continued after the workshops, demonstrating the lasting relationships a well-designed and facilitated co-productive process typically builds. In follow-up interviews project stakeholders confirmed that the involvement of a diversity of actors and the iterative collaboration method were key success factors (Table 4).

Table 4
Enabling factors, barriers, and the added value of the Tandem process in Sweden. For further details, see André et al (2021).

Location Tandem steps applied	Barriers and enablers of the co-production process	Added value of applying the Tandem approach
Karlstad municipality, Sweden Steps 1–7	**Barriers:** Lack of scientific knowledge related to multiple hazards; staff turnover inhibiting process continuity; and a limited focus on exploring different adaptation measures. **Enablers:** Structure of the collaboration including external reference groups; inclusion of natural and social science expertise; previous relationships; the long timespan of engagement; and pre-existing knowledge and experience of extreme weather events/flooding.	Involvement of a diversity of actors and the iterative collaboration method was used to tailor outputs that evolved over time as needs, understanding and capacities changed. Knowledge about multiple hazards was used to improve understanding of the problem. Although defining the adaptation challenges and identifying the adaptation measures were gradual processes, through which awareness and momentum for addressing them have been growing over years, stakeholders were provided with more precise, tailored quantitative data in the new co-production processes. These insights fed into the planning process for a flood defense wall.
City of Stockholm, Sweden Steps 1–7	**Barriers:** Limited policy attention to heat stress in the past and a lack of municipal infrastructure to build on. **Enablers:** Structure of the collaboration including external reference groups; inclusion of natural and social science expertise; previous relationships; the long timespan of engagement; and the heat wave in the summer of 2018 that increased awareness and provided an opportunity to tap into the local environmental programme.	Results were mainly used to better understand the adaptation challenge and to motivate the search for more information. This information can be used in other contexts to address heat stress in planning. Results informed the City of Stockholm's Environmental Programme[1] as well as the Climate Adaptation Action Plan.[2] Based on new insights local policymakers gained awareness and were motivated to focus on heat stress and green infrastructure. The results also provided valuable planning support.

[1]https://miljobarometern.stockholm.se/content/docs/mp/2020-2023/environment-programme-sthlm-2020-2023.pdf.
[2]https://miljobarometern.stockholm.se/content/docs/tema/klimat/klimatanpassning/Handlingsplan-klimatanpassning-Stockholm-2022-2025.pdf.

3. Discussion: Added value of tandem

The case studies collectively demonstrate the multiple benefits of a process-centric and non-prescriptive approach to shared reflection and learning through the Tandem framework, supporting the development, uptake and use of climate information. This helps create trust and strengthened relationships and networks through the power that stems from convening a range of actors with different types of knowledge, increased capacity and confidence of both providers and users to create entry points and bridges across different problem and decision domains.

Interestingly, our study has highlighted a number of elements identified by Boon et al. (2024) as most relevant for defining a successful climate service for adaptation – that which is:

> *"relevant, credible, and accessible to users, acknowledges uncertainty, is communicated through a user-specific format, and is timely for user needs. It is developed by users and producers through tailored interaction, while building trust, and increasing users' capacity for using the service and understanding the issue at hand. The service delivers benefits to the user and supports better decision-making for adaptation" (Boon et al., 2024, p.5).*

Whilst there was disagreement about the importance of 'process' in the Delphi study that informed the definition a successful climate service above (Boon et al., 2024), all the attributes mentioned can be better supported through co-production processes as evidenced in our case studies and elsewhere (McClure et al., 2024).

3.1. *Increasing trust – moving from 'useful' to 'usable' climate information*

In Indonesia the process brought together farmers, agricultural extension officers and climate scientists from the national meteorological office (BMKG) to integrate scientific forecasts and the TEK used by farmers. A School of Climate and Living Tradition (SaLT) was introduced and supported by BMKG as a standard platform to integrate TEK into climate services. There was both an increase in information sharing from BMKG to farmers, through the delivery of regular weather bulletins at the time of the field schools, and in two-way communication, through a WhatsApp group allowing interaction between BMKG and participants.

Extension workers also appreciated the opportunity to advise farmers on weather forecasts. The current plan of the government is to expand the field schools to cover 16 additional crops. In Colombia, Tandem helped design a tool that translated "useful" hydrometeorological model results into "usable" climate information (according to councilors and institutions) and led to the formulation of a hydrographic basin management plan in its coffee producing regions. In Sweden, iterative knowledge exchange supported by Tandem produced data, numbers and knowledge about multiple extremes, more relevant to user needs, improving a shared understanding of the problem and the potential solutions by climate and impact researchers and city officials. This helped climate information producers better understand and tailor information to context, and users to better understand the climate science to inform adaptation decisions as well as its limitations. Users appreciated getting high quality, trusted information, which while not exhaustive, was considered "good enough" for decision-making (André et al., 2021). As of 2023, three years after project completion, results from the project have made their way into the City of Stockholm's climate adaptation plan (City of Stockholm, 2020). For the Karlstad case, the flood defense wall is in the planning phase, with construction expected to start in 2025.[5]

3.2. Institutional embedding through strengthened relationships and networks

The Tandem process itself established deeper connections, understanding and trust between actors, who already had existing relationships or created new ones. For example, the co-design of the climate service in the Campoalegre River basin that was carried out in 2019, led the same entities to request the Formulation of the Management Plan for the Campoalegre River basin (2020–2021). The results obtained in the Tandem application made it possible to quickly meet the collective information needs of the individual basin councilors and the other entities (Santos Santos & Gerger Swartling, 2020).

In Indonesia, established partnerships with local actors and an intermediary were enhanced by the bridging and iterative engagement process, setting the stage for the integration of TEK into the Climate Field Schools. This underscores the importance of the early scoping of existing processes and initiatives to embed and institutionalize actions (FCFA, 2015), and increase the likelihood of sustainability beyond the lifetime of the project.

In Sweden, a severe heatwave in Sweden in the summer of 2018 pushed adaptation challenges higher up the agenda. This facilitated communication on the need to consider heat stress with a wider group and increased the importance of the relationship and actual collaborations between SMHI and the City of Stockholm creating an opportunity to inform the city's climate adaptation plan.

