I-CISK
HUMAN CENTRED CLIMATE SERVICES

Deliverable D2.2
Concepts and methods to characterise and integrate local and scientific knowledge

September 2023

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I-CISK

Innovating Climate services through Integrating Scientific and local Knowledge

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Executive Summary

I-CISK recognises that knowledge on climate and adaptation from all stakeholders (e.g., scientists, local key institutions and potential end-users) is relevant for the design, production, validation, and effective application and use of CS. This local knowledge has its role in each step of the I-CISK co-creation framework which drives the interaction process within the living labs. Local knowledge is integral to the process of co-exploring, co-identifying, and co-developing. As such local knowledge priorities are interwoven across several work packages and tasks within the project.

This deliverable, more specifically, links with task 2.2 (T2.2) and is conceptualized to be an iterative one. The combined objective of the deliverable (this iteration and the next) is to identify and collect local knowledge, through mostly participatory methodologies, to link expertise from the consortium scientists and local knowledge from the LL and complement climate data from Copernicus and GEOSS and research with local data. This co-identification is considered within the particular social, economic, and sectoral contexts of the LL, and aims towards being goal-oriented and explicitly recognizing the multiple ways of knowing. This first iteration, in particular, summarizes current scholarship on local knowledge, thereby laying the foundation to build a framing of local knowledge that will be adopted and operationalised within the I-CISK project.

This deliverable argues for a broader framing of local knowledge, regarding it as an all-encompassing term to describe a range of different knowledges derived either through traditional or cultural norms, personal observations, lived or occupational experiences. Based on this, the holders of local knowledge and the ways in which they accumulate knowledge are also varied. Adopting such a framing of local knowledge within the climate service provision process is beneficial when considering the knowledges of the different agents involved in the CS design and provision, particularly local service providers and purveyors.

Chapter 1 situates the deliverable in the context of the project establishing relevance and synergies with the I-CISK co-creation framework. Chapter 2 reviews the concept of local knowledge and provides a working definition for the same. Additionally, the chapter goes into a discussion about the various dimensions of local knowledge providing examples from climate change adaptation, disaster risk reduction and other relevant literature. Finally, the chapter also describes the role of local data and how it fits within our framing of local knowledge. Chapter 3 delves into the ways in which local knowledge or local data can be collected and integrated within the context of climate services. The chapter specifically discusses the importance of participatory methods. The chapter concludes with the approach currently being piloted within the I-CISK project which aims to integrate local data and knowledge upstream in the climate service value chain (i.e., by climate service providers and modellers). Chapter 4 brings the local knowledge discussion to the living labs within I-CISK project. For this first iteration of D2.2, we provide examples from living labs in Spain and Hungary, where data collections processes have helped in identifying and characterising the local knowledge of various knowledge holders. Finally, the deliverable concludes with describing the next steps that will be undertaken to operationalize the framing of local knowledge adopted within the I-CISK project as well as engage in a discussion with the broader climate services community.

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List of Abbreviations

ABM – Agent based Modelling

CCA – Climate change adaptation

CS – Climate Service

DRM – Disaster Risk Management

DRR – Disaster Risk Reduction

EWS – Early Warning System

FGD – Focus Group Discussion

LL – Living Lab

LK – Local knowledge

MAP – Multi Actor Platform

SK – Scientific knowledge

1 Introduction: the importance of local knowledge in the Climate Services value chain and its role in the co-creation framework

The I-CISK project acknowledges that multiple sources of knowledge feed into the climate service (CS) value chain Figure 1Figure 1). At one end of the value chain, end users build their adaptation decisions, which they do based on multiple sources of knowledge. Basically, end users triangulate between the local knowledge on climate and weather they hold and the scientific knowledge that reaches them from a variety of information sources (such as the CS from the National Meteorological and Hydrological Services) (Hermans et al., 2022). For each end-user group, there may be a different variety of source with varying importance that they rely upon and triangulate. Their local knowledge includes present and past experiences, observations on for example ecological, meteorological, and celestial dimensions, and of adaptation options and their effectiveness. At the other end of the CS value chain, the data providers, integrators, and developers primarily use scientific knowledge, but they also may integrate local knowledge on important climate parameters, thresholds, and triggers, as well as climate (such as coming from the Copernicus Climate Data store), at the appropriate spatial and temporal scale, in a climate product. Service providers and purveyors, such as meteorological experts or agricultural extension workers working at the regional or local level, may include their own prior expert knowledge and experience regarding climate patterns and impacts in the transmission of the scientific forecasts coming from the national level. In this way, scientific climate data is tailored and translated into understandable and useful information so that end-user engagement and empowerment of the service purveyors end users is improved. These multiple sources of knowledge, that the actors along the CS value chain hold, can be mapped on a continuum of local and scientific knowledge. Calvel et al. (2020), Lemos et al. (2012), Kumar (2010), demonstrate the need to combine and integrate the multiple sources of knowledge as there are all too often gaps in usability and usefulness of the CS as the service is often not sufficiently localised and contextualised.

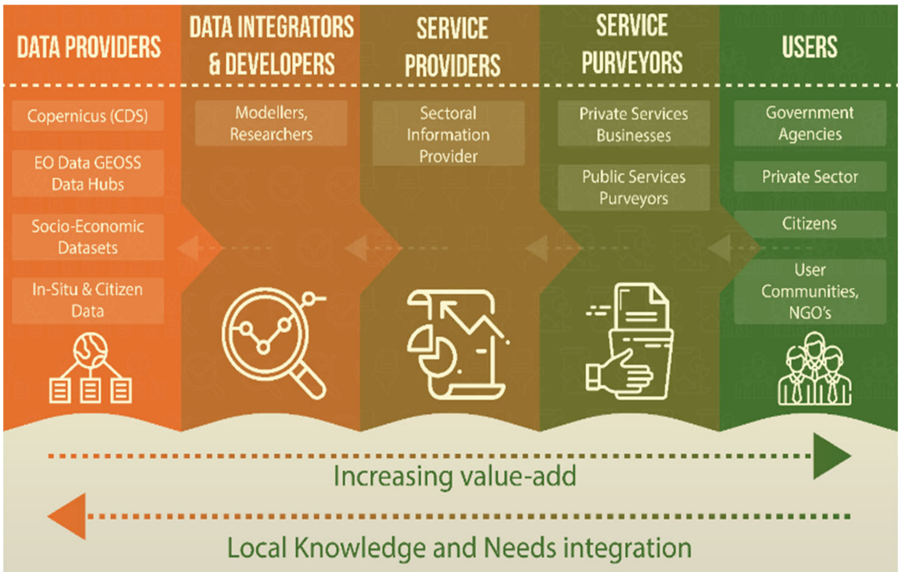

Figure 1 CS value chain as described in the ICISK proposal

This deliverable is an iterative one, with this first version summarising current scholarship on local knowledge and laying the foundation to build towards a framing of local knowledge that will be adopted and operationalised within the I-CISK project. Knowledge on climate from all stakeholders (e.g., scientists, local key institutions and potential end-users) is relevant for the design, production, validation, and effective application and use of CS. Therefore, the objective of this deliverable (and the corresponding task 2.2 within which this deliverable has been developed) is to identify and collect local knowledge, through mostly participatory methodologies, to link expertise from the consortium scientists and local knowledge from the LL and complement climate data from Copernicus and GEOSS and research with local data. This co-identification is considered within the particular social, economic, and sectoral contexts of the LL, and aims towards being goal-oriented and explicitly recognizing the multiple ways of knowing. This deliverable provides an overview of the methods to integrate scientific and local knowledge and of the methods to characterise local knowledge and collect local data. In addition, the deliverable will give for two Living Labs (Spain and Hungary) an example of how the local knowledge is characterized and used as well as how local data is collected. Section 2.1 in this deliverable develops a definition of what is considered as local knowledge. Also, local data and the methods to collect local data will be discussed, for example data collected through citizen-science initiatives (I-CISK, 2021). This sections links to D3.1 section 3 *How local knowledge can be used for informing scientific models* (Pesquer et al. 2022). Chapter3 of this deliverable describes methods to characterise local knowledge of the different actors along the CS value chain and how to make use of the local knowledge to improve the usability and usage of the service. The methods will be linked to the I-CISK framework for co-creation as defined in Milestone MS10 (I-CISK, 2022). Co-creation is seen as the process of joint knowledge and service creation and integration of the multiple sources of knowledge and data between the different actors. In I-CISK, this process takes place within the Living Labs. Living Labs are defined as “places for innovation - multidisciplinary ecosystems in which the I-CISK co-creation process will take place. They are an experimental setting and a safe space for stakeholder involvement (Fuglsang et al., 2019) (Masih et al. 2022). To generate user-centred CS and ensure they are adequate for end user needs and context, the ICISK Framework for co-creating CS (I-CISK, 2022) defines a sequence of iterative steps as illustrated in Figure 2.

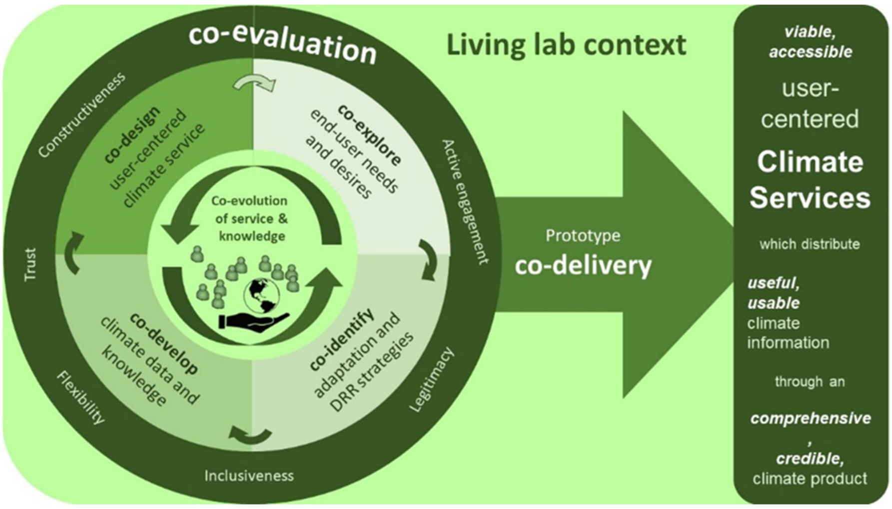

Figure 2 Co-creation of user-centred CS: building blocks of the process that take place in a LL context. (Source: I-CISK, 2022)

Adopting such a framing of local knowledge within the co-creation process can be beneficial when considering the knowledges of the different agents involved in the CS design and provision, particularly local service providers and purveyors (Figure 1). Several evaluation criteria for the process of co-creation directly relate to the use of local knowledge (see the outer circle of Figure 1) and make clear why it is beneficial to leverage local knowledge:

- **Inclusiveness**: recognising the importance and relevance of LK in the co-design of CS is important for generating user-centred CS;
- **Active engagement:** The process of co-creation also means that actors in the LL are actively involved and share their own knowledge to co-create new knowledge. They need to have (or be provided with) **capacity** to do so, but also be prepared to be held responsible and **accountable**.
- **Legitimacy:** CS that include LK and were co-developed with LK holders may be seen as more legitimate and credible than CS that ignore LK and LK holders.

