Deliverable D1.1
Characterization of the I-CISK Living Labs

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Innovating Climate services through Integrating Scientific and local Knowledge

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Executive Summary

This report characterizes the living labs (LL) established under the I-CISK project. It provides information on key features of each, such as geographical and climatic settings; weather, water and climate related hazards; sectors impacted by hazards, climate services (CS) use and needs; and potential impacts of the new CS services to be co-created under I-CISK project. Six Multi-Actor Platforms (MAP) are established, one in each LL, to effectively contribute to the development of these next generation CS, which are tailored to the user needs and the spatial and temporal scales relevant to them. The information synthesised in this report has been collected from various documents (e.g. journal articles, reports, websites), progress made under different work packages (WP) of I-CISK (e.g. deliverables and milestones), analysis of readily available data and information, and discussions with the key actors participating in MAP. A summary of the key characteristics of the I-CISK LL is provided in the following Table.

The I-CISK LL are located in geographically diverse landscapes in the European Union (EU) region and beyond. Five LL are in the EU region (from west to east) in the Netherlands, Spain, Italy, Hungary and Greece; one is in Georgia in the Caucasus Region, one of the countries included in the European Neighbourhood Policy. We initially planned to establish one LL in Namibia, Southern Africa Region, but this did not work out well because the Namibia Red Cross Society (sub-contractor of RC 510 as mentioned in the I-CISK project proposal) decided that they could not host the Living Lab anymore due to changes in leadership, capacity constraints and strategic priorities. We are currently working on establishing an alternative LL in Lesotho, and will integrate its information to this report at a later stage. The I-CISK LL represent four distinct climate regions of the world: (1) Mediterranean climate, Köppen classification Csa (the LL in Andalucía, Spain and Crete, Greece); (2) Humid subtropical climate, Köppen classification Cfa (the LL in Emilia-Romagna, Italy and Alazani River Basin, Georgia); (3) Marine west coast climate, Köppen classification Cfb (the LL in Rijnland Delta, the Netherlands); and (4) Humid Continental climate, Köppen classification Dfb (the LL in Erzsébetváros municipality in Budapest, Hungary). These LL also represent the climate change hotspot regions of the world: 1) semi-arid regions (Andalucía), Deltas (Rijnland, parts of Crete Island), and glacier and snowpack dependant the river basins (Rijnland-Rijn River, Emilia-Romagna-Po River, Alazani River). The variability in precipitation and temperature is quite high within and across the LL. Climate change has and is projected to further change the precipitation (decrease in annual totals in most cases with increase in intra-and-interannual variability) and temperature (increasing trends in all the LL).

Multiple weather, climate and water related risks are identified in each LL, with drought and water scarcity emerging as the major risk for most contexts, i.e., both in water-limited semi-arid environments as well as humid and coastal climate environments historically known as water-abundant, which are currently facing increasing pressures due to increasing water withdrawals for human use compounded by climate change impacts. The floods, heatwaves and high variability in climatic patterns and water availability are also important hazards in focus. All these hazards impact multiple sectors, and each LL will focus on developing at least one CS within the LL context that caters for the needs of two or more sectors i.e., water management, environment (including forestry), agriculture, livestock, tourism, health and energy.

The role of the MAP is pivotal in the co-development of user centred CS, and the process of co-creation of new CS will be enriched by active participation of MAP members representing about 90 key actor organizations across the six LL. The diverse group of actors well represent policy makers, academia and research, industry and business community, and citizens, alongside actors representing the whole value chain of CS development (e.g. providers, purveyors and end-users). The participation of such a diverse and highly relevant group of actors will ensure that a transdisciplinary approach will be used throughout the process of co-creating

innovative next generation CS. It will also ensure that these CS are sustainable and contribute to safeguarding different economic sectors and society against multiple climate and water related risks in Europe and beyond.

Summary of selected characteristics of the I-CISK living labs.

Living Lab	Climate information Köppen classification with mean annual precipitation in mm and temperature in °C (and monthly range)	Main Hazards in focus under I-CISK	Main sectors in focus under I-CISK	Stakeholders participation in Multi Actor Platforms	Climate services currently in use	Climate services needs/ potential ambition under I-CISK
Rijnland Delta, the Netherlands	Marine West Coast (Cfb) P: 825 (40-90) T: 11 (4-18	Drought, water scarcity	Water management, Tourism and water recreation, Agriculture,	Policy makers (4 organizations), research and academia (2), business and industry (2), civil society organizations (2).	Drought monitoring system (including medium-range forecasts), streamflow predictions	Longer timescales, including sub-seasonal, seasonal and climate projections, strengthen stakeholder engagement and communication
Andalucía, Spain	Mediterranean (Csa) P: 485 (2-70) T: 17 (9-26)	Drought, water scarcity, heatwaves, wildfire	Water management, environment including forestry, agriculture, livestock, tourism and recreation	Policy makers (4), education community (1), research and academia (3), business and industry (3), civil society organizations (1) and other relevant actors (1)	reservoir management support, seasonal forecasts, climate projections, climate scenarios viewer, drought monitoring, river basin monitoring	Sector-tailored information (e.g. forecasts of rainfall patterns, seasonal distribution, start of summer and winter seasons), impact-based forecasts, improved spatio-temporal resolution, longer-range forecasts
Emilia-Romagna, Italy	Humid subtropical (Cfa) P: 800 (45-100) T: 13 (2-23)	Drought, water scarcity, floods and highly variable water supply	Water management, agriculture, environment, energy	Policy makers (2), education community (1), business and industry (2), civil society organizations (3)	Regional climate projections, agriculture water demand forecasts	Improved spatio-temporal resolution, integration of local data, river discharge forecasts, effectively communicated uncertainty
Erzsébetváros, Budapest, Hungary	Humid Continental (Dfb) P: 570 (30-70) T: 11 (-1 to 22)	Heatwaves, Urban heat islands	Tourism and recreation, Health	Policy makers (3), academia and research (2) and civil society (1).	CLMS Urban Atlas, historical global land surface temperature, meteorological data, air quality monitoring	Tailored CS and wider range of variables related to heatwaves, including health impacts
Crete, Greece	Mediterranean (CSa) P: 655 (0-140) T: 18 (11-26)	Drought, water scarcity, floods	Tourism and recreation, water management, energy, agriculture	Policy makers (3), business and industry (2) and civil society (1)	Weather forecasts, climate change impact assessments and vulnerability analysis, hindcasts, short-term forecast service for reservoirs	Sector-tailored information and indicators, improved spatio-temporal resolution, hazard severity indicators, uncertainty and reliability, compound hazard CS
Alazani river basin, Georgia	Humid subtropical (Cfa) P: 730 (30-106) T: 10 (-3 to 22)	Flood, drought, water scarcity	Water management, agriculture, environment, energy, tourism and recreation	Policy makers (5 organizations), research and academia (1) and civil society (9)	meteorological and hydrological forecasts, extreme event warnings, agrometeorological bulletins, frost early warning, seasonal outlooks, climate projections	Multi-hazard early warning system, impact-based forecasts, maintenance and integration of observation network and data, sector-tailored information

(Source: Adapted from I-CISK D2.1 (Moschini and Emerton et al., 2022).

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1 Introduction

There is increasing evidence that human-induced climate change, including more frequent and intense extreme events has already caused widespread adverse impacts to people and nature across the world. These impacts are much beyond the natural variability of climate, and are expected to increase in the future. The impacts of climatic extremes vary across regions and sectors depending upon the risk factors and adaptation capacities. In some regions, natural and human systems are pushed beyond their ability to adapt to the rising impacts of weather and climate extremes (IPCC, 2022).

The climate services (CS) have a crucial role in building climate resilient societies and economies in the face of climate variability and change at multiple scales such as short-term early warnings for disaster risk reduction to long-term climate change projections for strategic planning. The European Research and Innovation Roadmap for CS (EC, 2015) describes CS as: “the transformation of climate-related data — together with other relevant information into customised products such as projections, forecasts, information, trends, economic analysis, assessments (including technology assessment), counselling on best practices, development and evaluation of solutions and any other service in relation to climate that may be of use for the society at large. As such, these services include data, information and knowledge that support adaptation, mitigation and disaster risk management.”

The advances in the development, provision and use of CS has helped in managing the climate variability and change to a certain extent. However, the progress is still below the full value proposition of the available CS due to several reasons such as failure to incorporate the social and behavioural factors and the local knowledge and customs of the users. The I-CISK project addresses these gaps as it aims to develop next-generation CS that follow a social and behaviourally informed approach for co-producing CS that meet the climate information needs of citizens, decision makers and stakeholders at the spatial and temporal scale relevant to them. In geographically and sectorally diverse living labs (LL[1]), the I-CISK project showcases its human-centred co-design, co-creation, co-implementation, and co-evaluation approach across key sectors vulnerable to climate change in Europe and beyond.

The I-CISK LL have been selected in geographic areas that are identified as climate change hotspots, in Europe and beyond (Szabo et al., 2016; de Ruiter et al., 2020), and that are susceptible to increasingly compound multi-hazard events in the current and future climates (Ridder et al., 2020). Within these LL, I-CISK will co-design and launch pre-operational CS Information Systems (CSIS) with well-embedded local partners, working in collaboration with stakeholders from multiple sectors, including citizens, public authorities, and enabling institutions and the private sector. The service that these CSIS provide will integrate local knowledge and scientific data to support decisions of end-users in adapting to climate change and managing multi-hazard extremes. These user-tailored CS will support climate adaptation strategies at multiple scales, as well as local and European policies, such as the European Green Deal, the Water Framework Directive, the European Union

[1] 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); real-life environments in which multiple heterogeneous stakeholders are connected through public-private-people partnerships and in which innovation-development activities can be conducted (Hossain et al., 2019)” (I-CISK MS10, 2022). These definitions are quite generic and are applicable to the living labs with focus on water and climate, and also captures the key elements included in the Water Europe’s definition of water oriented living labs (WoLLs) “ WoLLs are real-life, water oriented and demo-type and platform-type environments with a cross-sector nexus approach, which have the involvement and commitment of multi-stakeholders (including water authorities) and a certain continuity (good chance to continue to their existence), and provide a “field lab” to develop, test, and validate a combination of solutions as defined in the SIRA, which include technologies, their integration as well as combination with new business models and innovative policies based on the value of water.” (Water Europe, 2019).

(EU) Communication on Water scarcity and Droughts, as well as international science-policy interfaces (e.g., IPCC, UNDRR, WCRP).

This report presents the key features of the I-CISK LL by synthesising available information for each LL in terms of geographical positioning, hydrological landscape, climatic features including most relevant hazards, climate change projections, business sectors impact by extremes, and corresponding CS use and ambitions under I-CISK. The stakeholder analysis is conducted that provides the basis of identification of key actors who will form I-CISK Multi-Actor Platforms (MAP), participating in the co-creation activities in each LL. The report also reflects on expected impacts, exploitation and upscaling potential within and beyond the LL. Finally, roadmap to sustainability is presented for each LL.

2 Task objectives and Context within I-CISK

The main objective of this deliverable is to present the salient features of the LL established under I-CISK. The deliverable is directly related to the Task 1.1 related to the establishment of the I-CISK LL. The deliverable is part of WP1, which aims to provide a collaborative learning and innovative environment through LL in order to facilitate co-creation and demonstration of next generation of CS tailored to the users' needs for improved decision-making at a different spatial and temporal scales across a variety of geographical, climatic and sectoral conditions in the selected EU regions and beyond. The following specific objectives of WP1 are noted below, and this deliverable corresponds to objective 1:

1. To establish seven LL in diverse Europe regions and beyond (5 within the EU and 1 each in Georgia and Namibia),
2. To contribute to the co-development of next generation of CS in collaboration with key actors and stakeholders,
3. To evaluate I-CISK impact in each of the seven LL.

The Task 1.1 and associated deliverable (D1.1) provide a sound foundation for the all the WPs as the LL approach is central to the concept and methodology of the I-CISK project in realizing its objectives and impacts. Therefore, Task 1.1 (highlighted in yellow colour in Figure 1) and D1.1 contributes to all the WPs as indicated in the PERT chart to a certain degree. However, there are several tasks which will significantly benefit from the results of Task 1.1, highlighted using blue colour boundary in Figure 1.