3.3. Improving climate information uptake and use for planning and decision-making

In Bali, the Tandem scoping steps (Fig. 1, Steps 1–4) that built a shared understanding between users and providers of climate information were some of the most essential activities given the initial disconnect between the actors. Providing climate information in context-relevant formats, at appropriate temporal and spatial scales and using tailored language is key to uptake and use (Briley et al., 2015, Adams et al., 2015, Djenontin and Meadow, 2018, Jones et al., 2017). By integrating diverse knowledge systems, replacing technical terminology with traditional language and concepts, and using daily observations (as opposed to seasonal), BMKG increased climate information legitimacy and uptake by farmers.

In Colombia, the application of Tandem was carried out individually and in groups, which allowed differentiation between users' information and capacity needs. This enabled the climate service to visualize different graphical outputs according to the type of user, improving the relevance and understanding of climate-related information and thus improving uptake and use. For example, the new climate service presented hydrological model results and forecast information using qualitative descriptions (e.g., high, medium or low) to translate to levels of risk or impact. This helped stakeholders understand the meaning of a specific variables in the real-world context (e.g., *high* precipitation in the short term could produce landslides or floods, whilst *high* temperatures in the long term could produce changes in vegetation). The co-designed graphical interface that translated hydrometeorological data into accessible, relevant and usable information for basin planning continues to be used. This process enhanced capacity and confidence in working with and recognizing the limits of climate information (e.g., Jack et al., 2020; Cortekar et al., 2017; Bruno Soares and Dessai, 2016; McClure et al., 2024).

In the Swedish case study, an important step was the co-exploration and re-assessment of information needs and adaptation solutions in the middle of the co-production process. This step helped to clearly define and specify user needs in relation to what would be feasible to deliver from the climate producers' point of view. This shows the importance of an iterative, co-production process where input from both users and producers is essential to shape the *relevance* and *usability* of the climate service. In Stockholm, the process was also anchored in regional planning scenarios which was key for the users in terms of developing relevant climate information that they could use in their future work. By starting from these regional planning scenarios there was a direct link to the institutional context that facilitated the uptake of the information.

3.4. Increasing capacity and confidence of users and providers

The Tandem co-production process can increase understanding and capacity of providers, as well as users, intermediaries and boundary organizations reducing the "usability gap" (Lemos et al., 2012), and in turn increasing the opportunities to further tailor climate information to context to make it more *relevant* and *accessible* for different users (e.g., Attoh et al., 2022). For example, in Indonesia, BMKG staff gained a better understanding of TEK, and the co-production process allowed a better appreciation and respect for the knowledge of both groups of stakeholders. By also developing capacity for better of understanding climate information, Tandem empowered farmers to co-explore different and alternative farming methods based on the information provided which they previously had not trusted. The definition of a successful climate service above (Boon et al., 2024), does not explicitly mention that the capacity of producers is also increased, alongside that of users' despite recognizing the benefit of better producer understanding of user needs and decision-making context in the Delphi study. We suggest that intangible benefits are not only 'the feeling of helping others, or input for scientific papers' (Boon et al., 2024, p.3) but also the increased capacity of climate providers in understanding of context so that climate information provision can be improved as shown in the case studies and earlier application of Tandem (Daniels et al., 2020). This ideally happens in parallel with an increased understanding by users of the use, limits and applicability of climate information (e.g. Jack et al., 2020; McClure et al., 2024).

In Colombia, watershed councillors had two roles: one as inhabitants of the watershed as coffee farmers, hydropower generators, public service providers, members of Indigenous Peoples communities, municipal governments, universities and community organizations; and the other as watershed councillors who needed to understand the watershed and its relationship with the current and future climate in an integrated manner. The dialogue between providers and users made it possible to use a shared language to describe the climate information based on specific needs in a local context. An online platform was thus co-developed with basin councillors to analyze how land use activities in

[5] https://karlstad.se/karlstad-vaxer/projekt/skare—oversvamningsskydd.

the Basin Management Plan would be affected by climate change.

In Sweden, the co-production process equipped users with knowledge that gave them a better understanding of hazards, their impacts and potential adaptation measures. Many perceived themselves as better armed with more precise, user-relevant, quantitative information, confirming previous assumptions, especially regarding the role of green infrastructure to mitigate high temperatures. This further facilitated internal and external communication between decision-makers and the general public to increase awareness and gain support for adaptation measures.

3.5. A non-prescriptive guide for collaborative and iterative learning

In Indonesia, the increasing benefits of successive workshops demonstrated how the iterative nature of Tandem helped hone a better understanding of the adaptation challenge for all actors. In Sweden, the structure of the collaboration – with external reference groups, both natural and social science expertise, and long timespan – was identified as an enabling condition. In Colombia, watershed councillors had varied levels of technical expertise and required climate information that they could all easily understand and use to appraise actions against varied future scenarios using multiple variables (e.g., population growth, climate change impacts, and changes in human activities). Various mapping exercises and individual interviews guided by Tandem's questions enhanced the inclusion of often marginalized voices. A survey focussing on gender and social equity considerations drew these elements out further to capture pluralistic values, norms, perspectives, needs, and preferences of a wide variety of participants and stakeholders.

4. Refining and improving tandem

Learning from the application of Tandem (Section 2) and its added value (Section 3), in this section we explore how Tandem can be improved to further enhance the co-creation of climate services that support accelerated, inclusive and equitable climate resilient action. Improvements suggested by the case study evidence are documented below with complementary refined or new Tandem questions (Fig. 3).

All questions in the updated Tandem guidance (Supplementary Material) have been revised and revisited in the light of this empirical research. For example, linkages between questions within the guidance have been identified with symbols (±denotes that the question is cross-cutting with another element and may provide useful inputs to it), which will be helpful when designing and facilitating knowledge co-production processes, ensuring stakeholder engagements and exercises build upon one another, rather than being disjointed. The guidance also includes suggested exercises and methods to support co-exploration of each element of the guidance.

4.1. Scoping and reviewing (climate and non-climate) vulnerability and risk

Researchers and practitioners in the case studies found that 'scoping' and understanding the different climate (and non-climate) context-specific vulnerabilities and risks before identifying the priority adaptation challenges was important. For instance, in Colombia, interviews started with an unstructured process that allowed council members to identify climate and non-climate stressors. Stakeholders used maps to identify areas where they experienced environmental or social impacts, such as vulnerable landslide zones, marginalized communities, or municipalities where people experienced water shortages – some of these may be unrelated to or indirect impacts of climate change. This stage is important to co-explore all stressors which may intersect with, or be compounded by other risks and impacts to exacerbate vulnerability, create new types of sensitivity or increase the potential for maladaptation.