Local knowledge has its role in each step in the I-CISK co-creation framework but is most pertinent in the first three steps of co-exploring, co-identifying, and co-developing. The process starts by **co-exploring** user needs and **co-identifying** adaptation strategies. This is critical in order to understand the context where CS will be used and adapt them accordingly. This work is part of T2.1 *Co-exploring climate information and adaptation information needs and obligations of the actors in the living labs* and T2.2 *Co-identifying local knowledge on climate & its impacts in the living labs and providing citizen science input into climate data* and is reflected in the corresponding deliverables (Moschini & Emerton, 2022; this deliverable). The step of **co-developing** climate data and knowledge into a climate product builds on these co-identified needs as well as the decisions and adaptation strategies that the newly developed CS should support. It involves ideation of a new climate product prototype. IDEO.org (2015) defines ideation as the phase in which one tries to make sense of all the collected data and information, where opportunities for design are identified and the most promising design options are built into rough prototypes. This is a phase that can be done within an internal project team and where the team members can combine their knowledge, experiences, skills, and practices, and combine scientific knowledge (SK) and local knowledge (LK). Box 1 gives a further explanation of how local knowledge and co-creation can be intertwined.

Box 1 Local knowledge and co-creation

Local knowledge and co-creation

The impetus to adopt post-normal view of science to solve wicked societal problems has consequently led to the recognition of approaches that prioritise transdisciplinary, interdisciplinarity, co-production, co-creation, and social learning (Funtowicz and Ravetz 1993; Kirchhoff, Lemos, and Dessai 2013). There has been a growing acknowledgement of the fact that scientific knowledge by itself is not enough, and stakeholders rely on their own way of knowing to understand risk and design coping capacity (Kirchhoff, Lemos, and Dessai 2013). Co-creation is therefore becoming a standard approach in developing CS, aiming to strengthen societal ownership, legitimacy, and long-term sustainability of the CS (Vincent et al., 2018). It includes active involvement of end-users of a product or service at the different phases of the process; starting from problem formulation to mutual quality control of scientific rigor, social robustness, and practical relevance of the tangible (c) and intangible (improved understanding, capacity) outcomes (Bremer et al., 2019). With these objectives in mind, understanding and incorporating local knowledge within CS design and delivery is an integral part of the co-creation process. Integration of local knowledge can help in strengthening the co-creation process by: helping build trust with the communities; local actors are more likely to view the process as legitimate and fair; managing uncertainty; informing and helping better embed research and policy endeavours in the local reality; produce more grounded understanding of systems that are owned by the communities as well as help in identifying management decisions that are more contextually appropriate; and finally, inform strategies for effective knowledge transfer and dissemination (Taylor and de Loë 2012; Newig et al., 2005). Mulder (2023), when investigating the localisation of humanitarian knowledge management, found that localised, horizontal knowledge management works better than centralised, vertical knowledge management. With horizontal knowledge management, local and scientific knowledge is combined on the basis of a network, both geographically and over time. This ensures that the participation of local knowledge holders is organised structurally, so that they can collaborate constructively over long periods of time. It includes creating spaces to accommodate a range of actors with different knowledges and priorities.

2 Background on local knowledge and local data

2.1 Defining local knowledge and its holders

The discussion on local knowledge spans beyond the literature on CS. Sometimes referred to as traditional knowledge, indigenous knowledge (Iloka 2016), traditional ecological knowledge, tacit knowledge or stakeholder knowledge, the discourse on local knowledge features within disciplines like ecology (Berkes, Colding, and Folke 2000), environmental governance and management (Taylor and de Loë 2012; Raymond et al. 2010), disaster risk reduction (Dekens, 2007; Hermans et al. 2022; Hadlos, Opdyke, and Hadigheh 2022) and climate adaptation. As a consequence, defining local knowledge is a challenge in itself, made even more complex within the context of CS where science and society have to work in tandem to build a common understanding and knowledge to support action. Table 1 provides an overview of some of the definitions of local knowledge within literature. Local knowledge is generally regarded by scholars more as a 'way of life' governed by culturally derived values (Failing, Gregory, and Harstone 2007; Berkes, Colding, and Folke 2000). Taylor and de Loë (2012) reviewed local knowledge within environmental governance literature describing it as a knowledge held by non-scientists based on local wisdom, practices, and experiences.

Table 1 Examples of definitions of local knowledge across disciplines

Discipline	Source	Definition
Anthropology	Geertz (1983)	''knowledge that is practical, collective and strongly rooted in a particular place''
Development	Food and Agriculture Organization (2005)	"a collection of facts related to the entire system of concepts, beliefs, and perceptions that people hold about the world around them. This includes the way people observe and measure their surroundings, solve problems, and validate new information. It includes the processes whereby knowledge is generated, stored, applied and transmitted to others."
Environmental governance	Failing et al. (2007)	"local knowledge is commonly viewed to consist of specific fact-based expertise related to local conditions, processes and practices."
Environmental management	Raymond et al. (2010)	"Local knowledge usually refers to the informal, lay, personal, often implicit or tacit, but possibly expert, knowledge held by land managers involved in environmental decision-making."
	Giordano et al. (2010)	''the body of knowledge held by a specific group of people about their local environmental resources''
Climate change adaptation	Naess (2013)	"unique knowledge developed over an extended period of time and held by a given society in a specific location"
Disaster Risk Reduction	Hadlos, Opdyke, and Hadigheh (2022)	"local knowledge is derived from a community's place-based relationship with the local environment"

Descriptions of local knowledge across disciplines (for e.g., ecology, environmental governance, environmental management) often focus on how it distinguishes itself from conventional (western) science (Berkes, 1999; Failing, Gregory, and Harstone 2007; Raymond et al 2010). Failing, Gregory, and Harstone (2007) in their review posit that local knowledge tends to be more experience based rooted in a place, without devolving into generalisable rules and tends to be holistically expressed (as opposed to western science which takes a reductionist approach). Hermans et al. (2022) distinguished scientific and local knowledge as the former being developed through a formal and agreed methodology, while the latter is being developed through the accumulation of (informal) observations of and interactions with the environment in which people live. Local knowledge is reflective of the accumulated knowledge of the people . Local knowledge is often used as a broad categorization to represent types of non-scientific knowledge. Raymond et al. (2010) reviewed local knowledge understanding within environmental management, characterising it as a knowledge that can range from being informal and lay, to implicit or even expert knowledge held by decision makers.

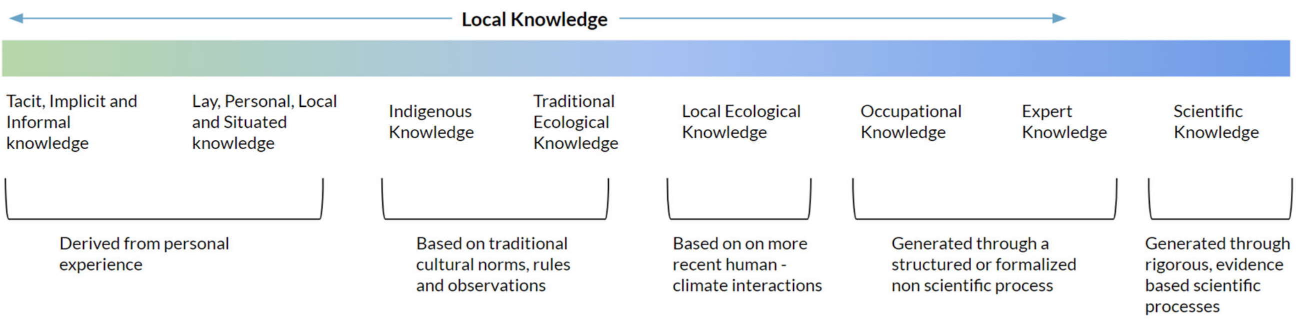

Figure 3 Different types of knowledges as characterised by Raymond et al. (2010)

Much of the understanding on local knowledge within CS aligns with descriptions where it is considered as being personal, lay, and tacit, i.e., deeply rooted within an individual's own experiences, value, and worldviews. However, the characterization of local knowledge by Raymond et al. (2010) goes beyond that and expands the framing of local knowledge to include knowledge that is gained as a result of formalised, structured, and non-scientific processes (expert knowledge). Here one can think of e.g., commercial farms that have collected local rainfall records over a long period of time (Landman et al., 2020). This knowledge can be both tacit or explicit (Figure 1). We, therefore, propose to consider knowledge more as continuum with local knowledge comprising of different forms of knowledges and with different holders of local knowledge (see Figure 3. Box 2 describes the holders in more detail.

Based on this framing, the working definition of local knowledge adopted within the I-CISK project is - ***local knowledge is an all-encompassing term that includes a range of different knowledges derived either through traditional or cultural norms, personal observations, lived or occupational experiences. It provides an insight into the 'way of life' of individuals and communities, shedding light on how they perceive their surroundings, solve problems, and validate new information. Local knowledge is accumulated over time and is very dynamic in nature. It can be both tacit or implicit in nature, or more intentional as in the case of it being derived from structured and formalized processes. Finally, local knowledge is deeply rooted in the context from whence it originates and therefore may not be generalizable to other contexts***.

Box 2 Who are the holders of local knowledge?

Who are the holders of local knowledge?

The holders of local knowledge can be characterized by the way they generate their local knowledge (Raymond et al., 2010). The FAO definition notes that it is not only held by tribal or indigenous communities, but also by other communities, including those in rural and urban environments, settled and nomadic communities, original inhabitants, and migrants (Food and Agriculture Organization 2005). Raymond et al. (2010) show that local knowledge holders can also include professionals working at the local level, that acquire their knowledge through a structured or formalized, though not a scientific process.

The holders of local knowledge can also be linked to their role in the Climate Services value chain. A survey conducted in 2016 found that 63 percent of the respondents viewed themselves both as providers and users of climate services (Vaughan et al. 2016). Literature identifies this subset of users who play dual roles as 'intermediaries' or 'climate knowledge brokers '(referred to as climate service providers and purveyors in this paper, see Figure 1) who represent the operational arm of climate service, and are increasingly important in the communication of climate services to the end users. Their experience of the local context and understanding of end users needs and demand makes them an integral part of the climate service value chain. Despite this, the current framing of local knowledge tends to exclude them, regarding them only as an interface for translation and communication. We argue that upstream agents (service purveyors and providers) use their understanding of the context when translating the information appropriate to the context, and also that there is an 'interplay' between the new climate information and their existing knowledge that can be dependent on factors like organisation set up and culture (Lemos, Kirchhoff, and Ramprasad 2012). Therefore, our working definition of local knowledge includes not just tacit knowledge but also knowledge that is more formal and derived from occupational experience or is expert knowledge.