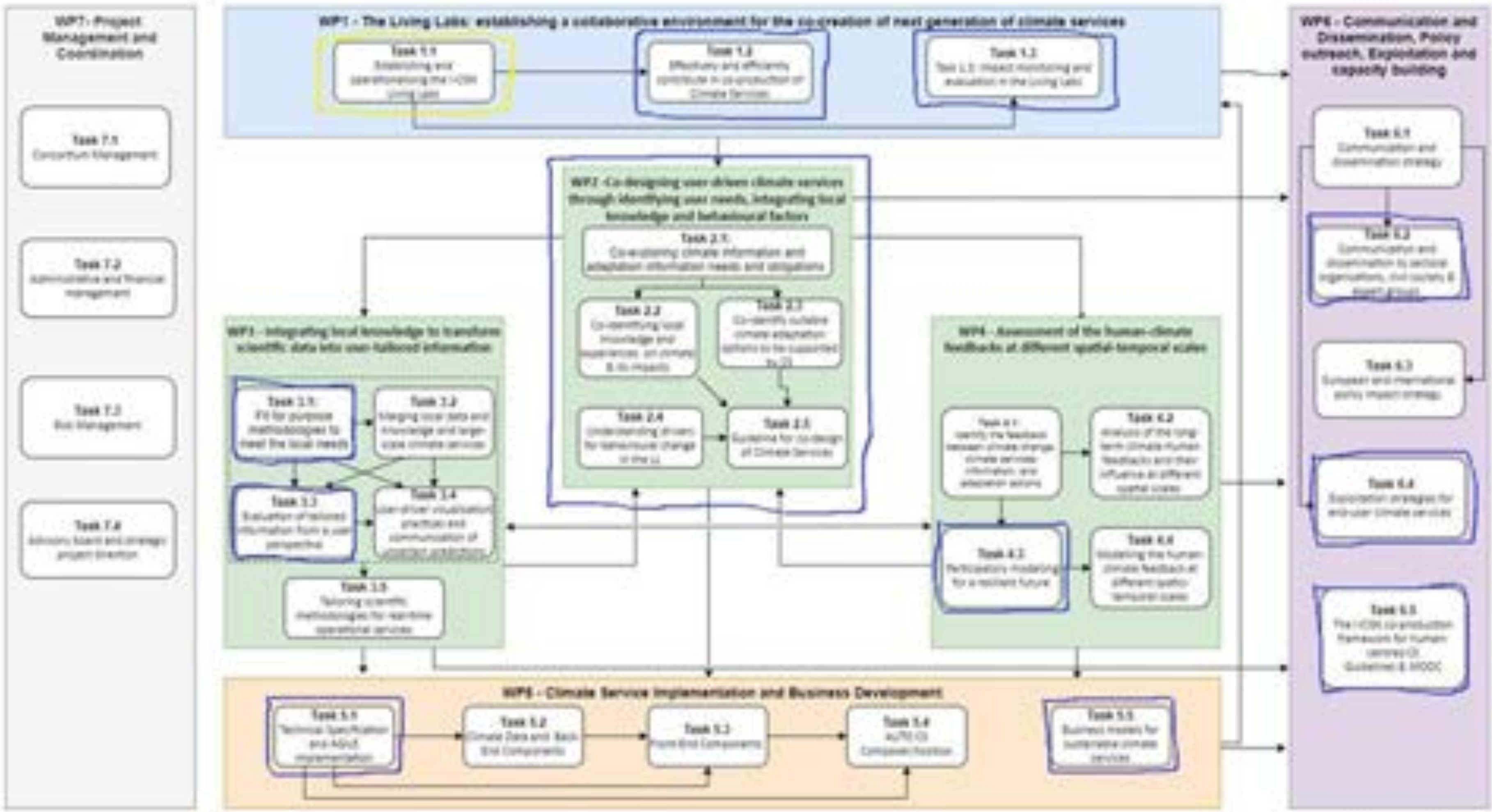


Figure 1. I-CISK PERT diagram showing interaction and collaboration between WPs and tasks.

Note: The task T1.1 is highlighted in yellow, and the tasks which will significantly benefit from the results of Task 1.1 are highlighted in blue

3 Methodology

The data, information and methods underpinning this synthesis report are shown in Figure 2. The methodology is based on four main components: (1) information compiled from various documents; (2) contribution from other I-CISK tasks and deliverables, (3) analysis of additional data, and (4) establishment of Multi Actor Platform to participate in the I-CISK co-creation process. These four components provide essential information that was synthesised in this LL characterization report. A brief description of different components of methodology is provided below.

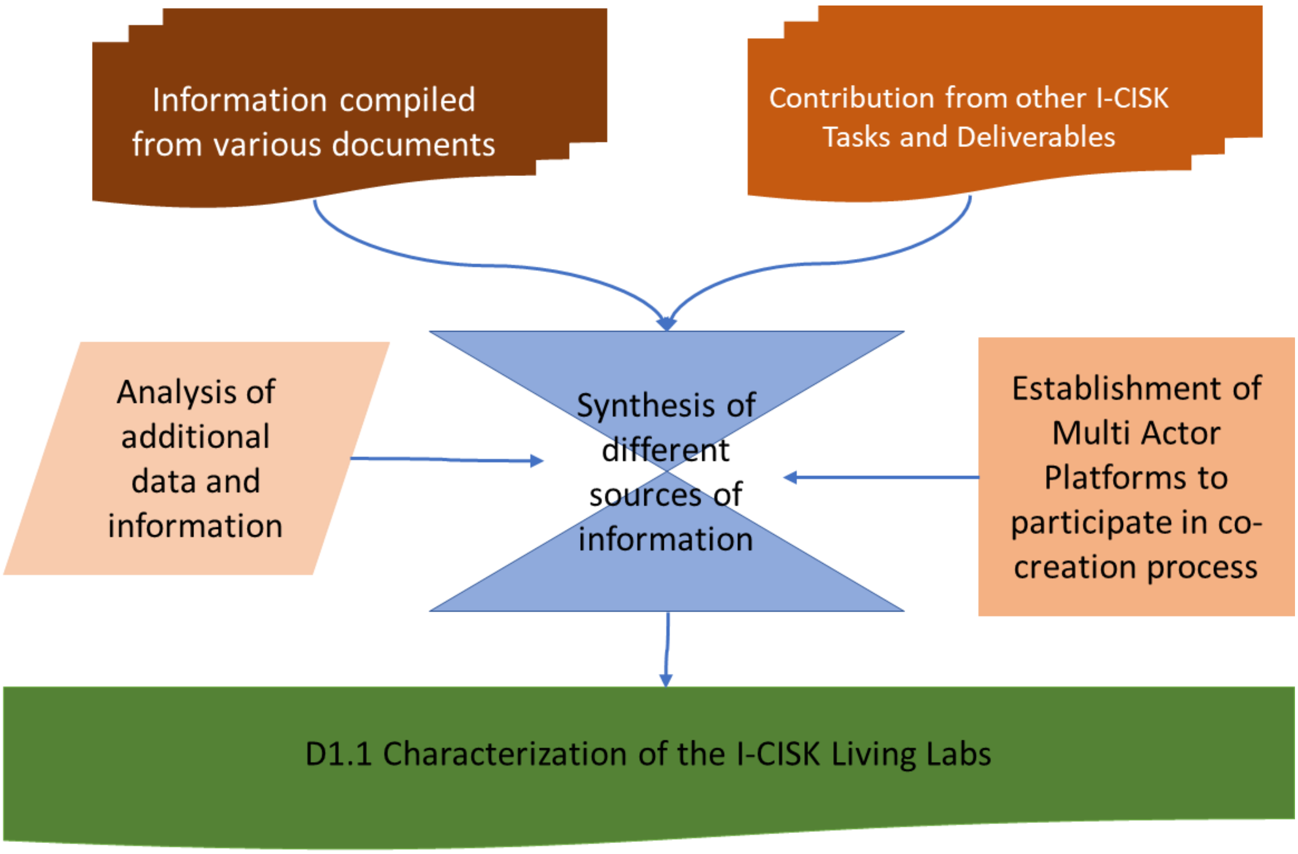


Figure 2. Methodological framework used for developing report on characterization of the I-CISK living labs

3.1 Information compiled from various documents

This synthesis report is mainly based on the information compiled from the individual LL characterization report. An outline was prepared to capture key characterization of each LL, which mainly covered an introduction to climate change issues; climatic settings including hazards; hydrology and water management; environment and ecology; important sectors of economy; CS availability and needs; governance and stakeholder analysis; stakeholder analysis in the co-design process; establishment of MAP; expected impacts; exploitation and upscaling; and roadmap for sustainability. A brief description of expected contents was outlined for each topic, which ensured consistency across the LL reports. The flexible approach was followed that enabled each LL to tailor the contents according to their own context and available data and information. The LL lead teams used the suggested format to draft individual LL characterization reports. Consequently, this flexible yet coherent approach resulted in seven well composed reports characterizing the I-CISK LL located in the Netherlands (Van Andel et al., 2022), Spain (Broekman et al., 2022), Italy (Mazzoli et al., 2022), Hungary (Bela et al., 2022), Greece (Ziogas and Tzimas, 2022), Georgia (CENN, 2022), and Namibia (NRCS and 510, 2022). The information provided in these reports was synthesized to write this integrated report. Additionally, relevant literature (e.g. journal papers, reports, information from various websites) was collected and analysed to supplement material available from the LL reports.

The Namibia Red Cross Society (NRCS), sub-contractor of 510 as mentioned in the I-CISK project proposal, came in May 2022 to the conclusion that they could not host the Living Lab anymore due to changes in leadership, capacity constraints and shifting strategic priorities. Further information on the engagement with NRCS since the proposal phase of I-CISK until this decision are provided in a formal letter drafted by 510 who are the leading partner working on establishing the LL in Southern Africa region. This letter will be shared with the EU Officer dealing with the I-CISK project. This decision has obviously consequences for the characterization of the LL deliverable. The information on the Namibia LL was integrated in an earlier version of this document. Given the decision of not going ahead with this LL, we decided to remove this content from the report. The earlier version of this report and the individual characterization report of the Namibian LL are available upon request.

The 510 and IHE Delft have been working on an alternative solution and are pleased to inform that the Lesotho Red Cross Society has given their commitment to host the LL, also around drought. Currently, we are working on developing the contract between Lesotho Red Cross Society and 510. We will develop the LL characterization report for the Lesotho LL and will integrate it to this main document within the next couple of months.

3.2 Contribution from other I-CISK tasks and deliverables

Parallel to the process of establishing the I-CISK LL (WP1 Task 1.1), there were a number of tasks from other WPs that were initiated during the reporting period, M1-7, such as Tasks 2.1, 2.5, 3.1, 5.1 and 6.1. There was a two-way interaction and feedback among WP1 task 1.1 and other WPs and tasks, which contributed to preparing this synthesis report. For example, WP2 task 2.1 focusing on CS use and needs was running in parallel to WP 1 Task 1.1. The individual LL reports prepared as part of WP1 provided useful information for (task and deliverable) T/D 2.1, in addition to responses from stakeholders in the LL to the survey questionnaires circulated as part of task 2.1 to learn about the CS use and needs within the LL. The D2.1 ‘Preliminary Report: Information on Climate Service Needs and Gaps was available in April 2022 (Moschini and Emerton et al., 2022), and provided a useful summary on CS availability, use and needs for this report (see chapter 8). Similarly, I-CISK’s prototype framework for co-creating CS was developed under WP2 Task 2.5 (Figure 3), which is documented in a milestone report (I-CISK MS10, 2022). The interaction among WP1 and WP2 teams was instrumental in developing this framework, which provides a flexible and adaptable approach to LL on the pathway of co-creation of CS.

Figure 3: Co-creation of user-centered climate services: building blocks of the co-creation process that take place in a living lab context

(Source: I-CISK MS10, 2022)

3.3 Establishment of MAP to participate in co-creation process

I-CISK recognizes that to achieve behavioral change, the active use of climate information in informing decision making toward climate adaptation and mitigation requires that citizens, stakeholders and decision makers are at the centre of the design, creation, implementation and evaluation of CS. The action-research approach of I-CISK, illustrated in Figure 3 (I-CISK MS10, 2022), shows the pivotal role the LL have in the human centred approach of I-CISK for developing the next generation of CS. In the I-CISK project, different types of stakeholders will be involved at different stages of the co-creation of the CS. Stakeholders in I-CISK are considered the broad group of people that are either affecting or affected by CS; these include end-users, decision-makers and citizens in general. Thus, the term, "stakeholders" encompasses all CS producers, intermediaries and consumers, or others who are affecting/affected by the decisions informed by CS (or absence thereof). Whereas, "actors" are the subset of stakeholders that are actively involved fully or in part of the I-CISK CS co-creation; these are the stakeholders affecting decisions, by creating either drivers or barriers. They include, for example, the project team, scientists, practitioners, decision-makers, private sector, public authorities, providers, end-users. In order to achieve the enhanced value of the CS, I-CISK aspires to close the gap between different actors involved in the CS value chain, and have grouped these value chain actors into three main categories (I-CISK MS10, 2022): (1) providers – actors who provide the necessary data, investment and regulatory context for the CS to be sustained, and supply climate information and knowledge, operating on a range of scales and in different sectors; (2) purveyors – actors who are knowledge brokers providing guidance on ways that CS can address regional problems, and ensure that products, scientific results and business opportunities are adequately communicated to end-users; and (3) end-users – actors who use CS at different levels of the decision chain, employ climate information and knowledge for decision-making, and may or may not participate in developing the CS itself, or may also pass information on to others, making them both users and providers. End-users include civilians, companies, developers, private organizations, local communities, governments etc. This formulation of climate change value chain actors is similar to that from Carter et al. (2019) who classified them as producers, intermediaries and national, regional and local users.

Moreover, I-CISK follows Responsible Research and Innovation (RRI) principles (https://rri-tools.eu/; Stahl et al., 2017; Thapa et al., 2019) and Multi Actor Approach (MAA) (https://ec.europa.eu/eip/agriculture/en; EIP-AGRI, 2017; Fieldsend et al., 2021) in stakeholder identification and engagement processes. The RRI approach recommends the inclusion of multiple actors representing policy makers, research community, education community, business and industry, and civil society organizations in the research and innovation process. The RRI approach is followed under I-ICISK in order to engage stakeholders in the co-creation process. While MAA aims to bring the right people together from science, practice, or anyone who can help achieve the project objectives. The approach aims to integrate transdisciplinary knowledge and experience to analyze issues and find solutions to address real problems. Under WP1 (Task 1.1), stakeholder analysis was conducted as part of establishment of the I-CISK LL, which resulted in the formation of a MAP for each LL. These MAP will be the main drivers of the co-creation process from the LL side. They will also further develop the core focus of the LL, and drive the collaborative process of co-creating CS. The analyses focused on mapping most relevant actors and examining their mandates, interest and influence within the scope of I-CISK project. A snowball sampling approach was followed in stakeholder identification process, starting with those stakeholders who were approached during the I-CISK proposal development phase. This process resulted in identification and analysis of most relevant actors participating in the MAP, playing significant role in CS co-creation process.