In Colombia, climate-related concerns included the effect of droughts on hydropower facilities; the effects of water availability, floods, and human health risks to municipalities; and, the impact of changes in temperature and precipitation patterns on farmers and agricultural communities. Participants identified important vulnerable ecosystems such as the Páramo ecosystems (alpine tundra regions), where climate change may alter their lower boundaries. In this river catchment, risks were primarily related to landslides, mainly in coffee areas during high precipitation periods. However, indirectly, supply systems could also become vulnerable because landslides may affect infrastructure, and sedimentation may affect water quality. Energy generation could also be affected in drought periods (Santos Santos & Gerger Swartling, 2020).

In Karlstad, awareness that the adaptation challenge was not limited to addressing river floods, but also cloudbursts gradually increased. The severe cloudbursts that had caused the closing of major roads and the disruption of rail services in 2014 triggered a realization that "there are multiple hazards that may happen simultaneously" (municipal officer, Karlstad, André et al., 2020).

Some Tandem guidance already existed regarding these elements but these have been emphasized earlier (see Table 5 containing new questions). As such a new 'scoping' and 'review' element has been added, which increases the focus on identifying both climate and non-climate risks and vulnerabilities, reviewing and building on existing climate information or services, and identifying the multiple actors that may need to be consulted on the same issue, due to their varying levels of sensitivity and adaptive capacity. However, these questions are equally important to cover if the scoping stage is not needed, thus they are also retained in Element 2 – Co-explore.

4.2. Power dynamics, gender and social equity considerations

Another lens is that of gender and social equity to co-explore power dynamics that may impede climate adaptation planning and implementation. In Colombia, institutions with more technical, economic, and political power dominated group dialogue, and thus, individual interactions were necessary and allowed for more holistic representation of basin actors. Here, it was found that women spent more time transporting water from sources further away to meet household needs, if local fresh waters sources such as aqueducts were affected by droughts or landslides (Santos Santos & Gerger Swartling, 2020).

In Indonesia, the co-productive process was important to build trust between local farmers and national level climate scientists to the degree that their knowledge could be given equal consideration in the process and in the development of training or in capacity development activities. These strengthened relationships led to the recognition of the value of TEK and the normalization of this as part of the Climate Field Schools. These experiences also highlighted the need to employ different formats of engagement to avoid unwanted power dynamics (Table 6). As such, suggestions for different exercises are included in the updated Tandem guidance.

4.3. Local and traditional ecological knowledge (TEK)

Historically, TEK was not considered by Indonesian meteorological services providing forecast information or delivering the climate field schools. This slowed down the rate of climate forecast uptake and decreased its relevance, credibility and legitimacy amongst farmers. Tandem's transdisciplinary nature means other knowledge types are key to co-explore. However, references to 'other' knowledge in the guidance were adapted so that TEK was on equal footing with scientific knowledge and was not at risk of being considered 'additional' when the guidance was applied (Table 7). This is important for building on opportunities to bridge and integrate across different knowledge systems and disciplines. For example, in various southern African contexts, this has been achieved through climate risk narratives (Jack et al., 2020), which are stories of the future that can incorporate a range of knowledge

Table 5
Updated guidance in the Scoping and Review element of the Tandem framework and sample evidence for gaps. ± Denotes that the question is cross-cutting with another element and may provide useful inputs to it.

Framework element	Evidence for gap	New Tandem guidance questions	Description and notes on application
1 a) Scope and review risks, vulnerabilities, challenges and decision context (optional, not always needed)	Stakeholders in the Campoalegre River basin identified vulnerable landslide zones, recurrent floods, municipalities water shortages and other socio-economic activities affected by climate risks through a participatory mapping process.	What are the greatest challenges within the decision context that do not allow safe living conditions or a good quality of life? What are the socio-economic challenges in the region, (including factors beyond the control of decision-makers) e.g., that affect access to or management of different resources? What is the current use of climate information – what relevant climate services or reports are available with regards to other risks and impacts (disaster, environmental, social etc.)? What are the different communities and activities at risk? How does vulnerability differ amongst groups and activities? Why are they vulnerable? *Be open to sources of vulnerability that are not necessarily related to climate.* E.g., *related to dynamic social vulnerability.* Where are the most vulnerable areas and why are they vulnerable? Be open to vulnerability that is not necessarily related to climate. E.g., related to ecosystem services. What types of vulnerability exist (e.g. socio-economic) that are not necessarily related to climate and what drives this vulnerability? Do climate or weather events and impacts affect/exacerbate these challenges, and if so, in what way? Is there any risk of exacerbated vulnerability here or elsewhere, due to compound or cascading risks? What language is used by different actors to describe the same concepts e.g., related to risk, vulnerability, resilience etc.? Can less technical (or local) language be used? How do these terms translate into the day-to-day work of actors? Can a shared understanding of different terms and their usage be reached? ±**Communication**	This stage follows an unstructured approach to co-explore issues that are not just focussed on direct climate risks or impacts. Co-explore and review existing challenges, which may or may not be climate related. Focus on different areas of (non-climate) vulnerability as well as the indirect impacts of climate change. Come to a shared understanding of the problem and prioritize the key issues to delve into more detail on. Start to review current use of climate information, climate services, available reports and relevant material with regards to other risks and impacts. Identify possible decision support needs for adaptation planning that increase climate resilience. Scope potential needs and interests of different stakeholder groups for the next stage, 'Identifying and engaging actors'. For the different actors identified, prioritize the adaptation challenges that are most pertinent to deal with first.

types and perceptions equally, as a vehicle for discussion.

Integrating TEK into conventional climate services offers an opportunity to strengthen the ability of local and Indigenous Peoples to anticipate, absorb and adapt to the impacts of climate by using knowledge based on their long experiences with their environment. Importantly, this integration is also crucial to enable the transmission and continuity of TEK to succeeding generations.

4.4. *Co-exploring horizontal and vertical governance at the appropriate decision-making scale*

Recognizing the complexities of politics, power and the informality of many policy and planning processes and understanding both horizontal and vertical governance (both formal and informal) can address the lack of coordination and collaboration between and within siloed institutional departments. Tandem recognizes this in its underlying questions and shows the importance of creating multi-stakeholder partnerships, platforms and networks that connect actors in coordinated and strategic ways through engagement in participatory processes. However, the case studies show that these questions also need to be considered from the appropriate scale of decision-making, for example at the individual smallholder farmer level in Indonesia or at the community representative level in Colombia, as well as at institutional planning and policy scales in Sweden (where many different levels may need to be considered) (Table 8).