Local knowledge derives itself from local values and use of traditional social structures, and is recognised and accepted within the community, it can help address barriers impeding the uptake of climate information (Patt and Gwata 2002; Dekens 2007). When discussing the role of local knowledge within environmental governance, Taylor and de Loë (2012) synthesize that incorporating local knowledge can lead to building trust with the communities; local actors are more likely to view the process as legitimate and fair; it can also inform and help better embed research and policy endeavours in the local reality; consequently local actors can also contribute new data and information to scientific studies; local knowledge also has the potential to produce more grounded understanding of systems that are owned by the communities as well as help in identifying management decisions that are more contextually appropriate; and finally, local knowledge can also inform strategies for effective knowledge transfer and dissemination. In the context of water resources management, local knowledge can also serve as means to manage uncertainty, by providing an insight into the social dimension that can help mediate interests and goals as well as help in achieving common ground (Newig, Pahl-wostl, and Sigel 2005). Building on this, research has argued that developing CS is not a neutral activity; instead, it is informed by and laden with particular values and priorities (Lemos and Dilling 2007). Therefore, studying local knowledge can help better extract and understand these values, and how they might impact priorities addressed in CS development process, information provision and benefits accrued from the same (Webber 2019). Furthermore, when discussing the usability of climate information, Lemos, Kirchhoff, and Ramprasad (2012) found that *'fit, interplay and interaction'* are crucial to informing the usability. The authors describe fit as the users' perception of credibility and salience of the information; while interplay is how the scientific information interacts with the users' existing knowledge and experiences (local knowledge); and interaction is the process through which climate information was produced (ibid).

2.2 Dimensions and indicators of local knowledge

The DRR and EWS literature introduces dimensions and indicators to categorise local knowledge (Hadlos, Opdyke, and Hadigheh 2022; Hermans et al. 2022). Hadlos et al. (2022) uses six overarching forms; namely, early warning systems, risk knowledge and perception, structural measures, livelihood-based adaptation, social cohesion, and beliefs that further influence choice of response and recovery strategies on the short term and livelihood adaptation strategies on the long term. Figure 4 provides an example of the dimensions of local knowledge across the flood risk management cycle as documented for communities in the Lower Shire Valley in Malawi (Šakić Trogrlić et al. 2019). These dimensions span from early warning indicators, dissemination and monitoring, early action, response, recovery, to cross-cutting issues like knowledge of flood hazard, institutional knowledge, and social capital.

Subsequently, one can further break down each dimension. For example, a specific fish species as a sign of upcoming floods is one of the animal behaviour indicators from the ecological dimension (Šakić Trogrlić et al. 2019). In theory, this usually qualitative information can be turned into a quantifiable indicator, such as the increase in the number of fishes, but in reality, this is often difficult. By quantifying these indicators, one can also assess the reliability of the indicators. Box 3 explains more about the reliability of local knowledge.

Box 3 Reliability of local knowledge

Reliability of local knowledge

Most approaches within the climate services literature tend to focus on capturing the local knowledge indicators within the meteorological category (Streefkerk et al. 2022, Bucherie et al. 2021) and then use this local knowledge information to inform scientific modelling. This can be attributed to evidence of traditional forecasting methods adding significant value in enhancing the spatial and temporal resolution of forecasts as well as being useful in communicating weather and climate information to local communities (Tadesse et al. 2015; Masinde 2015). In some cases, one-on-one validation of the local knowledge indicators with scientific knowledge has been done (e.g., Phalira et al., 2023), with varying success. Phalira et al. (2023) found, for example, that the eclipse of the moon which was associated with drought, is totally inconsistent with the occurrence of drought as measured through scientific indicators. Similarly, Guido et al. (2020), investigated the use of local knowledge by farmers when predicting rainfall during the growing seasons thereby guiding on-farm decision making. The authors find that given the changing and complex nature of climate processes there is a lack of evidence validating the heuristic heavily relied upon by farmers which connects the past climate to future seasonal conditions.

It is also important to acknowledge that the impacts of climate change have the potential to alter local weather and biophysical patterns in a way that might not find precedence in local knowledge of communities. A study conducted in the Lower Shire River basin in Malawi found that the reliability of local knowledge indicators was negatively impacted as a result of climate change (Sakic Troglic et al. 2019). This does not mean that local knowledge will be rendered useless with time; instead, it points towards understanding where some of the caveats with the use of local knowledge may lie. Alluding to the adaptability of local knowledge, Tschakert and Dietrich (2010) found that communities residing in hazard-prone areas of Africa displayed a good recollection of past thresholds that drove them into poverty traps and this experiential knowledge informed their ability to identify potential future thresholds.

We emphasize that by this process of “datafying”, the local knowledge no longer captures all the contextual knowledge and lived experience, and one is reducing the local knowledge to a scientific and quantifiable building block of knowledge. Tengö et al. (2021) also stated that a mapping exercise that logs mainly what is deemed important from a science-based perspective can fall short in holistic recognition of Indigenous cultural identities and histories.

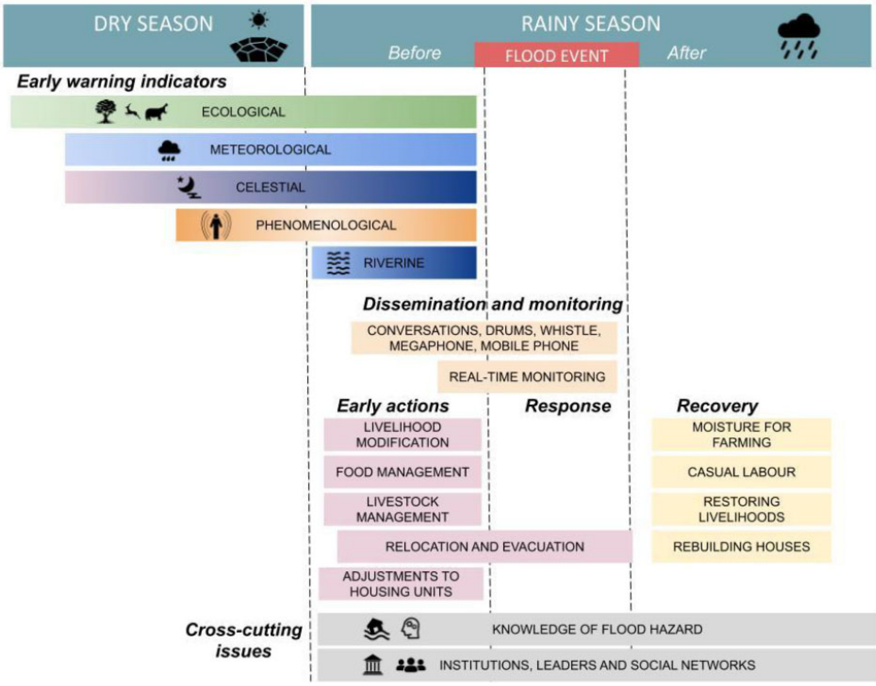

Figure 4 Dimensions of LK for flood risk management in Malawi
(Source: Sakic Trogrlic et al. 2019)

Table 2 provides examples from literature where research captured for various CS delivery domains and temporal scales local knowledge dimensions. The CS delivery domains range from DRR (Disaster Risk Reduction), DRM (Disaster Risk Management) to CCA (Climate Change Adaptation). Temporal scales can vary from weather to climate, so from current and past conditions, 1-10 days, 30-90+ days to more than 5 years. Most of the studies in Table 2 are from the Majority World, with one study that included a multitude of case studies around the world and one from the USA. Box 4 gives more background as to how local knowledge can inform decision making for DRR, DRM and CCA.

Box 4 Local knowledge for decision making on climate adaptation

Local knowledge for decision making on climate adaptation

Climate is rarely the only factor guiding decisions (Kumar 2010; Goddard and Goddard 2017). Research finds that end users tend to use climate information primarily when it adds value to their currently strategy leading to improved outcomes (Alexander and Block 2022; Kumar 2010). In fact, there are several additional elements (in addition to increased forecast accuracy) that are required to render climate forecasts useful. For example, information about the users themselves (capacities, risk perception, biases); factors governing the decision-making context (socioeconomic, political, or institutional factors); interaction across science-society interface (co-production, institutional support, trust in the information provided) (Bruno Soares, Daly, and Dessai 2018). When speaking about knowledge relevant to decision making, Failing, Gregory, and Harstone (2007) also highlighted the importance of understanding both fact-based knowledge (expressed probabilistically, reflecting uncertainty) and value-based knowledge (normative input, beliefs, risk tolerances). Local knowledge has also been regarded instrumental in building natural and social capital of communities and thereby affecting their choice of adaptation strategies (Naess 2013). Which factors appear more prominently within a given context may therefore understood by investigating the lived experiences of communities (local knowledge) and its impact on decision-making.

The importance of local knowledge has also been discussed within adaptation (Berkes 2009; Naess 2013). Integration of local knowledge within climate adaptation policy and practice has been identified as a win-win opportunity by promoting practices and solutions that have a basis in local context. Naess (2013) reviewed contributions of local knowledge to adaptation interventions, identifying the role of local knowledge in reducing vulnerability, improving adaptive capacity and in supporting adaptation planning. Evidence from countries in Africa shows that local and indigenous knowledge is integral to managing resources, especially in regions marred with scarcity (Leal Filho et al. 2021). The highly context specific nature of adaptation has led to the acknowledgement that using local knowledge in efforts to understand livelihoods decision making can improve the efficacy of adaptation interventions, their social acceptability and scalability (Zvobgo et al. 2022). In terms of forms of local and indigenous knowledge, a study reviewing water adaptation responses found it to include: factual knowledge about the environment and environmental changes; use of natural resources; cultural values; governance and social capital (Zvobgo et al. 2022). Examples from smallholder farming systems have also shown that local knowledge provides assets to individual and communities in the way of social and natural capital that helps them to cope and adapt (Naess 2013).

Table 2 A non-exhaustive overview of CS delivery domains, their temporal scale and local knowledge dimensions across literature DRR, DRM and CCA.