3.4 Analysis of additional data and information

Additional data and information were collected through various sources (e.g. journal papers, websites providing data and information on climate variables and disasters), improving the consistency and comparison of some facts and figures across the LL. For example, The World Bank, Climate Change Knowledge Portal (https://climateknowledgeportal.worldbank.org/) provides mean monthly precipitation and temperature data for the LL regions. This global data and information system facilitated coherent description of climatology of each LL as well as provided useful insights for comparing them (see chapter 5).

4 Geographical settings and major challenges of the I-CISK living labs

The section discusses the relevance of the selected LL by providing information on the geographical and climate setting, and by presenting specific climate related challenges faced by important sectors of the economy, and the specific needs for advancing the CS development, availability and use in the local contexts.

The I-CISK LL are located in diverse geographical and climatic regions facing various climate and water related hazards that impact multiple sectors of the economy in these regions (Figure 4). Five LL are within the EU region, located in The Netherlands, Spain, Italy, Greece, and Hungary; one is one is in Georgia in the Caucasus Region, one of the countries included in the European Neighbourhood Policy. Another one will be established in Southern Africa (most probably in Lesotho replacing originally intended LL in Namibia). These LL are established across different global climatic hotspots regions (Zsabo et al., 2016): 1) semi-arid regions (Andalucía, Spain), deltas (Rijnland, the Netherlands; and parts of Crete Island), and glacier and snowpack dependant the river basins (Rijnland-Rijn River, Emilia-Romagna-Po River, Alazani River). A brief description on the geographical settings and major challenges relevant within the scope of the I-CISK project are discussed below. More details can be found in the individual LL characterization reports.

Figure 4. The geographical location of I-CISK's Living Labs in Europe and Africa

4.1 Rijnland Delta, the Netherlands

The Rijnland LL is situated on the west-coast of the Netherlands, on the North Sea, between the cities of The Hague and Amsterdam. The Rijnland water board (https://www.rijnland.net/) is an important institution responsible for water management in this region. The LL area is mostly flat and below sea level. Extensive dunes along the coast are important for protection against the sea, but also for water supply to the cities through Managed Aquifer Recharge schemes. The surface water system serves both irrigation and drainage, with pumping stations discharging excess water to interconnected canals and out to the North Sea as shown in Figure 5 (Van der Zwan, 2022). During dry spells fresh water is let in from the Rhine river, and supplied to low-lying polders through the same interconnected canals. Currently during the dry season, a weekly drought monitor with a two-week forecast is prepared by the Water Authority. In case of imminent drought event, planned measures to manage water resources are shared with stakeholders. In this LL there is a need to develop sub-seasonal and seasonal drought forecasts. The information is lacking on the projections at the decadal and climate change time scales with outlooks on drought characteristics and frequency. By combining the short and long-term climate information in one service, it is envisaged that a co-development of climate adaptation strategies involving the actors from the Rijnland water board, and water use sectors, mainly tourism and agriculture can be established.

Figure 5. The command area of Rijnland, with key structures indicated for water system operation during droughts.

(Source: Van der Zwan, 2022)

4.2 Andalucía, Spain

The Andalucía LL is located between the Guadalquivir and Guadiana River Basin Districts (RBD) (Figure 6). It focuses primarily in the *comarca*[2] (region) of Los Pedroches, a primarily agricultural area located in the north of the province of Córdoba, in the autonomous region of Andalucía, Spain. It also includes the Sierra de Cazorla, Segura and Las Villas Natural Park in the upper Guadalquivir RBD as a complementary site for testing the CS developed for forest landscapes.

Spain is located within the Mediterranean region, where prolonged drought is a recurring feature. The country experiences significant climatic and rainfall variability, both seasonally—with dry, hot summers and colder, more humid winters—and interannual—with periodic drought cycles of varying intensity and duration. Spain has suffered several prolonged and extensive drought periods since the beginning of systematic hydrologic monitoring in 1941: 1941-1945; 1979-1983; 1990-1995; 2005-2008; and, most recently, 2016-2017. Climate change processes are predicted to affect the Mediterranean region severely (IPCC, 2021), and more severe

[2] In Spain the term *comarca* refers to a portion of territory that is considered homogeneous in terms of natural, landscape, cultural or historic characteristics.

droughts are predicted in the future among other adverse impacts such as decrease in runoff due to increased temperature and evapotranspiration, and seasonal shift of rainfall patterns - drier spring and fall seasons and rainfall concentration in winter (CEH-CEDEX, 2017).

The agricultural sector is particularly vulnerable to drought. This is the case for both rainfed and irrigated agriculture, since climate change processes will affect the availability of both blue and green water. However, rainfed agriculture and extensive livestock farming have a limited range of adaptation options available in the short term. The *Comarca* is a primarily rainfed agricultural region, where different land use systems and landscapes coexist (Figure 7). This diversity of landscapes and land uses, the high ecological and socio-cultural value of the *dehesa* and the *olivar de sierra* agroecosystems[3], their vulnerability to climate change and hydroclimatic risks, make Los Pedroches region a particularly relevant site for the I-CISK project. In addition, the Andalucía LL includes a second subregion, the Sierra de Cazorla, Segura and Las Villas Natural Park, located in the Upper part of the Guadalquivir river basin. This is a mountain region in the eastern and northeastern part of the province of Jaén, Spain. This second region will be interesting to complement the forestry approach of the Sierra de Cardeña/Montoro protected area. This will add a different climate scenario for the I-CISK models and it will provide an interesting test site for the CS and models provided.

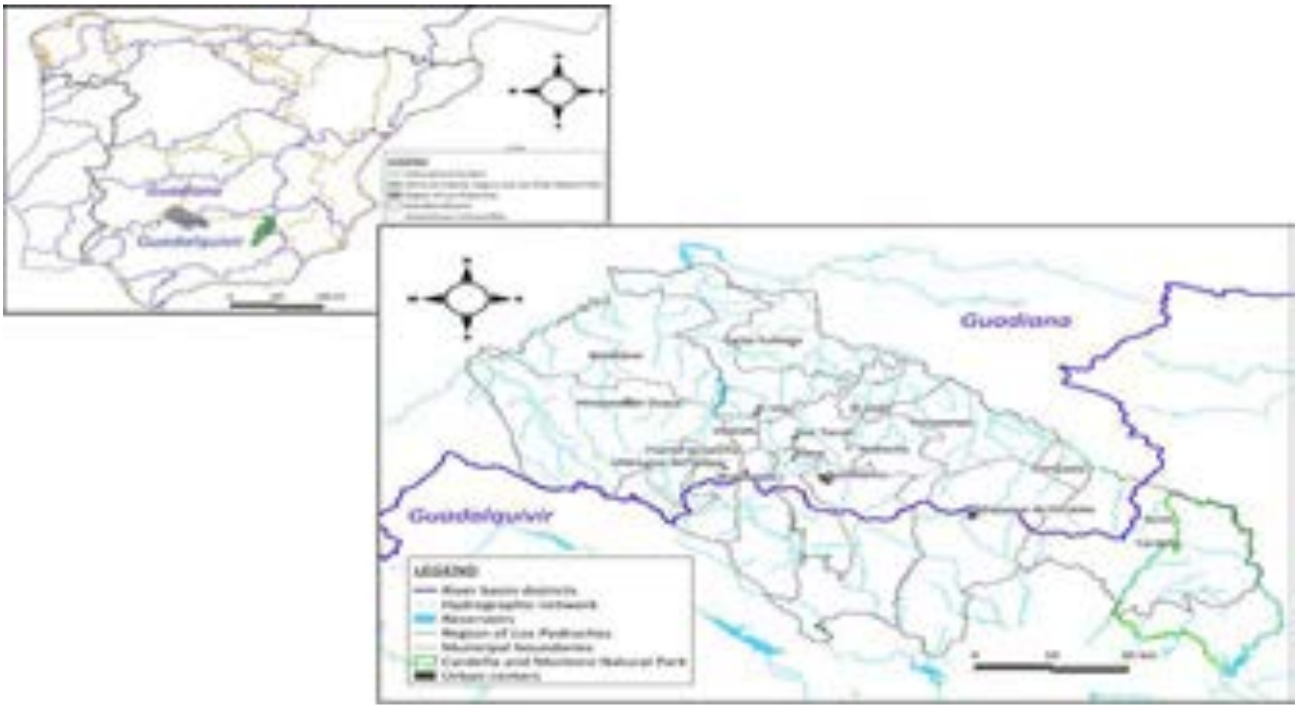


Figure 6. The Andalucía LL, highlighting the hydrological and administrative set up in the region of Los Pedroches, Córdoba, Spain.

[Source: Broekman et al., 2022

[3] The d*ehesa* is an agropastoral system unique to the Iberian Peninsula where oak trees – primarily holm oaks –, native grasses and free-range livestock – primarily Iberian black pigs, sheep and cows –, interact under management. The d*ehesa* occupies almost 60% of Los Pedroches region, and is one of the best reserved holm oak *dehesa* in the Peninsula. The *olivar de sierra* is a unique olive tree agricultural system planted in the XIX century in the Sierra Morena mountain range in the southern part of the region, where the steep terrain requires traditional management and harvesting practices, and where remnants of the original Mediterranean forest can still be found.

Figure 7. Different land use systems and landscapes: a) mixed forest, b) olive groves, c) panoramic view, d) pine forest, e) agro-system forestry area (*dehesa*) and f) water course.

[Source: Broekman et al., 2022]

4.3 Emilia Romagna, Italy

The Italian LL is located in the Emilia Romagna Region (RER) (Figure 8). Most of the RER territory is located in the geographical region belonging to the Po River basin district, one of the most economically productive and densely populated area of the country. The surface resources from the Po River and its tributaries are exploited by a wide range of users for agriculture, industry and human water consumption. Despite its abundant water resources, the area is vulnerable to the increased frequency and intensity of extreme weather events that contribute to the seasonal variation in water availability. The interconnected and "dense" human activities contribute to exacerbate the water vulnerability in the area, threatening for those sectors with low adaptive capacity.

In recent years, Italy including the RER has been proactive in developing climate change impact assessments and adaptation strategies. (e.g., https://www.arpae.it/it; ARPAE 2017; ERVET and ARPAE, 2018; ART-ER and ARPAE, 2019; Pietrapertosa et al., 2021). In particular, within the "Climate Plans in Emilia-Romagna" initiative, provinces and main municipalities have been involved in the construction and implementation of their own climate adaptation plans, through a shared and structured path in various progressive steps. The RER is aware that climate change necessitates significant economic and social choices, as well as behavioural changes in every sector. Such high level of commitment in climate change effects' characterization and adaptation at various levels, led in 2019 to the creation of a regional forum on climate change, guided by the regional Directorate-General for the Care of the Land and the Environment. The aim is to share transparently its choices on this issue, its efforts, and above all its results with citizens, businesses, and public administration. Moving to the connected risk for environment and economy, it shall be noted that since 2003, due to the increased demand from various human activities, there have been frequent water deficits. The increasing water consumption and lower water availability) can lead to the failure to meet water needs. This can also cause severe environmental problems, such as a lowering ecological and chemical quality of surface water bodies (depletion of freshwater environments and their eutrophication, with critical impact on hosted ecosystems and the most sensitive species).

The LL of interest is located where the availability of the water resource is crucial for maintenance of aquatic life and the natural environment, human quality of life and all the uses connected with economically relevant activities (such as agriculture and industrial production). Technical knowledge on use of climate information, availability of local data from wide and maintained ground monitoring network, and previous experience of some of the involved stakeholders in using and co-developing CS, set a favourable ground for this LL activities.

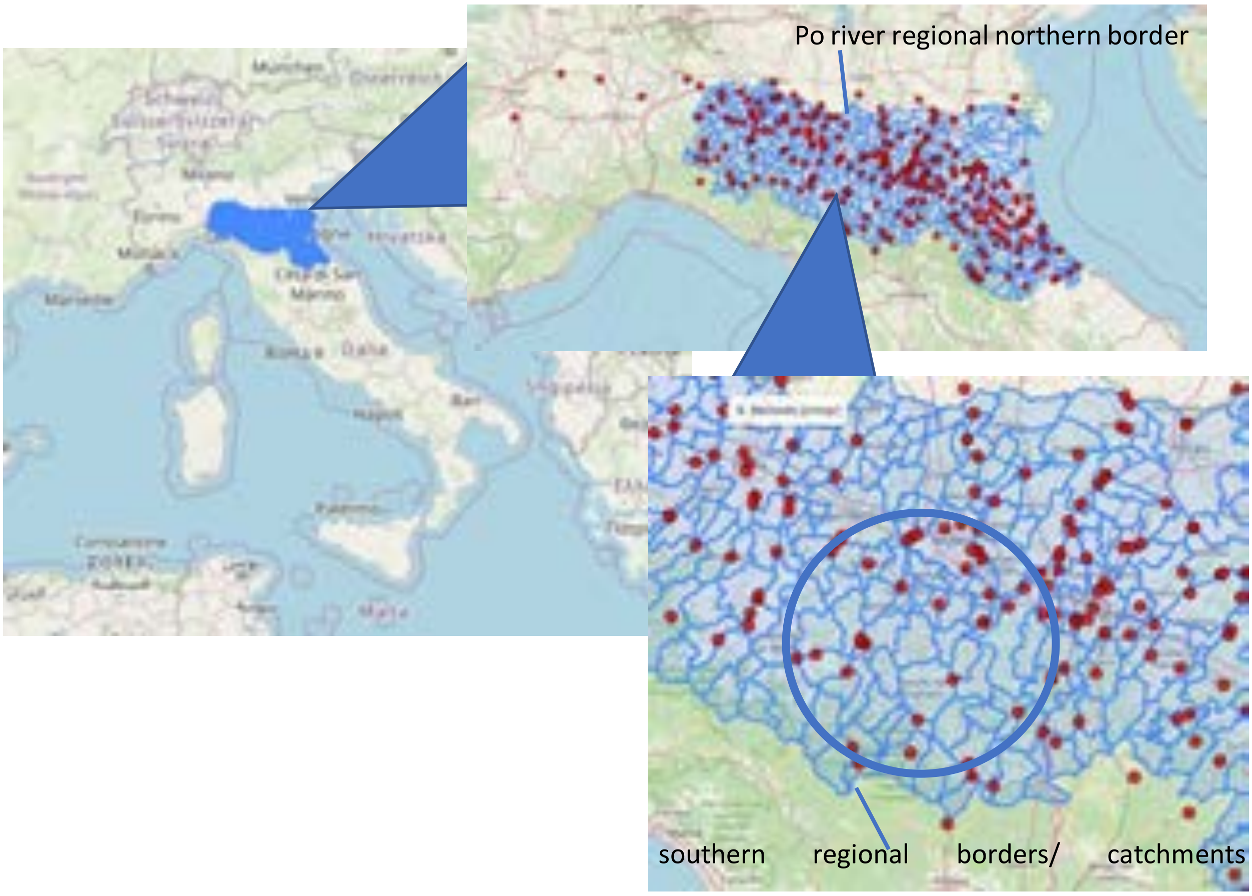


Figure 8. The location of the study area in RER- Italy, south of the Po River, in the upper provinces of Reggio Emilia and Modena

Note: administrative boundaries and dots representing river stage monitoring stations from Regional Environmental Agency networks.