As illustrated in Stockholm, civil servants in Swedish municipalities may often work in silos on their institutional mandate. For a city planner, green infrastructure was one of the few institutionally acceptable options for dealing with heat waves. Other possible measures (updating elderly care routines, for example) may fall under different department mandates. Since adaptation measures must often address concerns other than climate risk, it is important to ensure dialogue across municipal departments to break down these silos which lead to fragmented policy and planning and possibly increase vulnerability or the risk of maladaptation. In Stockholm, heat stress mitigation is only one among many arguments for green infrastructure and until recently this solution and the heat waves agenda developed largely independently, reiterating the issue that climate information itself is only one among many considerations for practitioners (André et al., 2020). However, in Swedish municipalities there are usually many different actors involved in community and regional planning. Accordingly, involving and facilitating a dialogue with a broader set of stakeholders could possibly increase the saliency and (long-term) robustness of the results and process (see e.g., André et al., 2021).

Table 6
Updated guidance in the Actor Identification, Engagement and Co-exploration elements of the Tandem framework and sample of evidence of gaps. ± Denotes that the question is cross-cutting with another element and may provide useful inputs to it.

Framework element	Evidence for gap	New Tandem guidance questions	Description and notes on application
1 b) Identify relevant actors, affected groups, decision makers and champions	In the Campoalegre River basin Council, men had a higher representation. There were groups that were not included in the decision-making process. Finding ways to include these groups motivated engagement and increased the potential for change.	In all participatory processes planned, is there a balanced representation across gender and other social identities? If not, can this be addressed? Is there a difference in the capacity of men and women or other groups (e.g., differentiated by socio-economic status, ethnicity, race, etc.) to face the challenges identified? Consider the impacts of these varying levels of sensitivity and adaptive capacity when planning adaptation interventions. ± **Communication**	Identify and engage actors in the knowledge co-exploration and co-production process for whom climate information is useful i.e., this may include both actors who do and do not have power to influence decision-making regarding the adaptation challenge and related issues, but who are affected by it. Identify and engage collaborators, particularly local intermediaries and boundary partners. Depending on power, gender, other social identities, and knowledge dynamics, it may be important to have a mixture of individual and small group discussions where all feel comfortable, rather than only larger group interactions. You may need to employ different methods of engagement, such as individual interviews / questionnaires / surveys etc. to avoid power dynamics, that may present themselves.
2 b) Co-explore governance context	Initially workshops in Colombia were dominated by certain voices, often experienced older males with a lot of technical experience who influenced decisions.	Is there any difference in representation (e.g. of men and women, other social identities or knowledge types) in the decision-making process, that affects use of, or access to climate information? Does this representation affect the management, use of, access to, and/or distribution of resources? e.g., for different economic activities, for household consumption etc. Is there any difference in representation (e.g., of men and women, other social identities or knowledge types) in their ability to influence the decision-making process? Are there gender or social identity-related differences within the legal framework related to the control of resources?	Consider different levels of engagement of actors and their knowledge in decision-making when co-designing co-production activities. For example, gender-based, formal or informal. You may need to employ different methods of engagement, such as individual interviews / questionnaires / surveys etc. to avoid power dynamics that may present themselves.
2c) Co-explore information needs	In the case of Colombia and Indonesia, climate information was initially presented to stakeholders in a technical way. The information was not tailored to local knowledge, context, scale, or specific groups (e.g., extension workers and farmers). Moreover, the climate information systems were unknown to many of the groups involved.	What differentiated information (and formats) are needed by different individuals and user groups at different temporal and spatial scales? (e.g. are there multiple aims for climate information identified in the earlier stages)? ±**Communication** Are data available to represent the different vulnerabilities identified earlier (including social vulnerability), and include them in any further analysis? If not, can this information be presented in other ways? ±**Communication** Are adequate training and capacity development available for the use of climate information, services or tools? Do these require technical or specialist knowledge and are they tailored to the local context? **±Capacity Development**	Aim to provide a comprehensive understanding of: specific climate data, language and information required by users; the capacity building interventions needed to interpret and apply it; and, how this information is best presented and communicated to support its uptake and use.
CROSS-CUTTING ELEMENTS			
Communication	Tandem improved the relevance and understanding of climate-related information and plans in the Campoalegre River basin of Colombia. This was achieved through the creation of shared terminology that aided the understanding of climate information e.g., the effect of precipitation on water flows in the basin and the differential impacts on community members.	What language is used by different actors to describe the same concepts e.g., related to risk, vulnerability, resilience etc.? Can less technical (or local) language be used? How do these terms translate into the day-to-day work of actors? Can a shared understanding of different terms and their usage be reached? **(this is ideally also addressed in the element above).** How do climate services and specific resource managers, e.g., water, communicate with communities? What participatory means of	The aim is to improve the relevance, credibility, legitimacy and useability of climate-related information. According to gender roles and other social identities, climate information communication needs are also different. To have a better understanding of these differences, gender/ identity-sensitive communication questions are recommended.

(*continued on next page*)

Table 6 (*continued*)

Framework element	Evidence for gap	New Tandem guidance questions	Description and notes on application
		communication are used? In participatory communication processes, are needs across gender and other social identities considered? If not, how can this be addressed? Which other actors should be engaged as part of a broader dissemination and engagement strategy (e.g. through demonstrations and presentations)?	

Table 7
Updated guidance in the Co-exploration element of the Tandem framework and evidence for gaps.

Framework element	Evidence for gap	New Tandem guidance questions	Description and notes on application
2 a) Co-explore challenges and goals ***This early stage may reveal useful impact indicators to co-develop with stakeholders for monitoring progress towards achieving shared goals.***	An obstacle in the Indonesian and Colombian cases was not giving equal value and visibility to different knowledge types. In Bali, identifying the differing objectives of all those involved to identify a shared goal was key. These conversations were facilitated in a cohesive, collaborative way to avoid excluding any valid viewpoints or needs. This achieved an increased recognition of the value of TEK and its integration with scientific climate information.	What is the range of knowledge, perception and experience of different actors (e.g., local farmers, agricultural extension officers, climate scientists, city planners, private sector, technical advisors, policy makers) on climate risks, adaptation challenges and solutions to identify synergies? How does this compare to more conventional, climate science perspectives and can they be connected or linked in some way? Are there opportunities to bridge or integrate scientific, indigenous and local knowledge systems? e.g., seasonal climate forecasts and traditional forecasting systems based on cultural beliefs about nature and ecology	It is useful at this stage to co-explore perceptions of climate change, development and adaptation challenges and solutions from multiple perspectives (e.g., local farmers, agricultural extension officers, climate scientists, city planners, private sector, technical advisors, policy makers, etc.), to identify synergies and potential silos. Finding ways to build trust and credibility, acknowledging differences in pluralistic values, norms, preferences and viewpoints, is key to a sense of ownership and uptake.