CS delivery domain		Temporal scale		Location	Local knowledge dimension	Description	Reference
DRR	Preparedness	Long range seasonal outlooks	30-90+ days	Malawi	Meteorological conditions	Anomalies in ambient temperature and/or wind direction and speed prior to wet season related to drought	(Streefkerk et al. 2022)
DRR	Preparedness	Long range seasonal outlooks	30-90+ days	Zimbabwe	Flora and Fauna	Density of leaves and fruits and flowering levels as an indication of drought conditions	(Chisadza et al. 2015)
DRR	Early warning	Short to medium-term forecasts	1-10 days	Malawi	Meteorological conditions	Wind speed, temperature and cloud formations over Lake Malawi as precursors to flash flood events	(Bucherie et al. 2022)
DRR	Preparedness	Short to medium-term forecasts	1-10 days	Nepal	Local impacts	Awareness and judgement of local impacts of heavy rainfall for disaster preparedness	(Sudmeier-Rieux et al. 2012)
DRR	Preparedness	Short to medium-term forecasts	1-10 days	Malawi	Early actions	Livelihood modification, food and livestock management, relocation and evacuation, adjustments to housing units	(Šakic Trogrlic et al. 2019)
DRR	Response	Current and past conditions	Today and past	Cambodia	Hydro-meteorological conditions	Local knowledge of spatial and temporal patterns of floods, droughts and rainfall	(Pauli et al. 2021)
DRM	Recovery	Current and past conditions	Today and past	Malawi	Livelihoods	Structural and livelihood measures implemented post flood event	(Šakic Trogrlic et al. 2019)
DRM	Mitigation	Current and past conditions	Today and past	Taiwan	Agricultural livelihoods adaptation	Crop selection	(Chen and Cheng 2020)
DRM	Mitigation	Current and past conditions	Today and past	Malawi	Agricultural livelihoods adaptation	Changing planting schedules	(Šakic Trogrlic et al. 2019)
DRM	Mitigation	Current and past conditions	Today and past	Philippines	Water management	Improving irrigation and water management systems	(Lirag and Estrella 2017)
CCA	Climate projection	Climate projection	> 5 years	Global	Flora and Fauna	Changes to the biophysical system as an indication of a changing climate at the local level	(Reyes-García et al. 2016)
CCA	Climate projection	Climate projection	> 5 years	USA	Climate change perception	Experienced climate knowledge to improve service delivery of CS	(Clifford, Travis, and Nordgren 2020)

2.3 Defining local data

Figure 3 shows the spectrum of local and scientific knowledges. Knowledge can be positioned in the Data Information Knowledge Wisdom (DIKW) pyramid. Capturing DIKW in the shape of a pyramid seems to suggest that data are the raw building blocks of knowledge. However, Mulder et al. (2016) flipped this conventional view, arguing that data is generated from different sources of knowledge, because there is a social process that underlies the creation, editing and translation of data. The knowledge one has or wants to obtain influences this social process. Mulder et al. (2016) analysed this in the very specific context of crowdsourcing data in a humanitarian crisis. We argue that for each context the data-to-knowledge generation process will be different and should be disentangled. Data collected through scientific instruments at the local level can through analysis generate new scientific knowledge. Also in this case, the existing scientific knowledge and associated social processes influence –to some extent- where the local data collection is going to be done. Usually, a researcher should be aware of and describe this influence in the scientific reporting, such as via a positionality statement in social science related paper or an explanation of the limitations in the data collection in the methods section in for example a geosciences paper. Observations of the natural environments over time lead to the building up of local knowledge, but also here people may be inclined to observe what they are used to, given their existing local knowledge and occupation. Apart from these more conceptual considerations, for the incorporation of local knowledge in CS, it is important that we understand the types of data that come with the spectrum of local and scientific knowledges.

Table 3 labels data by their process of generation (i.e., through for example, a rigorous, evidence-based scientific process or through personal experience) and the holders. Table 3 will be introduced in section 3.3 with the aim to describe the methods to characterise local knowledge and to collect local data.

Table 3 Overview of the different knowledges, their generation process, and holders

Category	Description of knowledge	Knowledge generated through	Holder of knowledge	
			Description	Usual place in CS value chain
Local knowledge	Tacit, implicit and informal knowledge	Personal experience	Tribal or indigenous communities, other communities, including those in rural and urban environments, settled and nomadic communities, original inhabitants, and migrants	User
	Lay, personal, local, and situated knowledge			
	Indigenous knowledge	Traditional cultural norms, rules, and observations		
	Traditional ecological knowledge			
	Local ecological knowledge	More recent human-climate interactions		
	Occupational knowledge	Formalized non-scientific process	Employees of the NMHS at the local level; agricultural extension workers; farmers; hotel owners etc	Service provider or service purveyor
	Expert knowledge			
Scientific knowledge		Rigorous, evidence-based scientific process	Scientist	Data provider, data integrator and developer
			Citizen	Data provider

3 Methods to integrate scientific and local knowledge, characterise local knowledge and collect local data

3.1 Ways to make use of local knowledge and local data across the CS value chain

This section aims to give an overview of the different approaches and practices that are currently used to bring SK and LK together. Local knowledge has a role in adding context along the CS value chain. Across this range of approaches and experiences, a set of best practices can be identified which underpin effective ways of working to leverage knowledge which supports developing adequate CS. More specifically, the objective of this section is to identify those approaches that are most effective and adequate for an actor in the CS value chain. Research on expanding the usability of climate information argues for producing information that is perceived as credible (valid and trust-worthy), salient (relevant to decision making) and legitimate (outcome of an inclusive and fair process) by stakeholders (Cash et al. 2003; I-CISK, 2022). Building on this, Lemos, Kirchhoff, and Ramprasad (2012), describe pathways to achieving usable climate information through improved *'fit, interplay and interaction'*. The authors describe fit as the users' perception of credibility and salience of the information; interplay is how the information interacts with the existing knowledge and experiences of users (local knowledge); and interaction is the process through which climate information was produced (ibid). In the context of environmental management, Dyball et al. (2009), discuss processes of social learning among actors. They explain that participation and interaction among different actors can range from coercion (the will of one group is imposed on the other), informing, consulting, enticing, co-creation to co-acting (active participation). This spectrum of interaction between communities and external actors can be used, to some extent, to describe ways in which the holders of LK and SK relate to one another, reflecting the power relations between actors.

Berggren et al. (2011) define knowledge integration as a combination of specialised knowledge to reach an end result, while it has also been interpreted as the process of transforming individual knowledge to a collective one (Okhuysen and Eisenhardt 2002). One of the major challenges to integration arises from the differences between positivist science and local knowledge, resulting in "epistemological anxiety" regarding the validity and use of local knowledge (Taylor and de Loë 2012). Nevertheless, literature also notes that disregarding local knowledge within a collaborative process can lead to outcomes that are perceived as illegitimate and imposed (Berkes, Colding, and Folke 2000; Taylor and de Loë 2012). Box 5 explains in more depth the role of local knowledge in the CS product versus its role in the process of developing a climate service.

Box 5 Climate service product versus process and the role of local knowledge

Climate service product versus process and the role of local knowledge

Research on climate services often discusses the usability of these interventions for end users. It is well acknowledged that barriers exist that have impeded the uptake of climate services. This has been attributed to several factors, such as credibility, legitimacy, scale of the forecasts, cognition, institutional practices and norms, and complex nature of decision making (Patt and Gwata 2002). The value of climate forecasts relies upon whether their use leads to changes in management strategies or decisions, thereby leading to improved outcomes (Kumar 2010). However, climate is rarely the only factor guiding decisions (Kumar 2010; Goddard and Goddard 2017). Scholars therefore argue that a shift is needed from current strategies that focus on providing better data to developing climate services that aid in decision making (Findlater et al. 2021). A paradigm shift is also needed in terms of thinking of climate services more as a process than just as a suite of products. Findlater et al. (2021) describes process-oriented thinking as one which prioritises translation, engagement, use and evaluation, whereas product-oriented thinking focusses more on production, data, quality, distribution, and tailoring.

Framing climate services as a process also benefits the discussion on local knowledge, as it provides opportunities to explore additional pathways through which local knowledge can add value. Taylor and de Loë (2012) synthesize that incorporating local knowledge can lead to building trust with the communities; local actors are more likely to view the process as legitimate and fair; it can also inform and help better embed research and policy endeavours in the local reality. Consequently, local actors can also contribute new data and information to scientific studies; local knowledge also has the potential to produce a more grounded understanding of systems that are owned by the communities as well as help in identifying management decisions that are more contextually appropriate; and finally, local knowledge can also inform strategies for effective knowledge transfer and dissemination. In the context of water resources management, local knowledge can also serve as a means to manage uncertainty, by providing insight into the social dimension that can help mediate interests and goals as well as help in achieving common ground (Newig, Pahl-wostl, and Sigel 2005). Building on this, research in recent years argues that developing climate services is not a neutral activity; instead it is informed by and laden with particular values and priorities (Lemos and Dilling 2007). Therefore, studying local knowledge can help better extract and understand these values, and how they may impact priorities addressed in climate services development process, information provision and benefits accrued from the same (Webber 2019).

Section 3.2 discusses the importance of integrating local knowledge and approaches to do the same in the context of CS. Section 3.3 provides an overview of participatory methods that are useful in collecting local data with a view to characterise local knowledge. Lastly, Section 3.4 delves into integration techniques used by upstream (data providers and modellers) within the I-CISK project to incorporate local data and knowledge.

3.2 Overview of methods to integrate scientific and local knowledge

At their core, CS are geared towards providing support to solve societal challenges by managing the science-society interface. This presents methodological challenges, particularly the combining of different knowledge bases to establish a common understanding of the problem, and acceptance of proposed solutions. These challenges have been extensively discussed in the context of transdisciplinary research and within the co-creation framework (Pohl and Hadron, 2008; I-CISK, 2022). The co-creation framework encourages the acknowledgment of a diversity of perspectives to understand and clarify their differences and use of participatory methods (I-CISK, 2022). These methods, in combination with quantitative methods, can help in depicting the perception of a collective, and their rationale without qualifying them. Table 4 provides a matrix of forms of collaboration and four (simplified) means of integration, identifying in total twelve primary ways of integration, as conceptualized by Pohl and Hadron (2008). The forms of collaboration, originally provided by Rossini and Porter (1979) posit that within common group learning, integration is the result of a learning process that involves the whole group; while in case of deliberation it is a consequence of knowledge exchange between experts (scientific and non-scientific) with each expert analysing part of the problem and; in the third form of collaboration, integration is undertaken by a specific sub group. The four fundamental means of integration include (Pohl and Hadron, 2008):

- building mutual understanding through use of language;
- building common theoretical understanding (through transfer of concepts across disciplines, adapting disciplinary concepts and their operationalization, or developing new bridging concepts);
- using 'hard' and 'soft' models to depict shared understanding or facilitate mutual learning and;
- integration is stimulated by the end product or process, joining the diverse interests of groups involved.

Table 4 can also be interpreted from the lens of local knowledge integration wherein, integration can be in the form of, for example, developing a glossary in local languages and informed by local understanding, re-framing climate change impacts based on local realities, developing models to understand local decision making or setting up stakeholder platform as a means to capture and integrate local knowledge.

Table 4 Possible forms of collaboration and means and means of integration as discussed in transdisciplinary literature.

Means of integration	**Forms of collaboration**		
	Common group learning	Deliberation among experts	Integration by a subgroup or individual
Mutual understanding (using everyday language, developing a glossary)			
Theoretical concept (bridging different concepts, new concepts that merge disciplinary and local knowledge)			
Models (qualitative or quantitative models, scenarios)			
Products and processes (forums, database, technical devices, policy or regulation)			

(The delineation of different means of integration is for clarity and comparison, in practice a mix of these integration approaches are used. (adapted from Pohl and Hadorn, 2008))

Within CS the discussion on knowledge integration is ongoing. Table 5 revisits the integration typology provided by Plotz et al. (2017) and extended in this research. We note that most of the approaches for integrating local and scientific knowledge are when producing the CS, so prior to the service becoming operational, or when evaluating CS. (Hirons et al., 2021) state that evaluation should be ongoing and combine meteorological verification with decision-makers feedback. However, integration also takes place when a CS is delivered. For example, when CS users triangulate information contained in the CS between their local knowledge and the knowledge provided in the CS.