(Source: Mazzoli et al., 2022)

4.4 Crete, Greece

The island of Crete island has been selected as a LL region in Greece (Figure 9). The LL is situated at the southern country boundaries, in the eastern Mediterranean. Crete, like the rest of Greece, is characterized by variable landscape with extensive mountainous regions in the central part, and limited plain areas close to the shoreline. Crete is among the flag-ships of the country’s tourism industry, with a thriving tourism sector. Being a large island, the largest in Greece and the 5th largest in Mediterranean, it concentrates a significant and variable economic activity and plays an important economic role for the country. As an island, it offers a good opportunity to study a region with well-defined boundaries and autonomous physical and energy resources management. As inferred from the above, the primary sector this LL will consider is tourism. However, tourism is a cross-cutting sector with interlinkages among other sectors that are economically significant and vulnerable to climate change. Water availability can impede with tourism as an economic activity since it is directly associated with the guest experience. Further, energy demand, especially for cooling needs during the hot summer days and nights, is an important consideration for the tourism industry. Flood impacts (coastal and river) are primarily related to transportation infrastructure (mainly ports and roads), which supports the economic industry as well as tourism related infrastructure. According to CCISC (2011), the Crete is among regions of Greece that are most vulnerable to climate change, presenting high vulnerability on tourism and transportation sector, followed by health, agriculture and water resources.

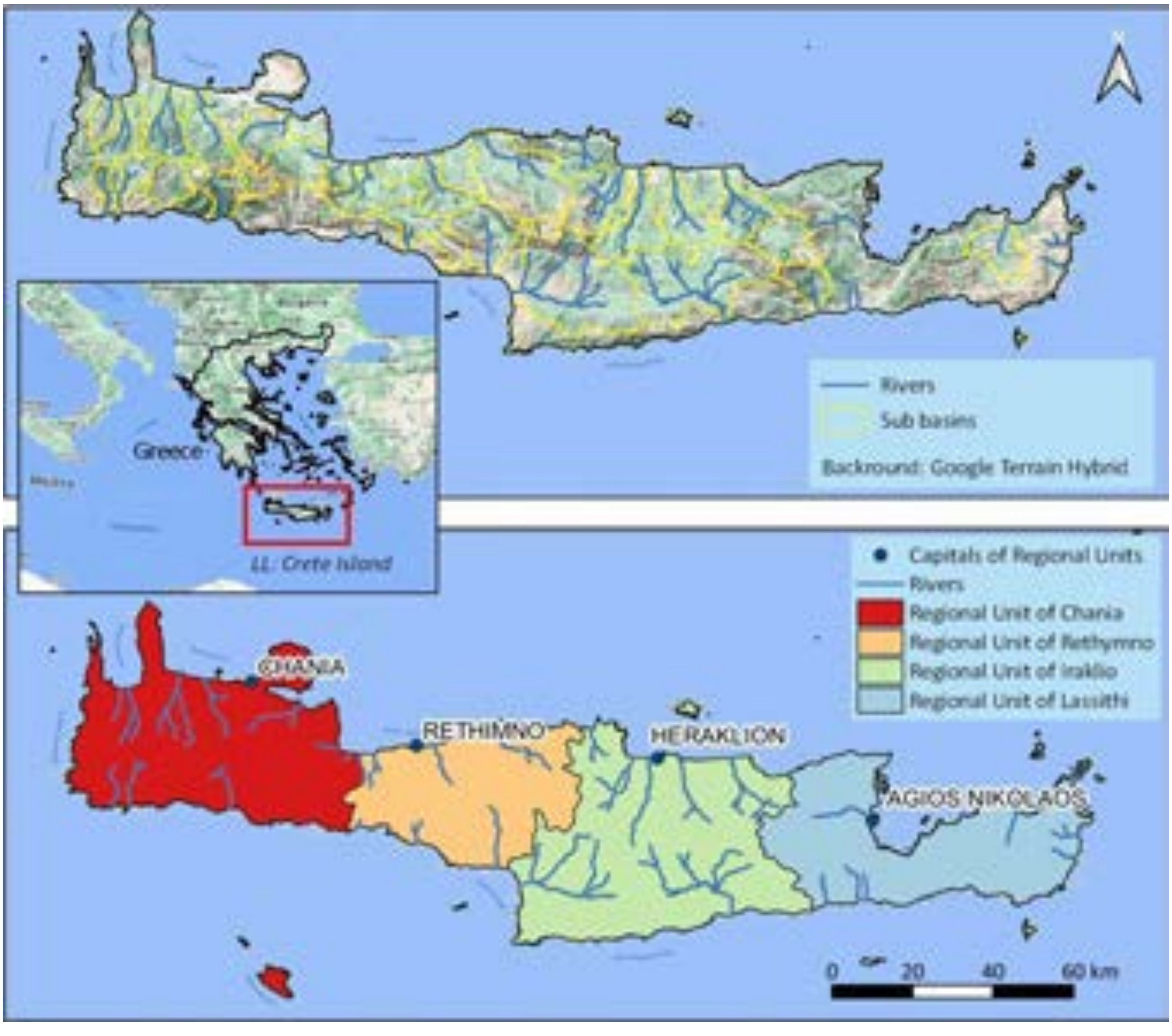


Figure 9. The Crete LL in Greece.

(Source: Ziogas and Tzimas, 2022)

4.5 Erzsébetváros, Budapest, Hungary

The Danube divides Budapest city into two parts, the eastern part, Pest is a flat area, the western part, Buda is a hilly region. The city is structured in a way that the city centre is densely built, the houses were built mainly in the late 19th and early 20th centuries and have a low rate of green areas. On the Pest side, a couple of large avenues and boulevards are bordering the residential areas, that are closed and densely built, in the Buda side mostly the foothills and the areas adjacent to the Danube are densely built. Most of the slopes have more or less green areas, and the hilltops and upper parts are still covered by forests that are forming a protected area. Budapest's natural ventilation channels are the northwest-southeast valleys and the Danube, in the Buda side a mountain breeze mitigates the summer heat and also produces cleaner, cooler air (Probáld 2014). These features led to very diverse local climatic conditions in Budapest, and in general, caused the more densely built Pest side more exposed to the urban heat island effect.

In Budapest, the effects of climate change are influenced by the city climate effects, which are most significantly manifested through the urban heat island effect. This means that the urban heat islands are exacerbating the effects of the summer heatwaves in the city. The inner part of the city where there are fewer green areas, more artificial surfaces, and more buildings can experience a difference of 7°C (2-4 °C during the spring and 3-6 °C during summer) in surface temperature compared to the green areas surrounding the city, but during the heatwaves, the difference can be 20-25 °C between the inner city and the forest in the suburban areas (Zsombor et al., 2021).

The Hungarian LL is situated in the Erzsébetváros district, an inner-city area of Budapest (Figure 10). The area is densely constructed with many protected-heritage buildings mostly from the late 19th and early 20th centuries. Because of the historical value of the district and the entertainment opportunities, parts of the district are attracting a significant number of tourists. In general, the economy of the district is characterized by small businesses. Europe has experienced an increase in heatwaves frequency in the past few years; Hungary is no exception with a particularly hot summer in 2021 (the 5th hottest in history), where 4 heatwaves took place. (másfélfok.hu). According to the climate change predictions, the severity and the length of heat waves are expected to increase in urban areas. Urban heat islands are contributing to the severity of heatwaves in the cities, more profoundly in the inner areas, where green spaces are scarce. The selected district is a good "sample" on how co-created CS can contribute to mitigation/adaptation/early warning in the contest of extreme events in urban areas The Erzsébetváros district is more exposed to heatwaves as it has a very low percentage of green spaces, a high percentage of artificial surfaces, a high density of buildings, and it lacks natural ventilation. Heatwaves are primarily generating health problems, especially for those who are vulnerable (e.g., pregnant women, elder people, children, people living with chronic illness). Air quality and air pollution caused by traffic in the district are further contributing to the health problems generated by heat exposure. The health effects and possible risks are generating additional burden for the municipality and its institutions. It also negatively affects some parts of the economy in the district, for example, tourism sector.

The adaptation strategies partly comprise passive measures like shading or providing water for the people during heatwaves, but they also encompass the improvement of green infrastructure in both public and private spaces. The establishment of new green areas is a challenge, as there is a demand for parking spaces, and in general, there is a shortage of available free spaces. In both strategies, the municipality has a defining role along with residents. Therefore, in this LL, we are dedicated to collaborating with the local stakeholders to co-create CS that are built on the integration of local knowledge, perspectives, needs. We are also dedicated in to have a special emphasis on the integration of the knowledge, perspectives, and needs of women. We are aiming to have a special emphasis on the involvement of the needs and perspectives of *women*, as they bear the responsibility of reproductive work, which means they are mainly responsible for care work: for children, for elderly. As children and the elderly are the most vulnerable groups to heatwaves, women have an important role in the adaptation measures against heatwaves. It doesn't mean that we exclude men, or their perspectives, just that we are emphasizing the inclusion of women's needs and perspectives.

Figure 10. The location of Erzsébetváros LL in Budapest, Hungary

(Source: Bela et al., 2022 based on Google Maps)

4.6 Alazani River Basin, Georgia

The Alazani River Basin LL is located within the territory of Georgia (Figure 11). Due to the complex mountainous topography and highly diverse climate settings, Georgia is subject to climate-related hazards such as floods, flash floods, landslides, debris flow/mudflow snow avalanches, hailstorms, windstorms and droughts. Over the last decades, the number of natural disasters has increased almost threefold and, in many cases, these have been considered catastrophic, causing fatalities and leading to significant economic losses (GoG, 2017). According to the Fourth National Communications of Georgia to the UNFCCC, the frequency, intensity and geographical extent of extreme hazards will all increase with climate change. Georgia's Intended Nationally Determined Contributions (INDC) estimates economic losses from climate-induced hazards without adaptation measures for the period of 2021-2030 to be $US 10-12 billion, while the cost of adaptation measures is estimated to be 1.5-2 billion USD (GoG, 2015).

The Alazani River Basin is a transboundary basin shared by Georgia and Azerbaijan (USAID and DAI, 2002; UNECE 2017; Akhobadze et al., 2020). The Alazani River begins at Mount Didi Borbalo at 2750m above sea level of the Main Caucasus Range. After a short run south, the river turns east and then carves its way through the Alazani plateau and flows to Mingachevir reservoir. The length of the river in Georgia is about 205km (total 390km). Around 190km of the river constitutes a natural border between Georgia and Azerbaijan. The total area of the river basin is 11,500 km^2, while in Georgia it accounts for 6700 km^2. The Alazani River basin faces socio-economic and environmental challenges, which have been amplified owing to climate variability and change. The region is highly dependent on agriculture (38% of the total region's GDP) which in turn relies on the water availability within the irrigation systems. Furthermore, the number of Hydro Power Plants (HPPs) has been increased in the basin over the last decade, while there are also several planned projects, that emphasizes that the water demand is likely to be increased throughout the next decades. In addition, it is envisaged to enhance water supply systems which will increase water stress. Also, weather, climate and water-related hazards significantly hamper the socio-economic development of the region and make it vulnerable to climate change. It is apparent that in order to achieve socio-economic benefits, the improvement of the CS is of great importance for the region's sustainable development. While a Green Climate Fund (GCF) supported project (https://www.adaptation-undp.org/projects/scaling-multi-hazard-early-warning-system-and-use-climate-information-georgia)aims to develop Multi-hazard (includes floods, landslides, debris flow/mudflow, snow avalanches, drought, hailstorm and windstorm) Early Warning Systems for the entire country there are still some areas that need to be enhanced to meet requirements of CS for different sectors. In particular, there is a need for downscaled seasonal to decadal climate predictions, and related information for agriculture, energy, water and other economic sectors to formulate adaptation strategies to reduce the risks from climate variability and change in the LL.

Figure 11. The location of Alazani River Basin LL, highlighting hydrological and administrative features of this transboundary basin.

(Source: CENN, 2022)

5 Climate and extreme events

5.1 Climatic setting

The I-CISK LL are located in the five major climatic zones across Europe and Africa, which are important climate change hotspots in the world representing Delta regions, semi-arid environments and glaciers and snowpack dependent river basins. The climate of the I-CISK LL is classified using Köppen-Geiger classification (e.g., Kottek et al., 2006; Bech et al., 2018; John 2020).