Table 8
Updated guidance in the Co-exploration elements of the Tandem framework and a sample of evidence for gaps. ± Denotes that the question is cross-cutting with another element and may provide useful inputs to it.

Framework element	Evidence for gap	New Tandem guidance questions	Description and notes on application
2 b) Co-explore governance context	Different solutions may be available and feasible, but this is not always discussed across departments resulting in siloed decision-making. That is, there is a lack of consideration of different levels of engagement of actors in decision-making. For example, formal or informal at the policy, institutional, or individual level and in terms of horizontal as well as vertical planning and policy. Adaptation measures often need to serve many different purposes beyond climate risks (e.g. in the Swedish cases).	How much horizontal and vertical coordination and collaboration exists in key organizations to support joined up planning, policy and action? How do adaptation solutions affect different stakeholder interests? Are there any synergies/mutual benefits and/or conflicts with other goals and policies? Are multiple risks being considered (climate and non-climate) and is there any risk of maladaptation, compound or cascading effects in other departments, sectors or locations? Are there multiple decision-makers at different levels and scales, for whom different climate information (and formats) would be required based on the different types of decisions they are making? (such as 'community groups' or households). ± **Communication** What decisions (e.g. at the policy, institutional or individual level) address the adaptation challenge and may benefit from a climate service or better climate information? How are these decisions made currently?	Reach mutual agreement on roles and responsibilities and how engagement throughout the process will be managed (a shared understanding and joint ownership of the process). Co-create a clear understanding of the decision and institutional contexts in which the climate service will be used. Identify windows of opportunity for integrating climate information to operationalize and institutionally embed it. Co-explore and assess adaptation solutions based on different stakeholder perspectives.

4.5. Agile starting points with early identification of impact indicators

In the Swedish case studies, the process of co-identifying adaptation challenges was integral to the discussion on solutions and having been discussed previously, a detailed scoping and review phase was not needed. Conversely, in Colombia, more guidance was needed to build a better understanding of the context prior to identifying and engaging stakeholders, so further scoping and review questions were needed. Element 1 (Table 9) has been added to help collectively identify the key issue(s) and thus, relevant stakeholders to engage with, in the first instance. As such, the Tandem process can be embarked upon at any stage, and this is more transparent in the circular, updated version (Fig. 3) of the framework as opposed to the earlier stepwise framework (Fig. 1). This process is far from linear. It is complex and messy (Vogel

Table 9
High-level overview of the guidance reflecting the updated version illustrated in Fig. 3.

Element	Description and notes on application
Scope, review identify and engage	
The processes in Element 1 can lay the foundation for deeper discussions of challenges, goals, governance and information needs in Element 2.	
1 a) Scope and review risks, vulnerabilities, challenges and decision context (optional, not always needed)	Initial scope and review of the risks, challenges, climate information and decision context (climate and non-climate).
1 b) Identify relevant actors, affected groups, decision makers and champions	This element helps to identify and engage relevant actors and champions and can begin to nurture new collaborations and partnerships that sustain beyond the lifetime of the project.
1 c) Engage relevant actors & champions	Many of these questions will be returned to in later stages and understanding of the issues increases.
Co-explore – go deeper	
Questions on socio-economic challenges (Element 1) are equally important to cover (even if the scoping stage is not needed because previous work has been done), so they are also included in Element 2. *This is an opportunity to delve deeper into some of the same questions with the targeted group of stakeholders that has been identified in Element 1.* *This may start to reveal some context-led impact indicators for monitoring progress towards achieving shared resilience goals.* *Many of these questions will be returned to in later stages, as understanding of issues, capacity and confidence increase.*	
2 a) Co-explore challenges and goals	This early stage may provide opportunities to co-develop context-led impact indicators with stakeholders for monitoring progress towards achieving shared goals.
2 b) Co-explore governance context	Consider the different types, scales and levels of participation, engagement and knowledge in decision-making when co-designing co-production activities. Also consider risks of maladaptation, compound and cascading risks.
2 c) Co-explore information needs	Co-explore information needs, data, models, sources, assumptions and formats Understand specific climate data and information required by users; the capacity building interventions needed to interpret and apply it; and, how this information is best presented and communicated to support its uptake and use.
Co-design solutions	
3. Co-explore, identify, appraise and co-design solutions	Appraisal should include consideration of uncertainty, maladaptation, compound and cascading risks, synergies, trade-offs and co-benefits.
Integrate new knowledge and partners	
4. Apply iterative and reflexive learning to deepen understanding of adaptation challenges. Monitor progress towards goals as confidence, knowledge, relationships and capacity increase.	MEL considerations should be integrated throughout the elements above and any learning should further refine and hone iterative co-exploration and co-production processes. Regular and systematic feedback mechanisms are established.
Cross-cutting elements and benefits provided by the processes above	
Communication	Tailored communication of climate and other information to meet user needs with appropriate, relevant formats and terminology.
Capacity development	A focus on developing the capacity of providers to understand the decision context as much as the capacity of stakeholders to understand the use and limits of climate information.
Partnership development	Strengthened relationships, partnerships and networks can be a valuable outcome and sustainable legacy of the co-production process.
Financing models	Strategy to sustainably embed, operationalize and institutionalize the climate service.

et al., 2019) but its strength lies is its agile, iterative, reflexive nature to delve deeper as learning, confidence and capacity around the application, limits and use of climate information increase among *both* producers and users of climate information (Daniels et al., 2020; McClure et al., 2024).

Lastly, all three case studies highlight the need for MEL frameworks, as creating a culture of learning and reflection is emphasized in the guidance. André et al. (2021) discuss criteria to evaluate knowledge co-production that go beyond established criteria to assess quality (e.g. credibility, legitimacy, saliency, usability and usefulness). Since co-production processes also create many non-tangible outcomes that are difficult to measure (Daniels et al., 2020), co-developing impact indicators that monitor progress towards resilience goals are re-emphasized early in the Tandem guidance. These can be more effectively co-designed together with stakeholders to strengthen ownership and sustainability (Visman et al., 2022).