Table 5 Typology of approaches to integrating local and scientific knowledge and data in CS (Source: Pesquer et al. 2022)

Level of integration	Description	Reference
Science-dominated	In this approach, the information provided through the climate service derived from scientific knowledge is considered the most valuable (described as coercion (Dyball et al., 2009)). This level of integration is often found in global forecasting systems that are developed using global scientific datasets and models.	
Consensus	In the consensus approach, scientific knowledge (e.g., seasonal forecasts obtained from a climate model) and local knowledge (e.g., seasonal forecast based on traditional knowledge of meteorological signs) are considered equally by scientific experts and traditional knowledge holders. The two knowledges are combined to develop a consensus forecast.	(Plotz et al., 2017)
Validation	Local knowledge is used to evaluate information provided by the climate service, or scientific knowledge is used to evaluate the accuracy of local knowledge-based forecasts. Referred to as science integration in Plotz et al.	(Landman et al., 2020; Gilles et al., 2022)
Triangulation	Scientific knowledge provided through the climate service is triangulated by users with their local knowledge of their environment. This could include comparison of (seasonal) forecasts the climate service provides with environmental cues observed by the user.	(Shah et al., 2012; Gwenzi et al 2016)
Informing	Local knowledge is used to inform how scientific knowledge can be interpreted. Examples include where (Meteorological) indicators based on local knowledge are used to inform how scientific datasets and models are interpreted.	(Bucherie et al., 2022; Streefkerk et al., 2022)
Conditioning and Bias Correction	Notes: here local knowledge and in particular local data is used to condition model uncertainties and correct biases. This is through formal mathematical approaches such as quantile mapping or Bayesian approaches.	

3.3 Methods to characterise local knowledge and collect local data

Table 3 gives an overview of the different knowledges, their holders and how the knowledge is generated. In this section, we will describe the data associated with these knowledges and how one can collect the data. Table 6 explains the relevance of participatory methods in capturing and utilising local knowledge in more detail. They depict shared representations of reality and allow us to engage in a purposeful learning process (Voinov et al. 2018).

Table 6 Participatory methods and their relevance for local knowledge (adapted from Voinov et al. 2018; IFRC, 2023)

Participatory method	Description	Relevance for local knowledge	Example of use
Surveys	Surveys comprise of suite of questions that are aimed at trying to study an issue.	Useful approach for fact finding. Surveys are flexible and less resource intensive.	Understanding climate change perception of end users of climate services (Clifford, Travis, and Nordgren 2020)
Interviews (structured and semi structured)	Interviews comprise of a series of questions that are meant to support a face-to-face consultation when exploring an issue.	Similar to surveys, they are useful in fact finding. However, they can suffer from bias, which may be overcome by moving to a semi structured format that allows for a mix of both open and closed questions	People centred dissemination and communication of drought warning (Calvel et al. 2020)
Role-playing games (RPGs) or Serious games	RPGs involve the creation of virtual world, with simplified real-world conditions and rules. It aids in exploring and understanding the context and develop possible solutions through dialogue and collective exploration by the stakeholders.	Useful in revealing competing goals, interests, implicit social rules, and interactions.	Building cross cultural knowledge on climate change to enable social learning and support adaptation decision making (Blackett et al. 2022)
Focus Group Discussion (FGD)	FGD are a qualitative research method and data collection technique in which a group of people participate in moderated discussion regarding a given topic or issue.	These can be very useful in bringing to the fore local knowledge on a range of issues, for example, revealing collective views and rationale or beliefs underpinning those as well as competing narratives on topics and issues. It can also help in gauging the awareness levels across different members of the group.	Exploring risk perception and adaptation decision making among farmers (Singh et al. 2022)
Rich pictures	This is a diagramming tool which makes use of visual media (like symbols, texts, clipart) to represent how a group of people think about a particular issue.	Can help bring to the fore tacit knowledge as it allows people to draw what they are not able to articulate	Stakeholders' understanding of sustainable development (Bell, Berg, and Morse 2016)
Cognitive mapping	Cognitive maps or concept maps are graphical representations of organized knowledge that are used illustrate relationships or individual's knowledge or belief about an issue of interest or a system.	Useful in presenting the organised understanding of individuals of the world around them, or in representing formalised knowledge (for e.g., organization structure, flow of information)	Understand and analyse stakeholders' perception of drought impacts (Giordano, Preziosi, and Romano 2013)
Decision tree analyses or problem tree	Decision trees are used to depict the sequence of decisions and system changes that occur over time and its consequence on outcomes viewed as relevant by the stakeholders	Useful in understanding decision making, associated actions and outcomes.	Adaptive management (Haasnoot et al. 2013)

Social Network Analysis	This is a method used for studying social relations among actors, and how these relations and their patterns can impact or be impacted by actors' views, behaviour, perceptions, and learning.	It can serve as a starting point to conduct deeper investigation of the role of social capital.	Understanding the role of actors involved in the provision of agricultural climate services (Tesfaye et al. 2020)
Cultural consensus	These are a suit of analytical techniques and models that are used to estimate cultural beliefs and degree to which individuals know or report those beliefs.	These methods are useful in identifying groups with shared values. They are helpful in bringing to the fore the degree to which cultural beliefs are shared between the individual and the group.	Comparing socio-ecological knowledge among different stakeholder groups (Hesed et al. 2022)
Geographic information systems (GIS)	These are computer-based mapping frameworks that can aid stakeholders in visualizing and understanding their problems spatially.	Useful in participatory mapping exercises allowing users to display and input their spatial knowledge	Participatory mapping to pinpoint areas susceptible to floods and measures taken to reduce vulnerability (Cruz-Bello et al. 2018)
Agent based modelling (ABM)	ABM is a simulation method used to depict system behaviour and changes over time. An ABM consists of agents which are represented by attributes, behavior rules, and interactions with other agents with the environment.	ABMs are well suited for representing complex interactions, allowing for the integration of local knowledge in the form of behavioural rules or other attributes associated with the agents.	ABM used to understand factors that promote adoption of seasonal forecasts (Alexander and Block 2022)
Seasonal calendar	This method helps in exploring the seasonality of events in community over a one-year period. A seasonal calendar can be used to explore the farming activities of communities in a year.	These offer a way to understand the sequence of decision making within a season, as well as the distribution of workload and resource use, and correlating livelihood activities with risks and hazard events.	Seasonal calendars of weather patterns, livelihood activities, local indicators of flooding, rainfall and drought (Pauli et al. 2021)
Transect walk	This method involves walking through the community to observe and discuss the daily activities, surroundings, resources, and risks face by the community.	This method can help in unearthing spatial local knowledge, complementing information on maps with local understanding. It can also be useful in engaging in discussion about infrastructural arrangements.	Documenting micro-level adaptation practices in data poor environments (Haque 2021)
Historical profile and visualisation	These techniques help in engaging in discussion by building a picture of past disaster events and their effect on the community. Community members create a timeline of significant events and developments over the past decades.	Can help in understanding how past events have shaped local knowledge of a community and reveal decision making patterns. Furthermore, research finds that individuals find it easier to recall information associated with a particular event (for e.g., hazards)	Study produced a flood disaster risk reduction timeline (Bwambale et al. 2022)
Storytelling	Storytelling and other narrative inquiry techniques are a qualitative research and data collection method that use the medium of stories as a way to gain insight into human lives, cultures, and behaviors of individuals.	These techniques are very useful in capturing the lived experiences of communities and the ways in which individuals make sense of their surroundings.	Study uses narrative approach to elicit perceptions about historical and current weather, water and climate patterns to understand how climate change is perceived (Marschütz et al. 2020)

Participatory methods are effective in capturing the holistic part of local knowledge. More quantitative techniques can be used in addition to capture expert and occupational knowledge. The collection of data is related to a large extent to the processes to characterize local knowledge. Table 7 therefore gives both the method to characterize local data and the method to collect local data.

Table 7 Overview of methods to characterize the knowledge and to collect the data (for both scientific and local knowledge)

Category	Description of knowledge	Method	
		Characterize the knowledge	Collect the data
Local knowledge	Tacit, implicit, and informal knowledge Lay, personal, local, and situated knowledge Indigenous knowledge Traditional ecological knowledge Local ecological knowledge	Focus group discussions, storytelling, key informant interviews, household survey, cultural consensus, social network analysis, decision tree analyses, rich pictures, ABM	Seasonal calendar, historical profile, transect walk, participatory GIS
	Occupational knowledge Expert knowledge	Expert workshops, key informant interviews, cognitive mapping, ABM, decision tree analyses	Logbooks of observations, measurements with own gauges, seasonal calendar, participatory GIS
Scientific knowledge		Climate modelling, weather forecast modelling	Scientific measurement instruments
		Citizen science Social sensing	Sensing/measurement instruments such as social media, mobile devices, distributed devices, participatory GIS

By definition, the data that comes with local knowledge is often qualitative and has local spatial coverage and small spatial granularity. There will be some variation is the spatial coverage and granularity among the local knowledge holders. For example, experts such as agricultural extension workers may have local knowledge and data that extends over a larger area than e.g., a smallholder farmer whose knowledge is linked to his/her own plot of land.

Scientific data can have global coverage with coarse spatial resolution, such as satellite data, or also have local coverage and higher spatial resolution, such as with citizen science data or local meteorological or hydrological observations. This local data complements larger scale datasets such as those obtained from global and/or regional climate predictions and projections. Citizen science is usually categorised under scientific knowledge, as it refers to a process in which data is collected through a (scientifically) formal process. However, Wehn et al. (2021) and Tengö et al. (2021) point out that citizen science generates and consolidates both scientific and local knowledge. The recent Citizen Science Guidance Note by the WMO (2021) summarises the influence of citizens (as sensors, interpreters, engagers, and collaborators) and scientists (instructing, collaborating, or co-creating) on different types of citizen science projects. When there is no influence at all from the scientists involved, we could argue that the data from such a citizen science project represents local data that is part of local knowledge. Likewise, social sensing is about data collection from citizens when there is no pre-conceived scientific approach, as it broadly refers to a set of sensing and data collection paradigms where data are collected by humans or devices on their behalf (Wang et al. 2015) (Lin et al. 2022), such as through analysing social media posting. However, Leach and Fairhead (2002) draw a line here, as they consider that citizen science implies a certain engagement with, and usually a more dominant discursive role for, the science of expert institutions than is the case with local knowledge. This corresponds with that understanding and characterising local knowledge (and associated local data) is usually done through qualitative techniques, such as focus group discussions and key informant interviews, whereas citizen science projects typically use more quantitative and formalised techniques (Hicks et al., 2019; CitizenscienceDRR, 2022).

Finally, Table 3 specifies the data characteristics but not the data category. UNFCCC (2020) categorises data required for adaptation into four main categories: observational, projected, and historical data of climate and socio-economic processes. Local knowledge and data can cover all these categories, except for projected data. Local knowledge holders can recognise early warning signs of a certain hazard coming, such as a dry spell or a flood and they can see the effects of climate change. It is not clear yet if local knowledge holders can look ahead beyond seasonal time scales in the way climate models can (at e.g., decadal scales). The socio-economic processes category refers to for example the adaptive capacity and vulnerability of households.