1. **Mediterranean climate (Köppen classification: Csa): The LL in Andalucía, Spain and Crete, Greece are located in Mediterranean climate hotspot region.** These LL are characterized by very high seasonal variability, with hot-dry summers and mild-wet winters. The spatial variability is also quite high in these LL, owing to large geographical areas with heterogenous topography influencing the spatial differences in the climate. The climate variability is projected to increase in the future, with a rise in frequency and intensity of extreme events.
2. **Humid subtropical climate (Köppen classification: Cfa): The LL in Emilia-Romagna, Italy and Alazani River Basin, Georgia represent humid subtropical climate regions.** Precipitation is distributed throughout the year in these regions, while the temperature gradient is quite large. Both LL depict high spatial variability in temperature and precipitation. Climate change is projected to alter the precipitation distribution and increase frequency of extreme events in these LL.
3. **Marine west coast climate (Köppen classification: Cfb): The LL in Rijnland Delta, the Netherlands is located in this climatic region.** The precipitation is distributed throughout the year, with distinct seasonality. Both precipitation and temperature show large intra-annual variability. The climate of Rijnland Delta shows some similarities with Crete, Greece, as both regions are under coastal climatic influences as well. The precipitation pattern is predicted to change in future with more extreme events, with droughts becoming an increasingly important issue.
4. **Humid Continental climate (Köppen classification: Dfb): The LL in Erzsébetváros municipality in Budapest, Hungary falls under humid continental climate zone.** While precipitation is distributed throughout the year, this urban area is characterized by high variability in temperatures and frequent occurrence of heatwaves. An increase is observed and projected under climate change in temperature and heatwaves.

More details on climatic features of the I-CISK LL are presented in Table 1 and Figure 12. A brief description of climate of each LL is presented below.

Table 1. Summary of the climatic settings of the I-CISK Living Lab Regions

Living Lab	Climate type (Köppen classification)	Mean Precipitation, Annual (monthly range), mm	Mean Temperature, Annual (monthly range), ^{0}C	Remarks on climate variability and change
Rijnland Delta, the Netherlands	Marine West Coast (Cfb)	825 (40-90)	11 (4-18)	Precipitation is distributed throughout the year; climate change is expected to increase variability and extreme events.
Andalucía, Spain	Mediterranean (Csa)	485 (2-70)	17 (9-26)	Hot and dry summers and relatively wet and mild winters with high interannual variability. Climate change will increase temperatures and decrease precipitation in both Guadalquivir and Guadiana river basins.
Emilia-Romagna, Italy	Humid subtropical (Cfa)	800 (45-100)	13 (2-23)	Very high spatial and temporal variability, with high seasonal variability (relatively dry summers, wet autumn and spring); Increase in temperature and change in precipitation distribution (both increase and decrease in a year) is expected in the future.
Erzsébetváros, Budapest, Hungary	Humid Continental (Dfb)	570 (30-70)	11 (-1 to 22)	Precipitation distributed throughout the year; Increase in temperature and hot days is observed, and also predicted to further increase under climate change. The intra-annual precipitation distribution is projected to change, although total annual precipitation is expected to stay the same. Extreme heatwaves are projected to increase under climate change
Crete, Greece	Mediterranean (CSa)	655 (0-140)	18 (11-26)	High spatial and temporal variability, with distinct seasonality (hot-dry summers and mild-wet winters). Precipitation is project to decrease while temperature will rise in the future due to climate change.
Alazani river basin, Georgia	Humid subtropical (Cfa)	730 (30-106)	10 (-3 to 22)	High spatial and temporal variability in both precipitation and temperature, mainly influenced by topography. A decrease in precipitation and an increase in temperature is projected under climate change.

Note: The precipitation and temperature data are compiled from The World Bank, Climate Change Knowledge Portal; https://climateknowledgeportal.worldbank.org/. The climatic information is derived from the data from CRU TS v.4.05 (Haris et al., 2020).

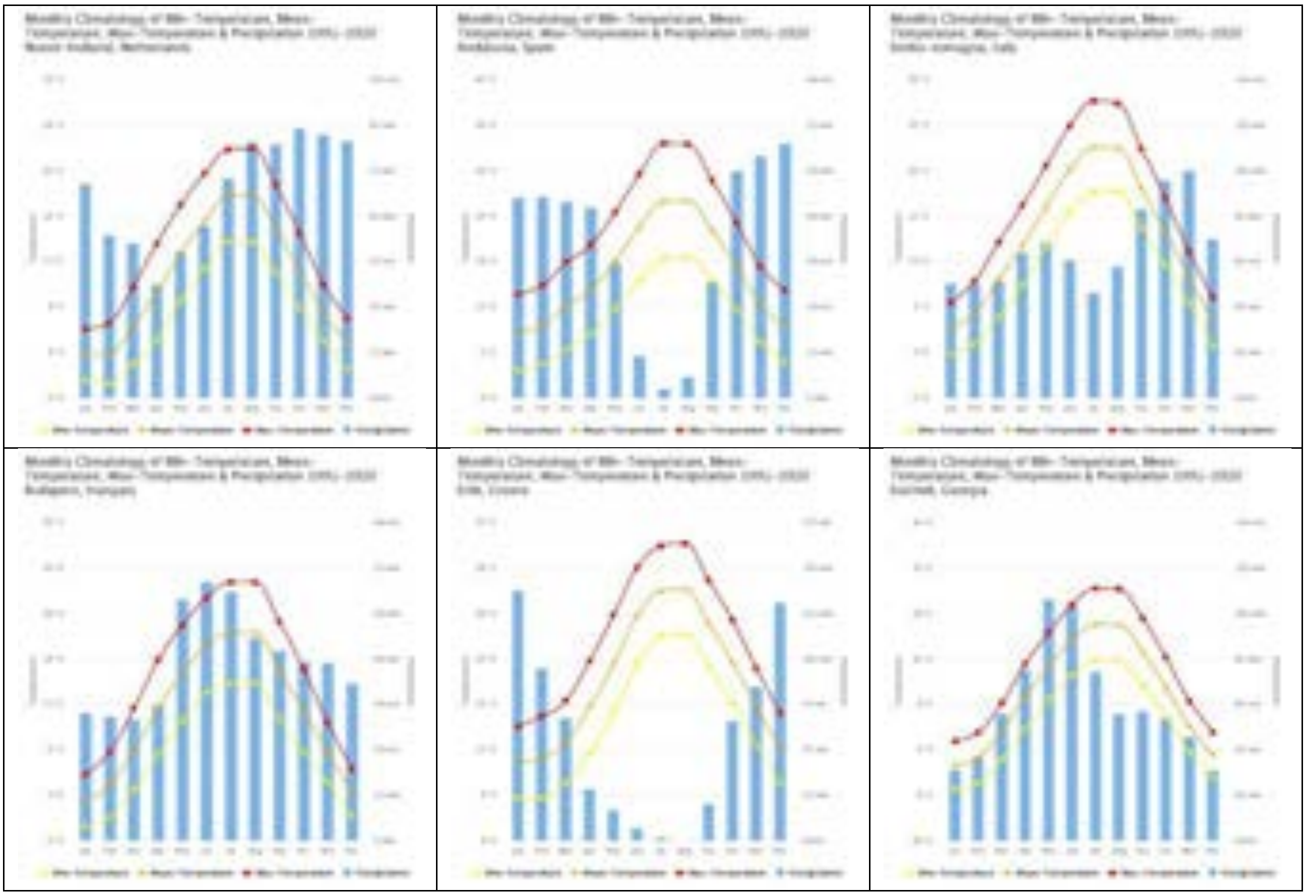


Figure 12. Monthly variation in precipitation and temperature in the I-CISK Living Lab Regions.

(Source: The World Bank, Climate Change Knowledge Portal; https://climateknowledgeportal.worldbank.org/. The graphs are based data from CRU TS v.4.05 (Haris et al., 2020).)

5.1.1 Climate of Rijnland Delta, the Netherland

The climate of the Rijnland Delta, the Netherlands, is Marine coastal/temperate oceanic (Köppen classification: Cfb). The Rijnland area receives a yearly average of 825 mm precipitation, with distribution across all the months ranging from about 40 mm/month in April to 90 mm/month in August (Table 1 and Figure 10). The mean annual temperature is ~11 ºC, with January-February the coolest months (average ~4 ºC) and July-August the warmest (average ~18ºC). The potential evapotranspiration is generally lower than precipitation during most of the months except during April-July when due to higher temperatures and lower precipitation, the evaporation demand is higher than the available precipitation. The precipitation deficit in Spring and summer (April-September) may trigger drought conditions in the study area. Climate change is projected to lead to higher temperatures, more pronounced (extreme) events, both wet and dry, and sea level rise (https://rijnland.klimaatatlas.net/).

5.1.2 Climate of Andalucía, Spain

The Andalucía LL has a hot-summer Mediterranean climate (Csa, according to the Köppen classification). There are some differences between Upper (Cazorla) and Mid Guadalquivir/Guadiana (Pedroches) river basin regions, but mainly they show hot and dry summers and relatively wet and mild winters with high interannual variability. The Upper Guadalquivir, has higher precipitation (>750 mm year) than the Mid region (500 to 750 mm year). In addition, the winters are cooler in the mountainous parts of the Upper region (< 10 °C annual average temperature) than the mid region (16 to 18 °C annual average temperature). During the summer, and specifically in the months of July and August, daytime temperatures sometimes exceed 35 °C, while at night it drops to 18 to 20 °C. In winter, temperatures are lower, with the maximum average oscillating between 10º-15ºC and the minimum average between -2 and 2 °C (https://araguadiana.wordpress.com/los-grupos/gdr-los-pedroches/la-comarca/os/gdr-los-pedroches/la-comarca/). Drought events and wild forest fires are considered the main climatic hazards in this region. Their impact on human activities and on the natural environments can be significant. The projections at RBD scale using different scenarios show general trends of increase of maximum temperature between 2 to 6°C until 2100 and decrease of annual precipitation (-10, -30%) until 2100 (http://www.aemet.es/ca/serviciosclimaticos/cambio_climat/result_graficos).

5.1.3 Climate of Emilia-Romagna, Italy

In the Italian LL area, the climate is warm and temperate with significant rainfall throughout the year (Köppen classification Cfa). The mean annual precipitation is about 1000 mm/year, with very high spatial and temporal variation across the RER. The South-Western parts receive over 2000 mm/year, while north eastern parts have about 500 mm/year (Figure 13). Similarly, temperature variability is also high, with minimum and maximum temperatures of about 0.5 °C during winter and 27 °C in summer, with mean annual value of about 12 °C (Figure 14). The Regional Climatic Atlas (ARPAE, 2017) synthetizes data and outcomes form the regional monitoring network and outlines climate condition changes (years 1991-2015) compared to the previous 30-year reference period (1961-1990). In particular, the regional average temperatures increased by 1.1 °C (+1.4 °C the maximum, +0.8 °C the minimum), while the annual rainfall decreased overall by only 22 mm (-2%) although with notable seasonal changes (drier summers and rainier autumns). A useful synthetic indicator linked to water availability and its changes during the decades is the hydroclimatic balance index, given by the difference between potential evapotranspiration (related to temperature pattern) and Precipitation, measured in mm of water. In the area of interest, a reduction of the balance index around 50-100 as annual average and 100-150 mm during summer season is known. Further effects are expected because of climate change, and the reduction of precipitation and increase in temperature cannot be neglected even in an intermediate emission scenario (RCP4.5), particularly during the dry season.

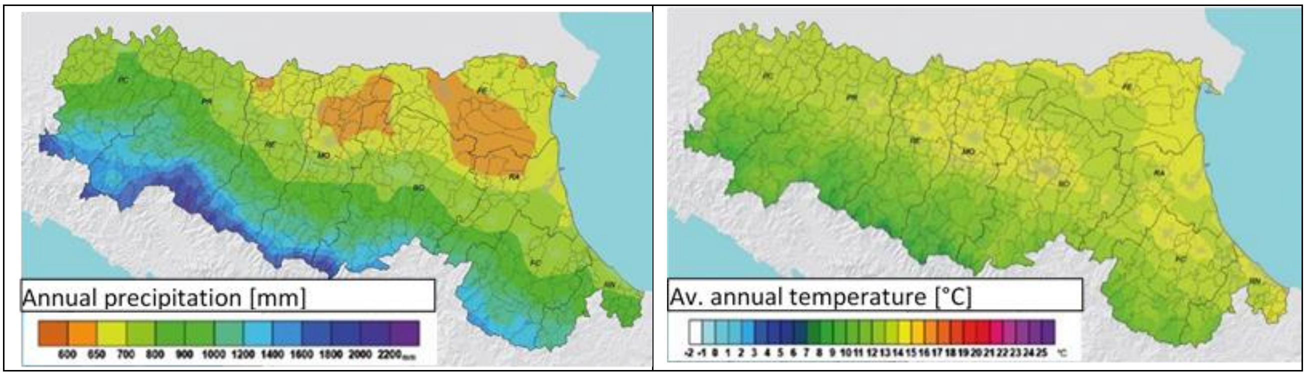


Figure 13. Monthly variation in precipitation and temperature in the Emilia-Romagna LL region, Italy

(Source: ARPAE, 2017)

5.1.4 Climate of Erzsébetváros, Budapest, Hungary

The climate of Budapest can be characterized by a mildly cold winter (its coldest month is January), and a hot summer (the hottest month is July). The annual mean temperature is ~22 °C, with maximum value in June-July (~28 ºC), and can go over 30 ºC during heatwaves in these summer months. The mean annual precipitation in Budapest is about 525 mm. The least precipitation falls in February-March, while the most falls in May and June (https://www.met.hu/). In Budapest, the consequences of climate change can be observed through two main types of phenomena. The mean annual temperature has increased by 1.51°C in the period between 1901 and 2020 (Figure 14), and the duration of sunshine is increasing. Besides the average values of temperature, the occurrence of extreme events has also become more frequent; for example, the frequency of both heatwaves and extreme precipitation has increased over the last 25 years (Zsombor et al., 2021). Extreme heat days (with maximum temperature ≥ 30 °C) have increased in Budapest during the period between 1901 and 2021 (Figure 14). The climate change projections for urban heatwaves are foreseeing that the national average annual temperature will rise by 1-2 °C between 2021 and 2050. The extreme hot days during the summer could increase further, and the days below 0 °C will decrease. Moreover, the hot days are expected to be more intense. Extreme precipitation events are expected to become more frequent, and more intense, although with an overall reduction of precipitation during the summer months (Zsombor et al., 2021).