5. Limitations and next steps

The Tandem framework was explicitly designed as a non-prescriptive guide and is not exhaustive in scope. The design and facilitation skills required for such engagements are key and example exercises were largely lacking from the original guidance. Suggestions on how Tandem workshops could be structured and facilitated through various exercises have been included in the updated guidance to help co-explore the underlying questions (see Supplementary Material).

Given the significant benefit of the enhanced gender and social equity lens, future Tandem studies should also integrate questions that interrogate any potential power dynamics and knowledge biases that are context specific and may go beyond what is available in the more general Tandem questions on this. However, gender framing also tends to be heteronormative which is detrimental to individuals belonging to other others. How can we ensure that when Tandem speaks about gender, we mean it in its fullest form, that is SOGIESC (sexual orientation, gender identity, gender expression and sex characteristics). Related to the earlier point, this may require exercises that can address sensitive questions e.g., using social network mapping to identify power relations, gender identities in all aspects, and existing and/or different forms of knowledge types and flows.

Tandem requires a carefully designed, negotiated and iterative process and this may be a challenge in time bound projects with limited and predefined allocation of resources and staffing (cf. Wyborn et al., 2019).

For example, a challenge to many projects undertaking this type of intensive stakeholder collaboration is often staff turnover within the organizations involved (Keeley et al., 2019). This can cause difficulties regarding continuity of the process and confusion regarding expectations and outputs. This is also expected to negatively influence opportunities for creating relationships beyond the project. On the other hand, there is no short cut to managing complex problem solving collectively and achieving long-term sustainability (Underdal, 2010). This speaks to the need to build capacity on the facilitation of knowledge co-production processes with intermediaries and boundary partners early on, to increase the likelihood of building a legacy for this approach when participants change roles.

Finally, MEL is notoriously hard to carry out due to the difficulty in attributing outcomes to interventions, particularly when many purported benefits of Tandem are 'soft' or intangible in nature, making them challenging to measure (e.g., capacity, networks, relationships, trust, rapport). However, there are emerging efforts that can support this process in the field of climate services co-production building on standards and principles in adaptation (André et al., 2021; McClure et al., 2024), humanitarian and development sectors (Visman et al., 2022) and agreed upon attributes and definitions of climate services (Boon et al., 2024).

6. Conclusions

This paper set out to empirically validate and further refine the Tandem framework that has been developed to support climate information providers, users, researchers, practitioners and policymakers to collaboratively co-design climate services for adaptation. Three case studies in diverse settings show that Tandem has proven beneficial as a holistic, flexible, stakeholder-oriented, context-led and decision-driven approach for co-designing climate services with rich stakeholder engagement. The experiences from these case studies led to insights that underpin the updated framework outlined in this paper. The case studies were conducted in distinct geographic, socioeconomic and development contexts: a farming region in Indonesia, two cities in Sweden, and a river basin in Colombia. In Indonesia, the co-productive process created trust and identified opportunities to bridge the gap between farmers and the national meteorological services BMKG, highlighting the overlooked value of traditional ecological knowledge (TEK) in climate science and communication. This resulted in scientific forecasts and TEK to be combined in climate field schools. In Sweden, Tandem supported a continuous exchange of knowledge on climate data and the motivations for adaptation solutions planned in two cities increasing the capacities of both climate information providers and users and aiding the urban planning process. In Colombia, Tandem helped translate complex model results into "usable" climate information for a basin management plan in its coffee producing regions. To achieve these valuable outputs, we found that Tandem has to varying degrees helped: 1) move from 'useful' to 'usable' information by building trust; 2) increase institutional embedding through strengthened relationships and networks; 3) improve climate information uptake and use; 4) increase capacity, confidence and a shared understanding of climate information by users, and the decision context by providers; and, 5) served as a non-prescriptive guide for users, intermediaries and providers to co-design and structure an effective process for collaborative learning and action.

We updated the framework to place greater emphasis on five key areas: 1) scoping and reviewing differentiated climate and non-climate vulnerability and risks; 2) incorporating gender, social equity and power considerations; 3) acknowledging the value of local and traditional ecological knowledge; 4) co-exploring horizontal and vertical governance at appropriate decision-making scales (formal and informal); and, 5) being agile, providing flexible starting points, with early identification of impact indicators.

Both the original and updated frameworks highlight the importance of leveraging the convening power inherent in assembling different actors and knowledge types together to build trust and create entry points for new relationships, networks and bridges across multiple domains and disciplines. The new iteration is intended to give climate services providers, intermediaries and users additional, practical ways to deal with the involved processes' inherent messiness and complexity. Further work is needed on developing MEL frameworks within Tandem and applying the guidance in new and varied decision-making contexts to increase its robustness and widen its applicability and usability. It is promising that new European Commission Horizon Europe projects (e.g., Directed[6] and AGORA[7]) demonstrate their ambitions to do this.

Funding

We are grateful for the support this research received. SEI's Initiative on Climate Services was supported by the Swedish International Development Cooperation Agency (Sida). The HazardSupport project funded was by the Swedish Civil Contingencies Agency.

CRediT authorship contribution statement

S. Bharwani: Conceptualization, Formal analysis, Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing. **Å. Gerger Swartling:** Conceptualization, Formal analysis, Investigation, Writing – original draft, Writing – review & editing. **K. André:** Conceptualization, Formal analysis, Methodology, Writing – original draft, Writing – review & editing. **T.F. Santos Santos:** Formal analysis, Methodology, Writing – original draft, Writing – review & editing. **A. Salamanca:** Conceptualization, Investigation, Methodology, Writing – original draft, Writing – review & editing. **N. Biskupska:** Conceptualization, Investigation, Methodology, Writing – original draft, Writing – review & editing. **T. Takama:** Conceptualization, Investigation, Methodology, Writing – original draft, Writing – review & editing. **L. Järnberg:** Conceptualization, Investigation, Writing – review & editing. **A. Liu:** Methodology.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Sukaina Bharwani is an Editor of the Climate Services Journal.

Data availability

The authors do not have permission to share data.

Acknowledgements

Our heartfelt thanks go to members of the Arabica Bajawa Coffee Cooperative in Flores and Pak Rikardus of LAPMAS for supporting our fieldwork, BMKG for the partnership, Officials of City of Stockholm and Karlstad municipality, SMHI, basin councilors and stakeholders in the Campoalegre River Basin, and Karen Brandon (SEI) for editing.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cliser.2024.100503.

References

Adams, P., Hewitson, B., Vaughan, C., Wilby, R.L., Zebiak, S., Eitland, E., Shumake-Guillemot, J., 2015. Call for an ethical framework for climate services. WMO Bull. 64, 51–54. https://dspace.lboro.ac.uk/2134/20128.