Table 8 Overview of data types per knowledge category

Category	Description of knowledge	Data	
		Spatial coverage and granularity	Qualitative or quantitative; holistic vs reductionist
Local knowledge	Tacit, implicit, and informal knowledge	Local, linked to the area in which a person lives and works. Granularity can be high, but usually not recorded in detail.	Qualitative, holistic
	Lay, personal, local, and situated knowledge		
	Indigenous knowledge		
	Traditional ecological knowledge		
	Local ecological knowledge		
	Occupational knowledge	Local, linked to the area in which a person works. Can be a more extensive area than for the local knowledges above.	Transition from qualitative to quantitative and holistic to reductionist
	Expert knowledge		

Scientific knowledge	Local to global coverage. Granularity depends on the precision of the measurement instrument.	Quantitative, reductionist
	Local coverage. Granularity depends on the sensor the citizen uses.	

3.4 Upstream integration of local knowledge by the data integrator and developer

This section focuses on explaining how from a data integrator and developer perspective local knowledge and local data can potentially be used. It focuses on the co-developing phase of the co-creation framework. The I-CISK framework envisages that the step of "co-developing climate data and knowledge into a climate product" includes the following activities:

- synthesising of observations and model outputs
- identification of short-term and long-term data (indicators, thresholds, timing) missing to support climate change adaptation; disaster risk mitigation; EWS questions and challenges
- combining with (sectoral) climate knowledge
- combining with local knowledge and data, including citizen science
- transforming the scientific datasets to a spatial and temporal scale appropriate to user needs
- seamlessly integrating climate data across timescales from sub-seasonal to seasonal, to decadal and climate change.

Suggested methods for this step include the participatory methods we introduced before, evaluations of existing CS with respect to the LK included, and existing literature on including LK in CS. Joining indigenous LK and SK also requires discussion between scientists and non-scientists, to convey the meaning of e.g., uncertainty in models and results, and to help interpret how results can be used for implementation.

Innovation and enhancement of existing CSs and downstream impact-based products, and consequently on the support of decisions and policies in multiple sectors accounting for their local trade-offs are needed. Within I-CISK state-of-the-art tools and methods, as well as integration of citizen observatories and user's local knowledge are used to address the local needs and sectoral gaps of current CS. Large- and local-scale complex process-based mechanistic models of the earth system (impact models such as E-HYPE and WWH, and local statistical models) are used and innovated to characterise, estimate, predict, and communicate changes and impacts. The geographical focus is on the living lab regions, identified as climate change hotspots, addressing their sectoral needs, and understanding of impacts from multiple extremes, whilst the targeted investigations lead towards sets of best scientific-tailored practices for ensuring the usefulness of CS. A circular interaction between the different WPs allows exchanging and feedback of information required to translate datasets into tailored information and indicators for local use, but also bring these revolutions to the forefront of CS and finally provide an evolved CS. The impact models within I-CISK are driven by assimilated local data and state-of-the-art observations (i.e., earth observations), reanalysis data, sub-seasonal and seasonal forecasts, decadal predictions, and climate projections, with particular focus on datasets available in the S2S project datasets and in Copernicus Climate Change Service (C3S) through the Climate Data Store (CDS) platform, including the high-resolution Euro-CORDEX and CMIP5.

Local data and knowledge are currently collected and used alongside earth observations (EO) for both validating historical CS records and improving predictions, and hence exploring the potential of existing CS for the development or evaluation of the individual local modelling chains in a co-creation process. The model setup is based on both open available products and local in-situ datasets, whilst calibration and validation are undertaken via re-analyses of past conditions giving emphasis on extreme events, and the comparison of model results and event local-based documentation and knowledge. This results in their maximum usability for the sectors and underlying local conditions in the living labs. Not only predictions from existing CS and quantifies their propagated uncertainty for local users are benchmarked, but there is also focus on testing various techniques to increase accuracy and reliability at local conditions and decrease bias and uncertainty in climate predictions and their impacts at high lead times and future horizons. Three complementary approaches are investigated in Task 3.1, each targeting different elements in the CS modelling chain: (a) Downscale of ensemble meteorological forecasts and climate predictions to the resolution of impact modelling to better account for local characteristics and use of local data, whilst reducing existing systematic biases, using tailored bias-adjustment techniques for the identified indicators (i.e. distribution scaling or Bayesian Joint Probability); (b) Implement dynamic sub-sampling methods, i.e. based on teleconnections indices and information theory frameworks , capable of identifying representative subsets from large ensembles and leading both towards better predictions of local extremes and provision of subsets of results that are manageable for user-driven impact assessments; (c) Investigate the benefit of a multi-model ensemble approach and averaging methods to better account for and quantify both climate and impact model predictive uncertainty. The goal is to move beyond the traditional BA/downscaling approach of large-scale CS, where the forecasts are adjusted using global/continental re-analysis products which do not account for local information. By adjusting to local data directly we can quantify the differences in the forecasts and hence find the added value from local information.

Development of state-of-the-art methods to evaluate the usefulness of CS for decision-making purposes at local scales are explored as well as the predictability of multiple hazards to cover regions of interest in the living labs. While traditional scientific methods and techniques are important to provide an understanding of the prediction systems in order to continuously improve them, there is a need to undertake a user-driven evaluation of existing CS and predictions alongside the enhanced products developed in WP3, combining state-of-the-art large-scale scientific datasets with local knowledge to provide valuable information answering key questions users face regarding prediction performance.

A summary of the above-mentioned methodologies can be found in Figure 5. The steps in which local data and knowledge are directly integrated for the evolution of CS are presented in italics.

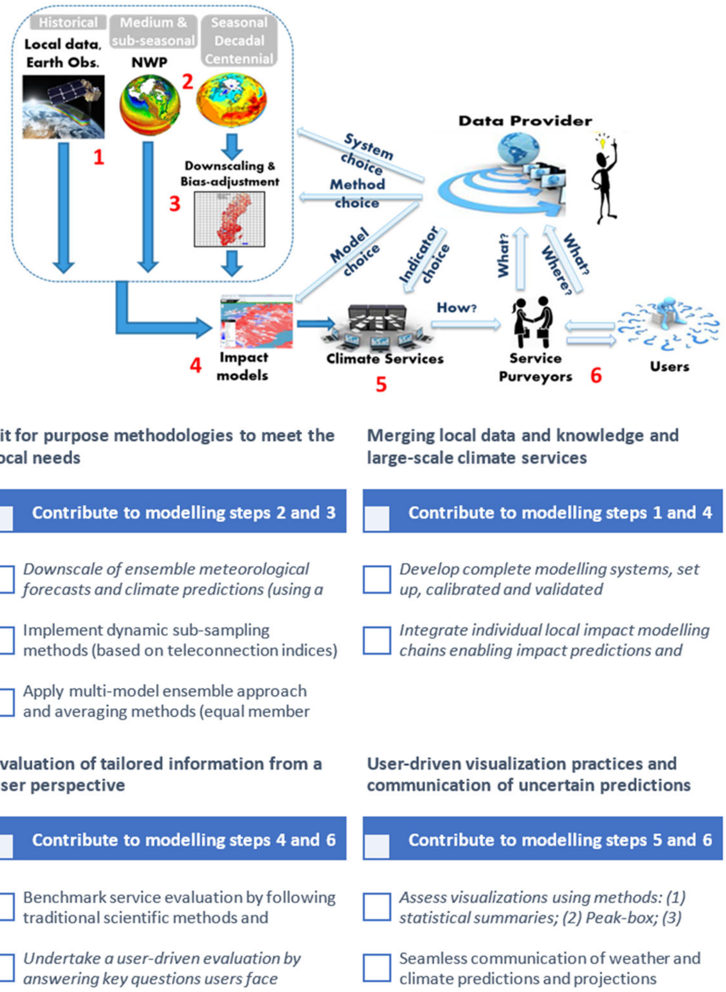

Figure 5 Methodology of linking local knowledge and data into CS to serve local needs.
Local data and knowledge are integrated aiming for the evolution of CS, and the steps in which this process occurs are presented in italics.

4 Characterization and use of local knowledge in the Living Labs

4.1 Introduction

The I-CISK project aims to innovate the ways local knowledge is understood and utilised within the design and delivery of CS. In the earlier sections of this deliverable the current understanding and use of local knowledge, and methods to integrate local and scientific knowledge are discussed. In this chapter, we highlight initial work that has been done in two of the living labs, Spain and Hungary. We adopt the framing presented earlier that local knowledge is an all-encompassing term that includes a range of different knowledges derived either through traditional or cultural norms, personal observations, lived or occupational experiences. It provides an insight into the 'way of life 'of individuals and communities, shedding light on how they perceive their surroundings, solve problems, and validate new information. It is accumulated over time and is very dynamic in nature. Local knowledge can be both tacit or implicit in nature, or more intentional as in the case of it being derived from structured and formalized processes. Finally, local knowledge is deeply rooted in the context from where it originates and therefore may not be generalisable to other contexts. With this in mind, we try to characterise local knowledge and data in the example two living labs. This is based on, who the holders of local knowledge are and the dimensions of local knowledge that are identified. In doing so, we utilise the continuum of local knowledge (developed based on the characterisation provided by Raymond et al. (2010)) to identify and characterise different holders of local knowledge and the type of local knowledge they possess (see Figure 3, Chapter 2). In terms of the dimensions of local knowledge, we limit to knowledges relevant to meteorological, hydrological, and biophysical observations, climate change perceptions and experiences, culture and norms, livelihood practices, coping and adaptation strategies, decision making, use of information and other context relevant dimensions. Current characterisation covers several of these dimensions. The information on local knowledge has been developed based on discussions with the multi-actor platform (MAP) members in each of the Living Labs, primary through targeted data collection processes (for example through surveys and questionnaires) and through review of existing literature.

4.2 Local knowledge in the Andalucía-Los Pedroches Living lab

The MAP in the Spanish Andalucía-Los Pedroches LL (ALPLL) is made up of a variety of stakeholders that, in most cases are both producers and consumers of CS and use a variety of sources of information to make adaptation decisions. MAP members such as the Andalusian environmental information network, REDIAM, or the Guadalquivir and Guadiana River Basin authorities generate CS (for instance monthly drought risk reports, or REDIAM's CLIMA database) but also rely on climate data and reports from the Spanish National Meteorological Service (AEMET). Some agricultural extension or research members of MAP, such as IFAPA or CICAP, also generate local climate information through a variety of projects: a network of local meteorological stations; a network of measuring devices of evapotranspiration from pasture and *dehesa* ecosystems, measurements of animal stress or other parameters in response to climatic conditions; or other initiatives in collaboration with local farmers and ranchers to analyse the relationship between climate and plant and animal productivity.

The main climate related information used in the ALPLL, both by natural area managers and by farmers, ranchers and farming cooperatives is data which is provided primarily by AEMET as well as information from a variety of media channels (eltiempo.es, TV, press). Apart from these short-term previsions, users rely heavily on their own memory of past climatic conditions and their experience in order to make adaptation decisions. In order to facilitate the use of this past knowledge, MAP members have requested I-CISK to generate a CS that makes official historical climatic data (temperature and precipitation) easily available (through an app) to help contrast empirical data with their recollection and experience, thus helping improve their decision-making process.