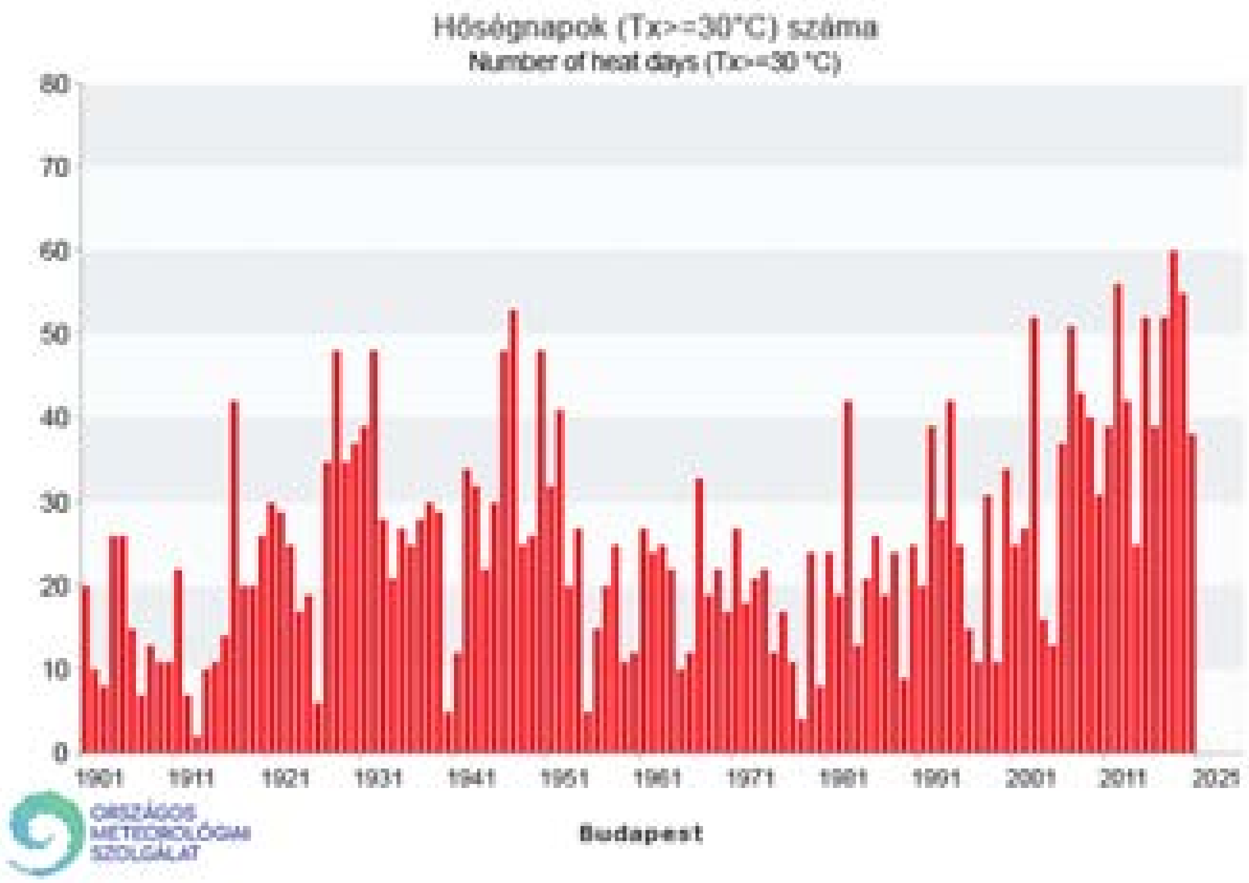


Figure 14. Number of extreme heat days in Budapest between 1901 and 2021

(source: https://www.met.hu/)

5.1.5 Climate of Crete, Greece

Crete has a Mediterranean climate (Köppen classification: Csa) with mild and wet winters (December-March) and hot and dry summers (June-September). There is very high spatial and temporal variability of the climatic pattern. Figure 15 shows monthly average temperatures for 4 stations across the island. Precipitation presents an unequal distribution, both geographically (from east to west) and physiographically (lowland to mountainous areas), with annual mean of about 750 mm and high range of variability across the Island (400-2100 mm/year. The average monthly precipitation ranges from ~37 -107 mm (December to January to ~0-3 mm (July to August). Figure 16 shows monthly precipitation for 4 stations across the island. According to the National Strategy for the Adaptation to Climate Change (MOEE, 2016), precipitation is expected to decrease by 5% to 19% by the end of the century, while extreme precipitation events are expected to rise in eastern Greece. Regarding temperature, projections show a rise by up to 3°C to 4°C by the end of the century.

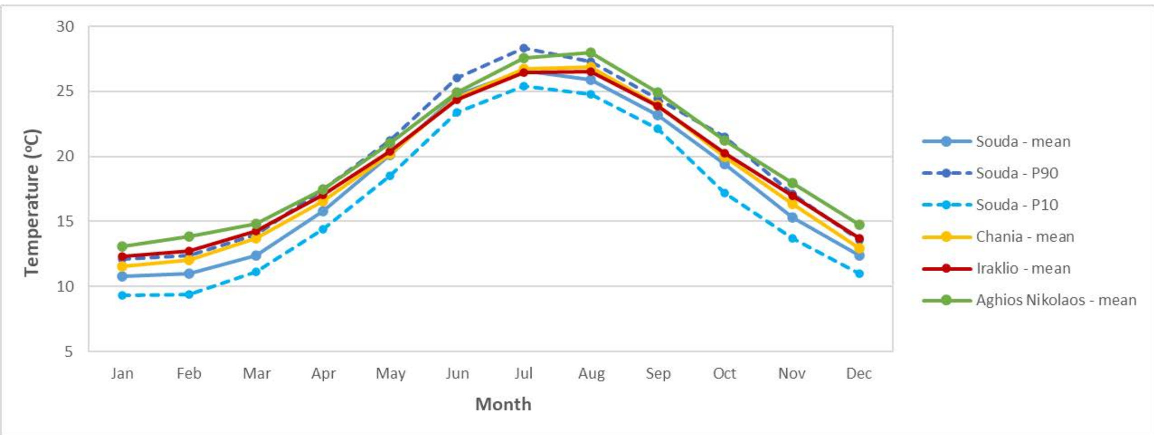


Figure 15. Monthly average temperature in 4 stations across the island: (Souda: 1971-2000, Chania: 2006-2017, Iraklio: 2006-2017, Aghios Nikolaos: 2006-2017).

(Source: Ziogas and Tzimas, 2022)

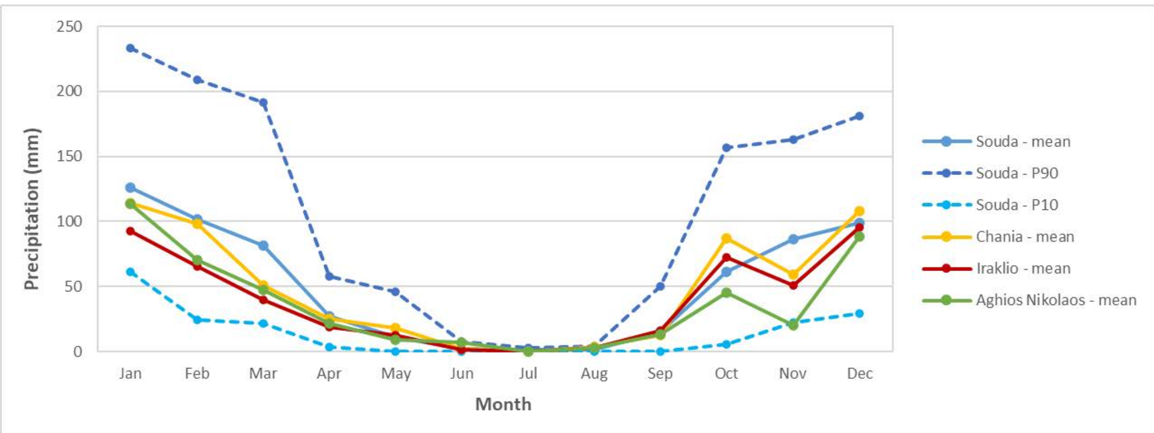
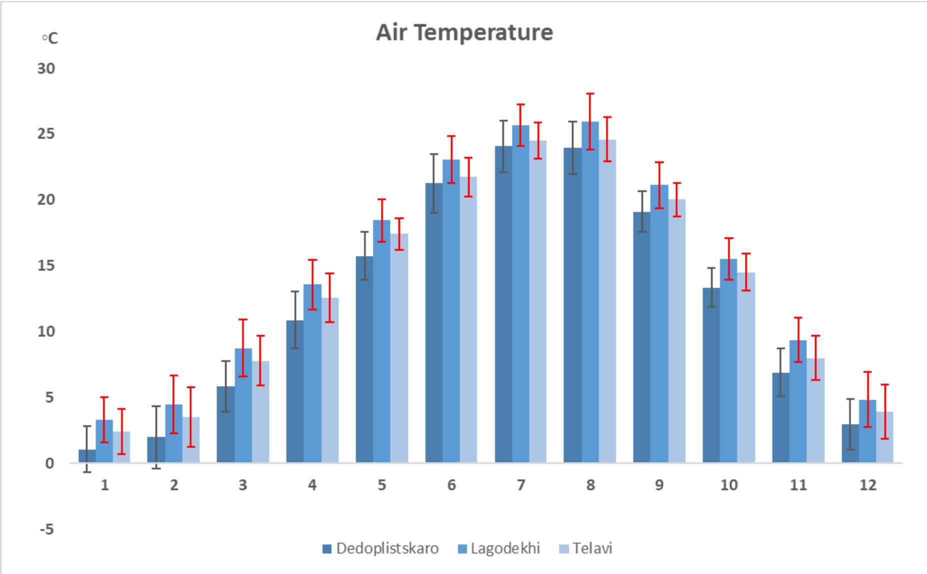


Figure 16. Monthly precipitation in 4 stations across the island: (Souda: 1971-2000, Chania: 2006-2017, Iraklio: 2006-2017, Aghios Nikolaos: 2006-2017).

(Source: Ziogas and Tzimas, 2022)

5.1.6 Climate of Alazani River Basin, Georgia

The Alazani River Basin is characterized by climate conditions varying from subtropical continental to humid. The most dominant Köppen climate type is humid subtropical (Cfa) (http://drm.cenn.org/index.php/en/background-information/paper-atlas). The mean monthly precipitation and temperature measured at three stations within the Alazani River Basin are shown in Figure 17, which illustrates the high spatial and temporal variability of the climatic pattern across the river basin.



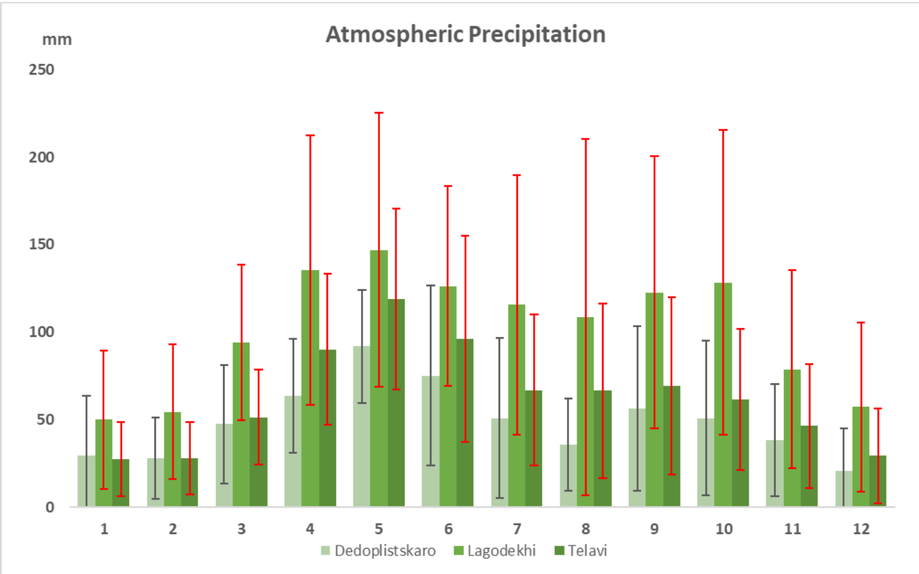


Figure 17. Mean monthly air temperature and atmospheric precipitation (histograms) and standard deviations (vertical lines) for the three gauging stations in the Alazani River Basin

(Source: CENN, 2022).