[6] https://directedproject.eu/.
[7] https://adaptationagora.eu/.

André, K., Järnberg, L., Gerger Swartling, Å., 2020. Co-Designing Climate Services to Support Adaptation to Natural Hazards: Two Case Studies From Sweden. SEI Discussion Brief. Stockholm Environment Institute, Stockholm.
André, K., Järnberg, L., Gerger Swartling, Å., Berg, P., Segersson, D., Amorim, J.H., Strömbäck, L., 2021. Assessing the quality of knowledge for adaptation-experiences from co-designing climate services in Sweden. Front. Clim. 3, 636069 https://doi.org/10.3389/fclim.2021.636069.
Attoh, E.M.N.A.N., Goosen, H., van Selm, M., Boon, E., Ludwig, F., 2022. Climate services for the railway sector: A synthesis of adaptation information needs in Europe. Front. Clim. 4, 968298 https://doi.org/10.3389/fclim.2022.968298.
Berg, P. (2021). HazardSupport: Översvämningsrisk i Skåre [Hazardsupport: Flood risk in Skåre], Myndigheten för samhällsskydd och beredskap (MSB) [Swedish Civil Contingencies Agency] MSB Report: MSB1678, January 2021, ISBN: 978-91-7927-094-0, available in Swedish on: https://www.msb.se/sv/publikationer/oversvamningsrisk-i-skare/.
Biskupska, N., Salamanca, A., 2020. Co-Designing Climate Services to Integrate Traditional Ecological Knowledge: A Case Study From Bali, Indonesia. SEI report, Stockholm.
Boon, E., Meijering, J.V., Biesbroek, R., Ludwig, F., 2024. Defining successful climate services for adaptation with experts. Environ. Sci. Policy 152, 103641. https://doi.org/10.1016/j.envsci.2023.103641.
Brasseur, G.P., Gallardo, L., 2016. Climate services: Lessons learned and future prospects: CLIMATE SERVICES. Earth's Future 4 (3), 79–89. https://doi.org/10.1002/2015EF000338.
Bremer, S., Meisch, S., 2017. Co-production in climate change research: Reviewing different perspectives: Co-production in climate change research. Wiley Interdiscip. Rev. Clim. Chang. 8 (6), e482.
Briley, L., Brown, D., Kalafatis, S.E., 2015. Overcoming barriers during the co-production of climate information for decision-making. Clim. Risk Manag. 9, 41–49. https://doi.org/10.1016/j.crm.2015.04.004.
Bruno Soares, M., Dessai, S., 2016. Barriers and enablers to the use of seasonal climate forecasts amongst organisations in Europe. Clim. Change 137 (1–2), 89–103. https://doi.org/10.1007/s10584-016-1671-8.
Carter, S., Steynor, A., Vincent, K., Visman, E., Waagsaether, K. (2019). *Co-Production of African Weather and Climate Services*. Future Climate for Africa and Weather and Climate Information Services for Africa, Cape Town, South Africa. (https://futureclimateafrica.org/coproduction-manual.
City of Stockholm (2020): Handlingsplan för klimatanpassning [Action Plan for Climate Change Adaptation], https://miljobarometern.stockholm.se/miljomal/klimathandlingsplan-2020-2023/.
Cortekar, J., Lamich, K., Otto, J., Pawelek, P.. Review and Analysis of Climate Service Market Conditions. EU-MACS Deliverable 1.1 [Deliverable for EU-MACS European Market for Climate Services project]. http://eu-macs.eu/wp-content/uploads/2017/07/EU-MACS-D11_CLIMATE-SERVICE-MARKET-CONDITIONS.pdf.
Cvitanovic, C., Hobday, A.J., van Kerkhoff, L., Wilson, S.K., Dobbs, K., Marshall, N.A., 2015. Improving knowledge exchange among scientists and decision-makers to facilitate the adaptive governance of marine resources: A review of knowledge and research needs. Ocean Coast. Manag. 112, 25–35. https://doi.org/10.1016/j.ocecoaman.2015.05.002.
Cvitanovic, C., McDonald, J., Hobday, A.J., 2016. From science to action: Principles for undertaking environmental research that enables knowledge exchange and evidence-based decision-making. J. Environ. Manage. 183, 864–874. https://doi.org/10.1016/j.jenvman.2016.09.038.
Daniels, E., Bharwani, S., Gerger Swartling, Å., Vulturius, G., Brandon, K., 2020. Refocusing the climate services lens: Introducing a framework for co-designing "transdisciplinary knowledge integration processes" to build climate resilience. Clim. Serv. 19, 100181 https://doi.org/10.1016/j.cliser.2020.100181.
Daniels, E., Bharwani, S., Butterfield, R. (2019). *The Tandem Framework: A Holistic Approach to Co-Designing Climate Services*. SEI Discussion Brief. Stockholm Environment Institute, Stockholm, Sweden. https://www.sei.org/wp-content/uploads/2019/05/tandem-framework.pdf.
Djenontin, I.N.S., Meadow, A.M., 2018. The art of co-production of knowledge in environmental sciences and management: Lessons from international practice. Environ. Manag. 61 (6), 885–903. https://doi.org/10.1007/s00267-018-1028-3.
FCFA (2015). *Mainstreaming Climate Information into Sector Development Plans: The Case of Rwanda's Tea and Coffee Sectors*. Climate & Development Knowledge Network. http://www.futureclimateafrica.org/wp-content/uploads/2016/01/Paul-Watkiss-report-Rwanda.pdf.
Fünfgeld, H., Lonsdale, K., Bosomworth, K., 2019. Beyond the tools: supporting adaptation when organisational resources and capacities are in short supply. Clim. Change 153 (4), 625–641. https://doi.org/10.1007/s10584-018-2238-7.
Gerger Swartling, Å., Tenggren, S., André, K., Olsson, O., 2019. Joint knowledge production for improved climate services: Insights from the Swedish forestry sector. Special Issue. Environ. Policy Governance 29, 2. https://doi.org/10.1002/eet.1833.
Jack, C.D., Jones, R., Burgin, L., Daron, J., 2020. Climate risk narratives: An iterative reflective process for co-producing and integrating climate knowledge. Clim. Risk Manag. 29, 100239 https://doi.org/10.1016/j.crm.2020.100239.