Traditional local knowledge in the form of weather-related proverbs or the *cabañuelas*, a traditional climate prediction system, are also mentioned by farmers and forest guards as informal sources of climate predictions. However, observed changes in temperature and rainfall patterns over the last few years, have influenced perceptions on the reliability of traditional knowledge and local experience.

In the ALPLL three types of local information are currently being gathered in order to develop the co-identified CS:

- Climate information from local meteorological stations to adapt climate predictions and projections to the temporal and spatial resolution needed, and to characterise uncertainty and fit of climate model outputs.
- Phenological information on historical plant productivity – for pasture, olive trees and forest tree species – in order to establish relationships between plant productivity and climatic conditions.
- Local knowledge regarding the evolution surface and groundwater resources and uses in order to characterise the hydrological cycle in the region and model its projected evolution in response to climate change projections and changes in demands.

4.2.1 Methods used to identify the LK used in the LL

The ALPLL is relying on different methods to identify and gather LK that should be considered in the co-development of CS and, where relevant, be incorporated in co-developed CS:

- **Document review** with a special focus on literature produced by local actors and related to processes that are addressed by the CS.
- **Access of online repositories** of public meteorological and hydrological **data** that are publicly available.
- **Review of social media sites** related to the region, including blogs, twitter accounts, Facebook pages and other fora where information on different issues – such as water availability, climate, etc. – is exchanged by local residents.
- **Interviews**. These methods allow us to identify the type of knowledge available, what actor has that information, its limitations and its relevance in decision making. In person interviews have created the space for actors to mention traditional knowledge – *refranes*, *cabañuelas* – that are acknowledged as not scientifically reliable but are known and used locally.
- **Workshops**. Annual workshops allow us to identify existing "formal" or scientific local knowledge, its relevance in decision making, potential improvements and interest in collaborating in the generation of new CS building from existing information.
- **Online periodic follow-up meetings with key members of the MAP**. These meetings have been critical in obtaining more accurate information and characterising local knowledge, to clarify doubts, and build on the collaboration.
- **Survey to gather local knowledge on hydrological data**. Given the limited availability of official data on hydrological variables, the LL team has developed a survey in order to gather information on surface and groundwater hydrology in order to feed a local hydrological model. The survey is divided into two sections:

- **Surface water hydrology**. It includes questions about individuals’ current and past memories of the status of local rivers and streams: when they have water, when they are dry, for how long, existing ponds, shoreline vegetation coverage, etc. The questionnaire is based on the online tool developed in the context of the LIFE project TRIVERS.
- **Groundwater hydrology**. This section includes questions about respondents’ wells, evolution of groundwater levels, geological information, etc.

Each survey response is georeferenced. Responses will be combined with information and data from river basin authorities and previous studies in the region, information on the evolution of permitted wells, LANDSAT information of the evolution of land uses and vegetation cover.

Table 9 below characterises the types of local knowledge (LK) identified in the ALPLL.

Table 9 Characterization of knowledge and data identified in the Andalucía-Los Pedroches living lab

Type of LK identified	LK Holder	LK Dimensions	Description	Timescale
Reports	ADROCHES	Land use Economic Production	ADROCHES is a regional rural development organisation focused on the Pedroches region that issues economic development strategies. It has reports on the livestock sector – size, development, environmental impacts.	Several years
Local data collection stations	CICAP - COVAP	Meteorological	CICAP-COVAP has a local meteorological station network (15 stations)	Continuous
	Regional government of Andalucía	Meteorological	Network of meteorological stations in Andalucía with a few stations in the region. Information is freely available online.	Continuous
	REDIAM	Meteorological	CLIMA network	Continuous
	Guadiana and Guadalquivir River basin authorities	Hydrological	Network of hydrological and hydrogeological measuring stations. Only a few stations within the Pedroches region.	Daily
	Olive oil farmers Livestock farmers	Meteorological	Rain gauges. They have a network of personal contacts that share information on how much water has fallen and when	Short-term
	Local high school	Meteorological	Local meteorological station located in the central town's high school. Data is available online and is consulted by farmers and cooperatives.	Daily
Records	OLIPE – olive oil cooperative	Olive production	The cooperative has historical records of olive tree and processed olive oil production for all members of the cooperative.	Annual
	IFAPA	Pasture and acorn production	Pasture production models with a series of 20 years Currently collecting information for acorns (feed for extensive hog production)	Annual
	COVAP livestock cooperative	Milk production Pasture production Meat production	Historical records of milk production, evolution of the number of heads (cows, pigs and sheep) and meat production.	Annual
	Regional agrarian office	Total heads of cattle	Historical records of heads of cattle in the region (cows, pigs, sheep, goats)	Annual
Community memory and individual observations	Citizens	Hydrological	Observation of the evolution of surface and groundwater resources - decrease in water availability because streams do not carry water and traditional wells have dried up	Mid and long term (years)
Popular sayings ("*refranes*")	Farmers, forest guards, citizens	Meteorological	e.g.: "if you don't see the Guadamura [a river] running by Epiphany [January 6], buy hay and sell cattle." Explanation: if the Guadamura in January does not carry water, there will not be enough water for the livestock that year	Seasonal
Traditional knowledge based on observation: *Cabañuelas*	Farmers Livestock farmers	Meteorological	These are traditional methods of weather forecasting for the whole year based on the weather and other conditions during the first 24 days of August	Seasonal and monthly

Type of LK identified	LK Holder	LK Dimensions	Description	Timescale
Occupational experience	Farmers Livestock farmers	Hydrological Meteorological	The state of annual plants is a reflection of both the state of the groundwater and the amount of rainfall, in times of drought their color turns yellow.	Short- medium term
Occupational experience	Farmers Forest managers	Hydrological Meteorological	Woody crops (oaks) and forest species accumulate the water deficit and signal long periods of drought.	Long term (years)
Occupational experience	Farmers Forest managers	Meteorological Phenological	Change in the phenological cycles of plants evidencing a change in the seasonal periods	Seasonal Annual Long term (years)
Traditional knowledge	Farmers Livestock farmers	Meteorological	Position of the planets: there are certain planets that in certain positions affect weather conditions such as Venus which is a water planet and if the moon accompanies it can cause good water conditions.	

4.2.2 Some remarks on LK based on the work carried out so far

The exploratory work carried out in the ALPLL during the first 15 months of the I-CISK project has been key to shed light into the LK present in the region:

- LK in the form of local production of data and knowledge is highly developed and sophisticated. In this context, the added value that can be provided by I-CISK is in the combination, analysis and visualization of exiting data and knowledge into tailored CS.
- LK in terms of traditional knowledge, personal and occupational experience is used to make decisions with different degrees of intensity and confidence. Local actors are keen to systematically compare that knowledge and experience with "hard" data (e.g. historical records of precipitation, temperature, rainfall), so that they can assess to what extent their perceptions reflect actual, observed trends. This interest in contrasting perception with observation has spurred several local initiatives for data collection in the past few years in the LL beyond the regional and national monitoring systems. Since these initiatives are recent, they still do not have long enough a record of observations to feed predictions and projections to be produced by I-CISK. However, the I-CISK team is working on assessing how to incorporate some of these into the CS developed by the e.g., to assess reliability of predictions.
- The work carried out so far has been key establish the basis for CS development. However, the identification, characterisation and, where relevant, inclusion of LK in the CS is an iterative process. Thus, the relevant pool of LK present in the LL is likely to expand at each iteration with the MAP. For instance, the fieldwork foreseen for the year of 2023 to characterise the hydrological functioning of the LL is likely to reveal additional LK, which will be mapped and reported in the next phases of this task (Task 2.2).

4.3 Living Lab Hungary

In the Hungarian Living Lab - which is situated in Erzsébetváros, an inner district of Budapest - we aim to identify how stakeholders are experiencing urban heat waves and urban heat islands, and in general the urban climate. Besides this, our goal is to identify the local knowledge of the residents, the climate information they use, their CS needs, and their adaptation strategies. The uncertainties and barriers of adaptation strategies were also the focus of our inquiry in the context of the Living Lab (individual constraints: like costs, and institutional barriers: like contested use of the public spaces).

The stakeholders of the Hungarian Living Lab are members of the Climate Department of the district's municipality and the municipality of Budapest (although they are included to a lesser extent), researchers, an environmental NGO (Clean Action Group), and the residents of Erzsébetváros. We consider the residents of Erzsébetváros as holders of local knowledge.

As we do not have prior knowledge of the local knowledge or adaptation strategies of the residents, a primary data collection effort was undertaken. Instead of applying participatory methods, we chose to conduct an online survey among the residents of the district. The reasoning for the use of this method was that it is more suitable as an introductory method for a topic that may be unfamiliar and rarely discussed, as it requires less commitment and effort from the stakeholders than a participatory method. It also allows us to understand the opinions and perceptions of more stakeholders in a shorter time on a fairly unresearched topic. As a next step, and with the help of the results of the online survey we are organising two workshops for the residents in the Spring of 2022. In the summer a citizen science campaign, where residents will collect data on urban heat islands in the district with sensors will be launched.

The online survey was conducted in the autumn of 2022 among residents of Erzsébetváros, and those who are working in the district or regularly staying there for other reasons. Initially, we shared the survey on the Facebook page of the Climate Cabinet (Municipality of Erzsébetváros), while later on the members of the Living Lab also spread the survey through other platforms.

100 respondents participated in the survey. The majority of the respondents live in the district. Some respondents only worked in the district and lived elsewhere, and there were some people who both lived and worked in Erzsébetváros.

Local knowledge among end-users: climate change and urban heat waves and urban heat islands in an urban setting, perceptions, and experiences

The majority of the respondents noticed changes in the weather, which they attributed to climate change. Most of them mentioned the longer, more intensive heat waves during summers, the homogenisation of seasons, the diminishing amount of precipitation, the generally more erratic weather, and the torrential rains.

The majority of the respondents agreed with the next statements, which discussed the changing urban climate.