Climate change has already affected basic climate conditions of Georgia (GoG, 2021), and significant changes in air temperature and precipitation are projected in the future. Current trends and future changes in climate variables are presented in the Georgia' Forth National Communication on Climate Change to the UNFCCC

(GoG, 2021) (IPCC rcp4.5 scenario was used to predict the expected climate change for the time horizon: 2041-2100). More specifically, the findings, with regard to the LL region are as follows:

- Annual mean air temperature in 1986–2015, compared to 1956–1985increased by 0.4-0.7◦C. The most significant increase in temperature was registered in the lower part of the basin (Dedoplistskaro municipality), where the temperature rose up to 1 degree Celsius. The number of hot days and warm nights in the annual cycle has increased significantly in summer and autumn across the entire basin, confirming the summer warming trend. A significant increase of heatwaves episodes was observed together with the increase of average temperature;
- According to the scenario, in 2041-2070 compared to 1971-2000, the average annual temperature will increase almost evenly by ~1.5◦C throughout the basin. By the end of the century, temperature will continue to rise up tp 1.4◦C-1.7◦C. As a result, the warming rate for this period will be within the range of 3.0◦C-3.2◦C with greatest deviations up to 3.4◦C-3.7◦C in summer and autumn seasons.

In the past 30 years, annual precipitation total did not change in most of the basin area. According to climate change projections in the period between 2041-2070, annual precipitation over the entire area will be reduced by 9% on average by the end of the century (2071-2100). The variability in precipitation will increase with increasing frequency of dry spells and heavy rains.

5.2 Climate and water related disasters in the I-CISK Living Labs

The I-CISK LL are facing multiple climate and water related risks such as droughts, water scarcity, floods, highly variable water resources, heatwaves, landslides and storms (e.g. hailing). Climate change is projected to aggravate the occurrence and impact of these disastrous events. The projected increase in the frequency of these hazards in the context of the I-CISK LL mirrors the global trends as many countries in the world face similar challenges. At the global scale, number of disasters and consequent economic losses has significantly increasing in the 21st century compared to 20th century records as indicated by Figure 18 (WMO, 2020).

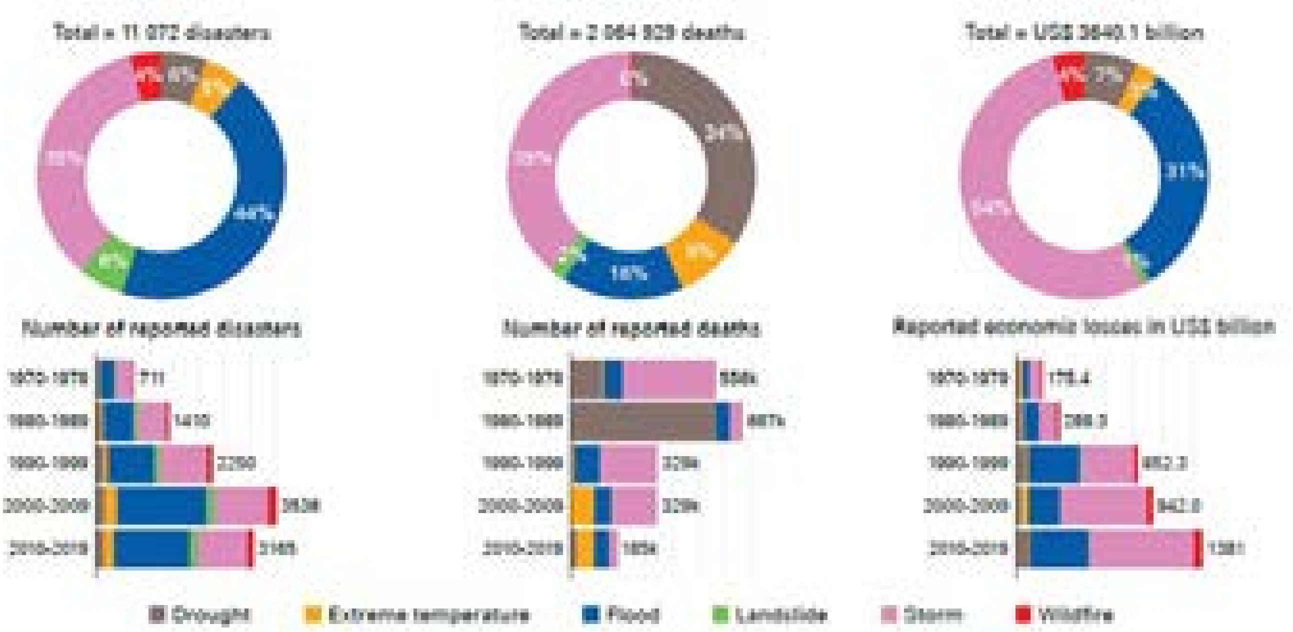


Figure 18. Distribution of number of disasters, number of deaths, and economic losses by main hazard type and by decade, globally.

(source: WMO, 2020).

In the I-CISK LL, drought emerges as the major hazard in focus for most of the LL followed by water scarcity, floods, highly variable water supply and heatwaves (Table 2). Drought will be the primary hazard under study in the LL in the Netherlands and Spain, and for rest of the LL, except Hungary, drought is an important hazard of concern. Next to drought is the issue of water scarcity which is important in all the LL except Hungary (with focus on urban heat island issues rather than water management related issues). Floods and highly variable water supply are of major concern for the LL in Italy, Greece and Georgia, where drought is also a secondary concern-these three LL focus on multiple climatic hazards. Heatwaves will be studied in Hungarian LL, with focus on addressing the issue of urban heat islands. In general, most of the LL focus on multiple hazards.

The following sections provide more details on the risk of different climate and water related disasters in the I-CISK LL.

Table 2. Summary of the climatic settings of the I-CISK Living Labs Regions

Living Lab	Drought	Water Scarcity	Flood	Highly variable water supply	Heatwave	Wildfire	Hail storm	Landslide
Rijnland Delta, the Netherlands								
Andalucía, Spain								
Emilia-Romagna, Italy								
Erzsébetváros, Budapest, Hungary								
Crete, Greece								
Alazani river basin, Georgia								

Legend of I-CISK concern for hazards	Primary concern		Secondary concern		Relevant for the LL but not in focus under I-CISK		Not of significant concern	

5.2.1 Drought and water scarcity: a major climate and water risk in the I-CISK living labs

Drought is the main risk under investigation in five of the six I-CISK LL, and is the hazard of primary concern for the LL located in the Netherlands and Spain.

In the Netherlands' marine coastal climate where flood control and draining access water has been the focus of water management in the past, drought was not of major concern few decades ago. However, over the last decade, drought issues have become a national concern in the Netherlands. The 2018 summer drought in the Netherlands (Figure 19) triggered policy discussions and actions to mitigate the impact of droughts across the country (e.g., Philip et al., 2020). The combination of precipitation deficit and low flows in the Rijn river during the 2018 drought caused serious problems in managing this water system. The Rijnland water authority had to take emergency actions to stop the system operations for recreational shipping as the fresh water inflows in the systems were too low to keep the system navigable while managing the saline water intrusion. The agricultural areas (both rainfed and irrigated) were also exposed to water shortages during 2018-2019 drought episode. Sea level rise may make it more difficult to manage this system in future drought conditions because of more difficulties in managing saline water intrusion. In general, when salinity levels are too high at the Noordzeecanal, the water board may limit operation of ship locks (Rijkswaterstaat, 2021a). In-line with national level prioritisation of sectors to be supplied with water during droughts (Rijkswaterstaat, 2021b), the tourism sector will face restrictions earlier than agriculture and domestic use sectors.

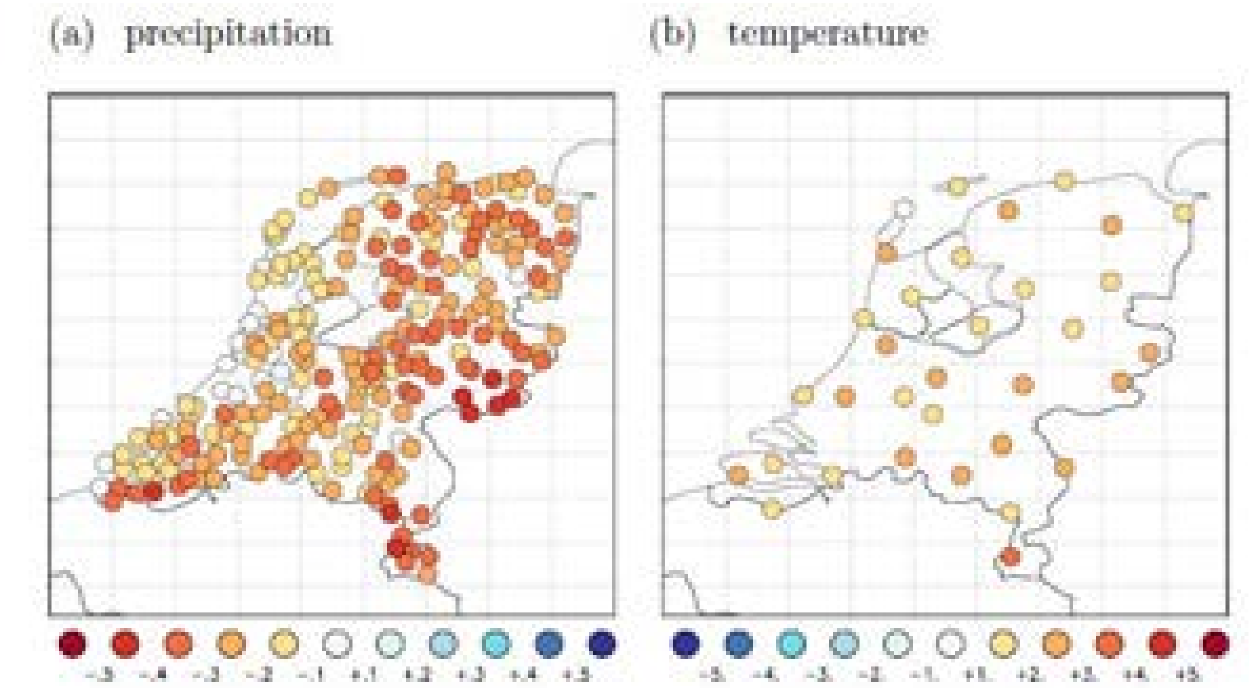


Figure 19. Summer mean (Apr-Sep) anomalies in 2018 for (a) precipitation [fraction], (b) temperature in [◦C]

at KNMI stations.

(Source: Philip et al., 2020)

Drought is a major climatic hazard in most of the Mediterranean climatic regions, and Spain is no exception. The historic records clearly show the periodic exposure of the Andalucía region to droughts (Figure 20). The region faces frequent droughts, which may last through a season or span through multiple years (e.g. 2-4 years). Examples of multi-year droughts include those observed during 1980s, 2000s, and recently after 2018. During the latest intensive drought period in 2018, livestock producers urged the Association of Los Pedroche municipalities to lobby the Andalusian Agriculture Department to reduce the sectors´ chronic sensitivity to drought. Different proposals were suggested, such as the restoration of old wells and a new water transfer infrastructure between the La Colada and Sierra Boyera reservoirs. Initial interviews with local stakeholders clearly point out increased temperatures and sustained rainfall pattern disruption cause broad environmental impacts affecting natural areas, wildlife, agricultural activities and livestock farming. The deterioration of ecosystems induces key vulnerabilities, such as wildfire risk increase and plagues. Disruption of seasonal rainfall patterns also causes a cumulative effect, gradually reducing the resilience of ecosystems and fundamentally affecting functionality of the local water cycle, depleting aquifers, rivers and streams, crucial for environmental quality and territorial development.

Figure 20. Standardized Precipitation Drought Index (SPDI) based on the data obtained from the network of meteorological stations available in Andalusia region, Spain

(Source: https://www.juntadeandalucia.es/medioambiente/portal/web/guest/landing-page-%C3%ADndice/-/asset_publisher/zX2ouZa4r1Rf/content/informaci-c3-b3n-climatol-c3-b3gica-trimestral-1/)

The Drought Citizen Observatory of Andalucía (https://observasequia.es/indice-de-vulnerabilidad/), a large interdisciplinary citizen science project coordinated by the Pablo de Olavide University in Seville, aims to make drought-related data produced by the Andalusian Environmental Information Network (REDIAM) more accessible (Figure 21). It has developed a drought vulnerability index for Andalucía based on exposure, sensitivity and adaptive capacity. For the *Comarca* of Los Pedroches, results show low to moderate vulnerability (0.431), low overall exposure (0.263), and moderate to high adaptive capacity. Vulnerability of Los Pedroches is strongly linked to the climatic hazards, provided the majority of land use is dedicated to rainfed agriculture and extensive livestock production, and no major water supply systems are in place except for drink water supply for urban areas.