Järnberg, L., André, K., Leander, E., Gerger Swartling, Å. (2020). Ten ways to support climate change adaptation and decision-making. SEI Discussion Brief. Stockholm Environment Institute. https://www.sei.org/publications/ten-ways-to-support-climate-change-adaptation-planning-and-decision-making/.
Jones, L., Champalle, C., Chesterman, S., Cramer, L., Crane, T.A., 2017. Constraining and enabling factors to using long-term climate information in decision-making. Clim. Pol. 17 (5), 551–572. https://doi.org/10.1080/14693062.2016.1191008.
Keeley, A.T.H., Beier, P., Creech, T., Jones, K., Jongman, R.H.G., Stonecipher, G., Tabor, G.M., 2019. Thirty years of connectivity conservation planning: an assessment of factors influencing plan implementation. Environ. Res. Lett. 14, 103001.
Klein, R.J.T., Juhola, S., 2014. A framework for Nordic actor-oriented climate adaptation research. Environ. Sci. Policy 40, 101–115. https://doi.org/10.1016/j.envsci.2014.01.011.
Lemos, M.C., Morehouse, B.J., 2005. The co-production of science and policy in integrated climate assessments. Glob. Environ. Chang. 15 (1), 57–68. https://doi.org/10.1016/j.gloenvcha.2004.09.004.
Lemos, M.C., Kirchhoff, C.J., Ramprasad, V., 2012. Narrowing the climate information usability gap. Nat. Clim. Change 789–794. https://doi.org/10.1038/nclimate1614.
McClure, A., Joseph, D., Bharwani, S., Jones, R., Grobusch, L.C., Kavonic, J., Janes, T., 2024. Principles for Co-Producing Climate Services: Practical Insights from FRACTAL. Climate Services 34, 100492. https://doi.org/10.1016/j.cliser.2024.100492.
Meadow, A.M., Ferguson, D.B., Guido, Z., Horangic, A., Owen, G., Wall, T., 2015. Moving toward the deliberate coproduction of climate science knowledge. Weather Clim. Soc. 7 (2), 179–191. https://doi.org/10.1175/WCAS-D-14-00050.1.
Norström, A.V., Cvitanovic, C., Löf, M.F., West, S., Wyborn, C., et al., 2020. Principles for knowledge co-production in sustainability research. Nat. Sustainability 3 (3), 182–190. https://doi.org/10.1038/s41893-019-0448-2.
Palutikof, J.P., Leitch, A.M., Rissik, D., Boulter, S.L., Campbell, M.J., Perez Vidaurre, A. C., Webb, S., Tonmoy, F.N., 2019. Overcoming knowledge barriers to adaptation using a decision support framework. Clim. Change 153 (4), 607–624. https://doi.org/10.1007/s10584-018-2177-3.
Prokopy, L.S., Carlton, J.S., Haigh, T., Lemos, M.C., Mase, A.S., Widhalm, M., 2017. Useful to usable: Developing usable climate science for agriculture. Clim. Risk Manag. 15, 1–7. https://doi.org/10.1016/j.crm.2016.10.004.
Santos Santos, T.F., Gerger Swartling, Å. (2020). Co-designing climate services for water planning: a case study from the Campoalegre River Basin in Colombia. SEI Discussion Brief, Stockholm. https://www.sei.org/publications/co-designing-climate-services-for-water-planning/.
Scott, D., Taylor, A., 2019. Receptivity and judgement: Expanding ways of knowing the climate to strengthen the resilience of cities. FRACTAL Working Paper 7. http://www.fractal.org.za/wp-content/uploads/2019/02/Scott-D-and-Taylor-A-Receptivity-and-Judgement-web.pdf.
Segersson, D., Amorim, J.H. (2020). Fysisk planering i ett varmare klimat: En fallstudie för Stockholm [Physical Planning in a Warmer Climate] MSB rapport December 2020 [Swedish Civil Contingencies Agency Report], ISBN: 978-91-7927-093-3. Swedish Civil Contingences Agency. Publisher: Danagård LiTHO, Available in Swedish on: https://www.msb.se/sv/publikationer/fysisk-planering-i-ett-varmare-klimat–en-fallstudie-for-stockholm/.
Steynor, A., Padgham, J., Jack, C., Hewitson, B., Lennard, C., 2016. Co-exploratory climate risk workshops: Experiences from urban Africa. Clim. Risk Manag. 13, 95–102. https://doi.org/10.1016/j.crm.2016.03.001.
Tanner, T., Zaman, R.U., Acharya, S., Gogoi, E., Bahadur, A., 2019. Influencing resilience: the role of policy entrepreneurs in mainstreaming climate adaptation. Disasters 43 (S3), S388–S411. https://doi.org/10.1111/disa.12338.
Taylor, A., Pretorius, L., McClure, A., Iipinge, K.N., Mwalukanga, B., Mamombe, R., 2021. Embedded researchers as transdisciplinary boundary spanners strengthening urban climate resilience. Environ. Sci. Policy 126, 204–212. https://doi.org/10.1016/j.envsci.2021.10.002.
Turnhout, E., Metze, T., Wyborn, C., Klenk, N., Louder, E., 2020. The politics of co-production: participation, power, and transformation. Curr. Opin. Environ. Sustain. 42, 15–21. https://doi.org/10.1016/j.cosust.2019.11.009.
Underdal, A., 2010. Complexity and challenges of long-term environmental governance. Glob. Environ. Chang. 20 (2010), 386–393.
van der Molen, F., Puente-Rodríguez, D., Swart Jac, A.A., van der Windt, H.J., 2015. The coproduction of knowledge and policy in coastal governance: Integrating mussel fisheries and nature restoration. Ocean Coast. Manag. 106, 49–60. https://doi.org/10.1016/j.ocecoaman.2015.01.012.
Visman, E., Vincent, K., Steynor, A., Karani, I., Mwangi, E., 2022. Defining metrics for monitoring and evaluating the impact of co-production in climate services. Clim. Serv. 26, 100297 https://doi.org/10.1016/j.cliser.2022.100297.
Vogel, C., Steynor, A., Manyuchi, A., 2019. Climate services in Africa: Re-imagining an inclusive, robust and sustainable service. Clim. Serv. 15, 100107 https://doi.org/10.1016/j.cliser.2019.100107.
Wyborn, C., Datta,A., Montana, J., Ryan, M., Leith, P., Chaffin, B., Miller, C., van Kerkhoff, L. 2019. Co-Producing Sustainability: Reordering the Governance of Science, Policy and Practice. Annual Review of Environment and Resources 2019 44: 1, 319-346.