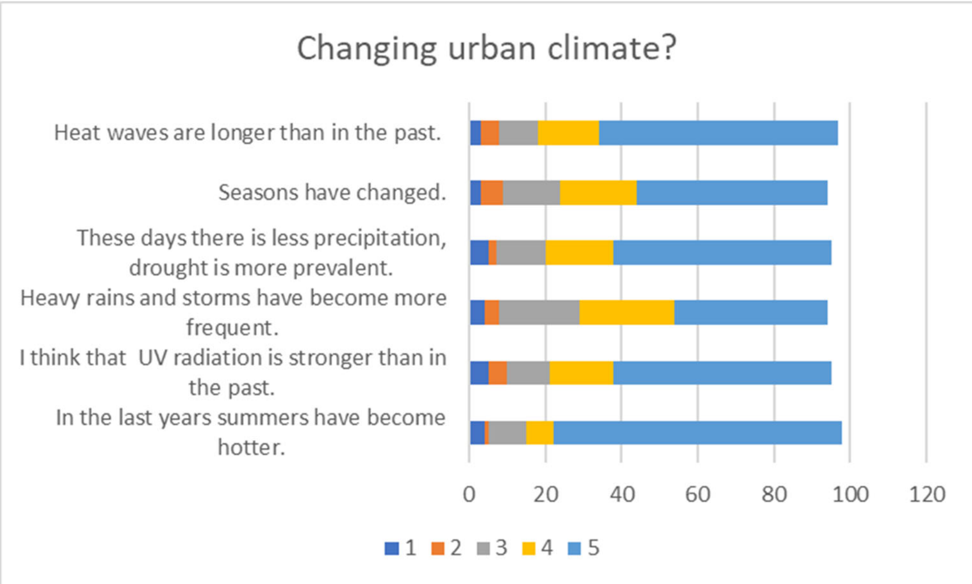

Figure 6 Responses to the question: Is there a changing urban climate?
(Legend: 1: don't agree at all, 5: totally agree)

The majority of the respondents agreed with the statements that were referring to the effects of urban heat islands and urban heat waves.

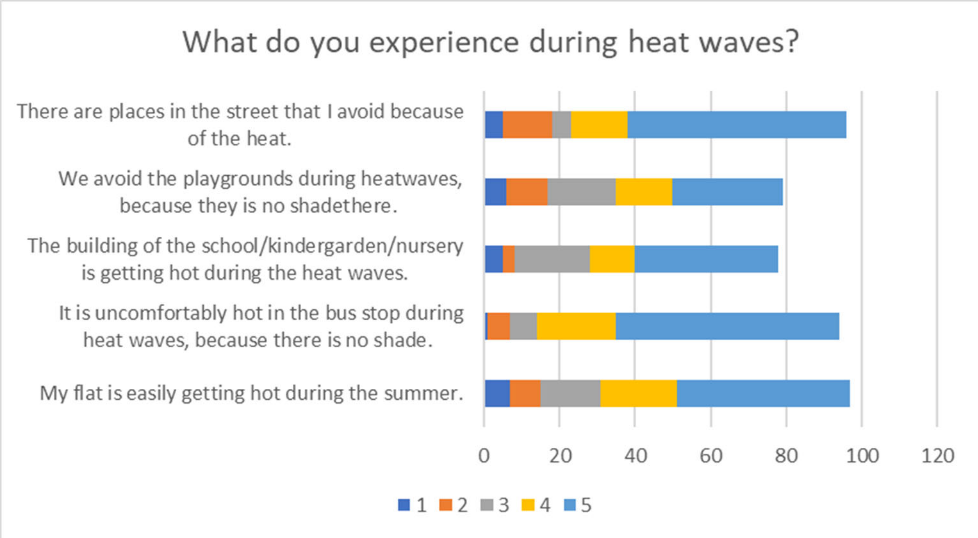

Figure 7 Responses to Question: What do you experience during heat waves?
(Legend: 1: do not agree at all; 5: totally agree)

The majority of the respondents agreed that there are places in the district that can be called hot spots, where it is uncomfortable to stay during summer. The respondents marked the following places in the district where they experienced being uncomfortably hot during the summer heat waves.

Figure 8 Hot spots in the district marked by respondents

Adaptation strategies: individual and non-individual practices and costs

The respondents followed individual adaptation strategies during heat waves: most drank more fluids, and protected themselves with clothing. Other than these, they avoided certain places that were affected by the heat, used shading in their apartments, and escaped to green areas/forests/watersheds to adapt to heat waves.

The respondents considered effective the following non-individual adaptation practices: enhancing the extent of the green areas, thermal insulation on buildings, greening the backyards/inner yards of the buildings, green roofs/walls, and shading of windows. Some of the respondents mentioned that shading some parts of the streets that are more exposed to sun radiation would be useful as well.

Most of the respondents answered that the adaptation to heat waves resulted in extra duties. The adaptation resulted in more tasks because of the respondents' own health situation or age, because they had to care for their children, or their older relatives/friends, or in general because of their responsibilities towards their families. Some of the respondents mentioned that they had to care more attentively to their pets during heat waves.

For most of the respondents, the adaptation to heat waves caused extra costs. They mentioned the costs of heightened water consumption, the additional electricity costs, and the cost of escaping to green areas/forests/watersheds.

Climate information and CS in use

The respondents used weather data/information acquired from a meteorological site, TV and radio, another website, or newspapers. Most of the respondents followed the information on heat waves and followed the suggestions as well, a minority followed the heat wave information, but did not act on the suggestions provided.

Most of the respondents regularly followed the news and information about climate change. They acquired information from magazines and websites that are producing popular scientific content (like Natgeo), and publications in newspapers and news sites.

The respondents considered the establishment of green areas, holding back consumption, and the mitigation of greenhouse gases with technology as the most effective ways of climate change mitigation.

Summary

Based on the results of the online survey we concluded that the respondents perceived that the urban climate was changing and experienced the effects of the urban heat islands. The respondents considered green areas effective in climate change adaptation. The individual adaptation caused most of the respondents to have more responsibilities and costs. Most respondents acquired weather data/information from a meteorological site. To be able to understand these findings in more depth we plan to complement the results of the online survey with the findings acquired by using participatory methods (workshops) and the citizen science sensor campaign.

5 Conclusions and future work

This deliverable is an iterative one, with this first version summarising current scholarship on local knowledge and laying the foundation to build towards a framing of local knowledge that will be adopted and operationalised within the I-CISK project.

Knowledge on climate from all stakeholders (e.g., scientists, local key institutions and potential end-users) is relevant for the design, production, validation, and effective application and use of CS. Therefore, the objective of this deliverable (and the corresponding task 2.2 within which this deliverable has been developed) is to identify and collect local knowledge, through mostly participatory methodologies, to link expertise from the consortium scientists and local knowledge from the LL and complement climate data from Copernicus and GEOSS and research with local data. This co-identification is considered within the particular social, economic, and sectoral contexts of the LL, and aims towards being goal-oriented and explicitly recognizing the multiple ways of knowing.

Through this deliverable and future work, I-CISK aims to innovate the way local knowledge is currently understood and utilised within CS. More specifically, we want to expand the current framing of local knowledge, viewing it more as continuum comprising of different types of knowledge each corresponding to different ways through it was generated or accumulated. The next steps will look at ways to operationalise this framing within the project as well as inform the discourse on local knowledge outside of the project. Furthermore, the living labs that form a part of the I-CISK project provide a unique opportunity to study local knowledge in contexts (countries in the Global North, sectors like tourism and urban local knowledge) that are currently less researched and often excluded from the discussion on local knowledge.

The following are the next steps that will be undertaken building up to the next iteration of this deliverable.

- **Building a common understanding and repository of local knowledge across the living labs**

One of the key challenges impeding the use of local knowledge is the lack of a common understanding of the topic. Therefore, as the first next step, the aim will be to establish a common understanding at the scale of the I-ICISK project. We plan to organise one-on-one meetings with each living lab team to discuss with them the findings of this deliverable and the proposed framing of local knowledge. Next to that, we will also provide all living lab teams with a framework and template to identify and characterize local knowledge and data within their contexts. We also aim to provide support in developing methodologies and protocols if there is interest in carrying out primary data collection processes relevant to local knowledge.

- **Linking with Work Packages (WPs)**

Even though most of the work associated with local knowledge primarily rests within WP 2, the focus will be to ensure that local knowledge is addressed to varying extents across several WPs. Table 10 provides an overview of WPs (and associated tasks and deliverables) and links with local knowledge.

Table 10 Ways in which local knowledge is interwoven across different WPs

WPs	Links with local knowledge	Relevant tasks (T) and deliverables (D)
WP 2	Local knowledge has its role in each step in the I-CISK co-creation framework but is most pertinent in the first three steps of co-exploring, co-identifying and co-developing. The process starts by **co-exploring** user needs and **co-identifying** adaptation strategies. The step of **co-developing** climate data and knowledge into a climate product builds on the needs as well as the decisions and strategies that the newly developed CS could fulfil.	T2.1, T2.2, T2.3, T2.4, T2.5 (D2.1, D2.2, D2.3, D2.5)
WP 3	Using local knowledge and data to inform local and regional climate models, innovating approaches to integrate local knowledge, and evaluating tailored information through user-centred evaluation which focuses on decision and user perception of 'useful' information.	T3.2, T3.3 and T3.4 (D3.2, D3.3, D3.4)
WP 4	Co-exploration of end user adaptation actions, priorities, and goals, and using local knowledge to inform participatory modelling efforts.	T4.1, T4.3, T4.4 (D4.3, D4.4)
WP 5	Developing a platform informed by user needs and requirements. Identifying and integrating local data and user-validated visualization practices. Ensuring that the developed tool aligns with competencies and is accessible for non-specialist users.	T5.1, T5.2, T5.3 (D5.1, D5.2, D5.3)

- **PhD research**

Research on local knowledge is also currently being undertaken by PhD researchers working within the I-CISK project. Planned research efforts include: systematising local knowledge understanding and developing a typology of local knowledge use for CS; capturing local knowledge associated with hydrology (surface and groundwater) and integrating it with scientific knowledge; understanding local knowledge of upstream agents; and role of local knowledge within decision making. This work with be carried out across several living labs.

- **Outreach and partnerships**

Finally, as mentioned above, some of the planned next steps will endeavour to inform the discourse on local knowledge beyond the I-CISK project. This will be done through regular participation in relevant conferences (for e.g., the UNESCO International Conference on Climate Risk, Vulnerability and Resilience Building, European Geosciences Union, European Climate Change Adaptation Conference, World Climate Research Programme: Open Science Conference and the Adaptation Futures conference) to create awareness, share lessons and obtain feedback from the broader community on the understanding and use of local knowledge. We also aim to build partnerships wherever possible to strengthen and mainstream the work on local knowledge. For example, our aim is to collaborate with the World Food Program in Lesotho to conduct a study on local knowledge use.

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Appendix 1 Glossary

Acronym	Definition
API	Application Programming Interface
C3S	Copernicus Climate Change Service
CDS	Climate Data Store
CEMS	Copernicus Emergency Management Services
CMIP	World Climate Research Programme's Coupled Model Intercomparison Project
CORDEX	Coordinated Regional Climate Downscaling Experiment
CS	Climate Services
CSIS	Climate Services Information Systems
DRR	Disaster Risk Reduction
GEO	Group on Earth Observations
GEOSS	Global Earth Observation System of Systems
GUI	Graphical User Interface
IPCC	Intergovernmental Panel on Climate Change
LL	Climate Services Living Labs
NHMS	National Hydro-meteorological Service
MOOC	Massive Open Online Course
OGC	Open Geospatial Consortium
S2S	Sub-seasonal to Seasonal
TRL	Technology Readiness Level
UNCCD	United Nations Convention to Combat Desertification
UNDRR	United Nations Office for Disaster Risk Reduction
UNFCCC	United Nations Framework Convention on Climate Change
WCRP	World Climate Research Programme
WFD	Water Framework Directive
WMO	World Meteorological Organization

Colophon:

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