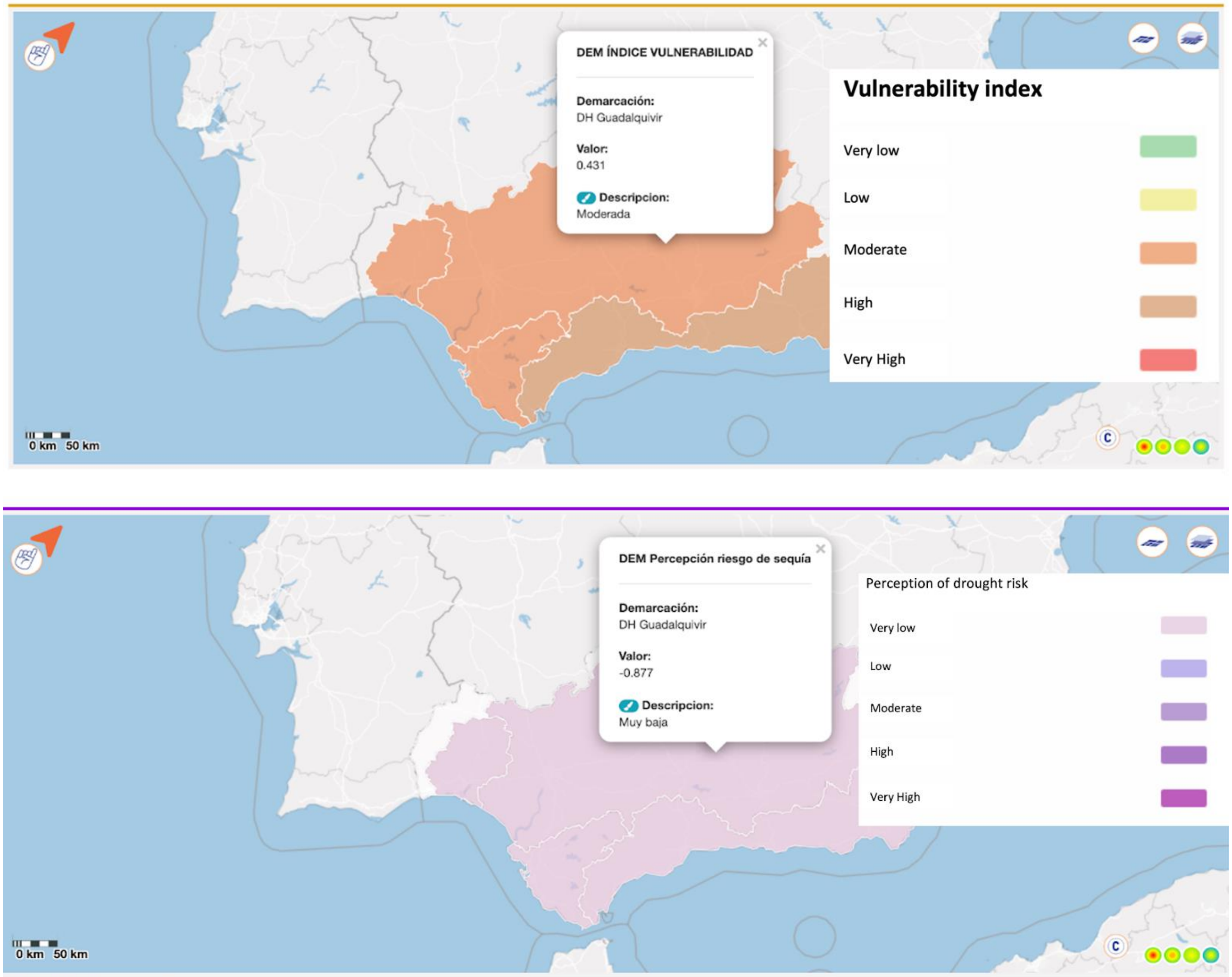


Figure 21. Vulnerability index and perception of drought risk from the Citizen Observatory of Drought project interactive maps for the Guadalquivir basin. For the Guadiana river basin this information is not available for comparison.

(Source: https://observasequia.es/indice-de-vulnerabilidad/)

Like Spain, the Mediterranean climatic region of Crete has been challenged in the past by drought periods of various severities. Drought is a critical hazard for the island since its touristic industry leads to increased water needs, which are often temporally concentrated. In the frame of the AQUAMAN project (https://aquaman.tuc.gr/) funded within the framework of the European Economic Area (EEA) Financial Mechanism 2009-2014), Standard Precipitation Index (SPI) has been estimated for the historical period of 1980-2009, for three different timescales. The three-month period (SPI 3) has been used to reveal seasonal characteristics, the six-month period (SPI 6) is used to reflect mid-term trends of precipitation and the yearly period (SPI 12) is used to describe long term trends of drought. The results are presented in Figure 22. As an example, for January 2000, according to the SPI 12 index, 9.4 % of Crete experienced extreme drought conditions (SPI <-2), 14.6 % severe drought (-2 <SPI <-1.5), 23.4 % average drought (-1.5 <SPI <-1) and the remaining 52 % had almost normal conditions (-1 <SPI <1). The severe drought of the period 1989-1991 is evident for a large percentage of Crete, especially for the year 1990, for every SPI reference period examined. Periods of extreme and severe drought can be identified throughout the whole period examined.

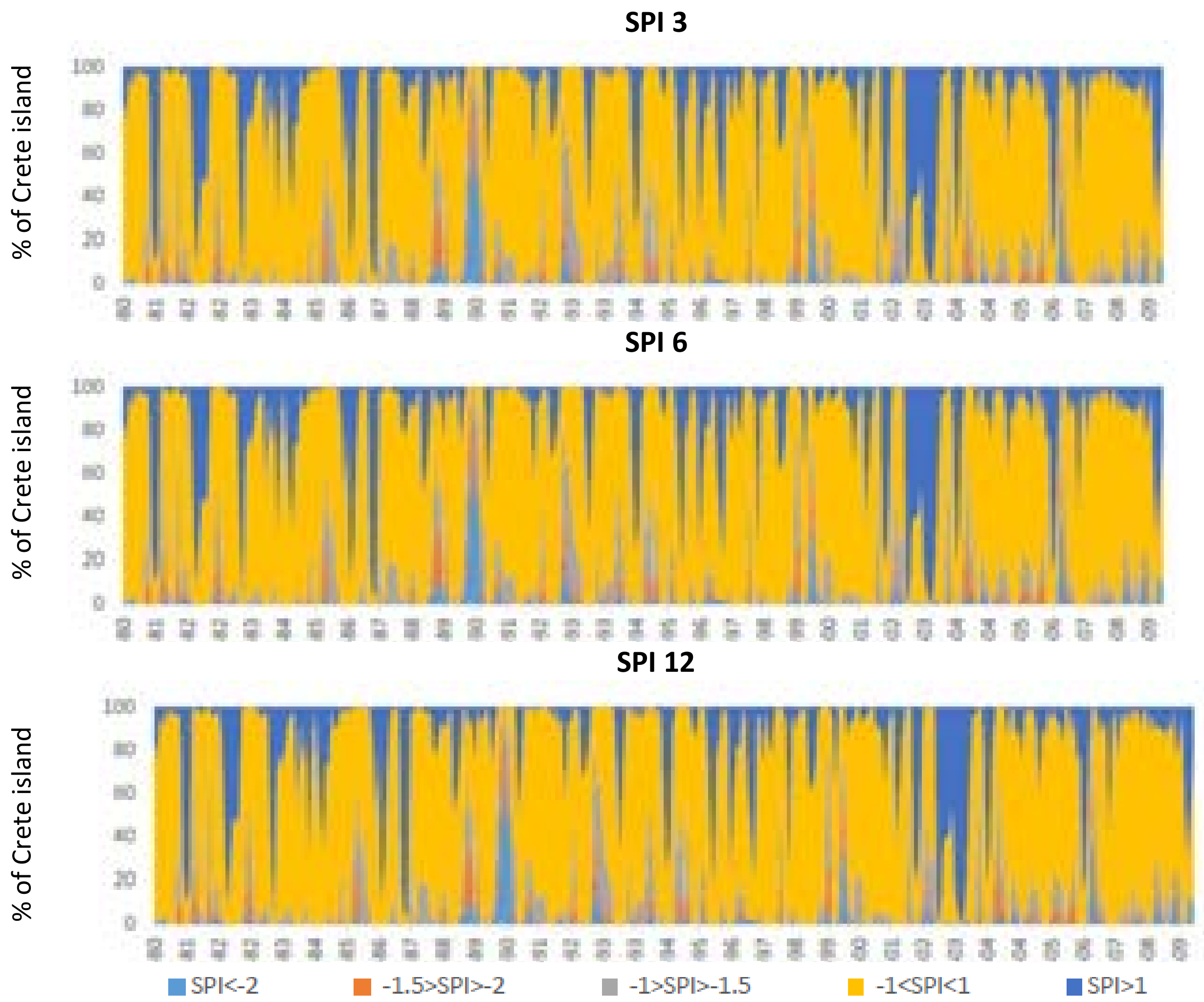


Figure 22. Standard Precipitation Index (SPI) distribution for Crete for the period 1980-2009

(Source: Modified from AQUAMAN Deliverable 1, 2016).

5.2.2 Flood risk in Emilia-Romagna, Crete and Alazani living labs

Floods are of primary concern in Emilia-Romagna, Crete, and Alazani River Basin LL. For example, in Emilia-Romagna region, during the Dec. 2019 flood from Panaro River, ~130 million euros[4] of damages have been suffered by citizens and businesses (the total estimated damage in the region is over 500 million euros only for the 4 most significant floods since 2014 according to the report of the Italian NGO "Legambiente[5]," also see Figure 23). In the case of Crete, several areas are prone to flooding. Figure 24 shows those areas where floods have occurred in the past 20 years along with the areas designated as flood plains (geographical areas which could be covered by a flood and that would have significant social and economic impacts). Additionally, the relative percentage changes of the flood magnitude in reference to the baseline scenario are presented. As shown there, the majority of the Crete's basins face an increase in the magnitude of the extreme flood event (T = 10 years and T = 100 years), for the mid-century period (2000-2049) compared to the baseline

[4] https://www.regione.emilia-romagna.it/notizie/2021/maggio/danni-da-maltempo-da-roma-oltre-130-milioni-per-lemilia-romagna-bonaccini-notizia-straordinaria-in-pochi-mesi-risorse-che-di-solito-richiedono-anni-grazie-al-lavoro-di-squadra-con-governo-sindaci-e-comunita-locali

[5] https://partecipazione.regione.emilia-romagna.it/seinonda/documenti/il-clima-ci-riguarda_dossier-legambiente-2.pdf

scenario (AQUAMAN Deliverable 2, 2016). For the LL in Georgia, the flooded Ilto and Alazani rivers during heavy rainfall threaten and cause significant harm to the local population, since the main agricultural land is located along the banks of the Ilto and Alazani rivers. Floods are recurring with different intensity every year and wash off arable lands of the population. The floods are intensifying due to heavy rains in the Alazani tributaries.

Figure 23 - Floods from Panaro river nearby city of Modena (left) during event of December 2019, source (4), and floods from Secchia River nearby Modena (right) during January 2014

(Source: https://partecipazione.regione.emilia-romagna.it/seinonda/documenti/il-clima-ci-riguarda_dossier-legambiente-2.pdf)

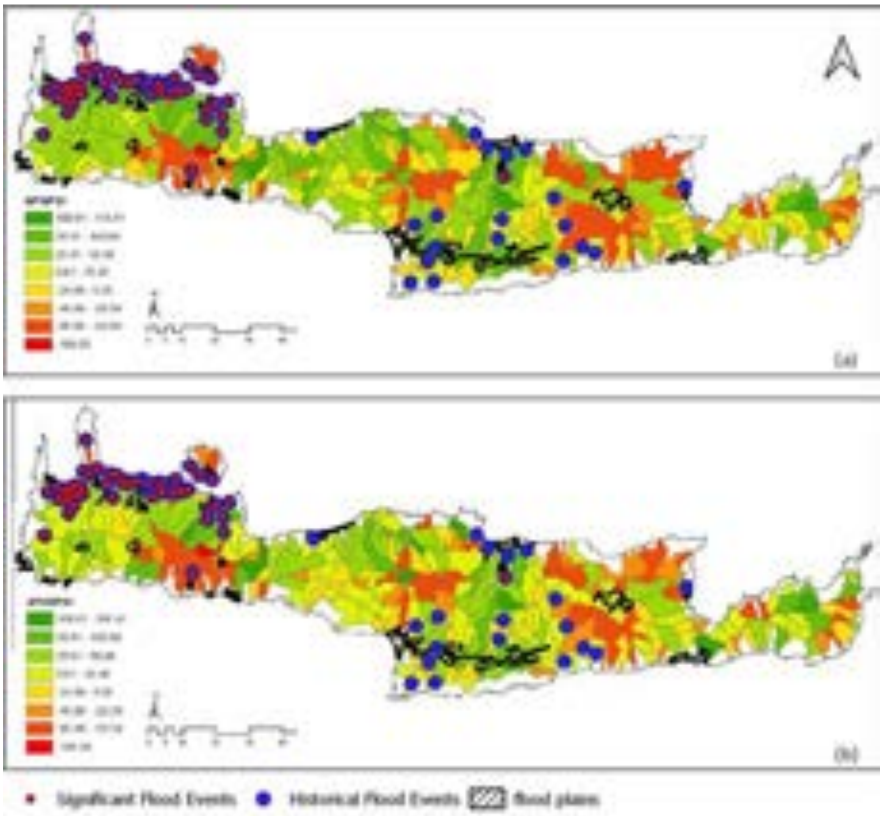


Figure 24. Relative percentage changes of the flood magnitude in reference to the baseline scenario event for the mid-century period (2000-2049): (a) T = 10 years and (b) T = 100 years

(Source: Modified from AQUAMAN project, Deliverable 2, 2016).

The river flows of the Alazani and its tributaries significantly fluctuates during the year. In winter, the rivers are dry and in spring inundations and floods are common. Overall, the rivers of the Alazani basin fall under the category of rivers with 25-50% spring runoff (USAID and DAI, 2002). For example, about 39% of the annual runoff of the Alazani River is generated in spring, 29% - in summer, 20% - in fall and 12% - in winter. Spring floods begin in February-March and reach maximums in May-June. As a result of intense melting of snow, the date of the beginning of the floods in Alazani and its tributaries varies from the first decade of March to the third decade of April. The flood season lasts for two to three months. The rivers are flooded almost every year, inundating agriculture, floodplain forests and residential areas in some parts of the basin.

5.2.3 Highly variable water supply in Emilia-Ramagna, Italy

The highly variable water supply is of concern in most of I-CISK LL, however, this issue is identified as an important focus of I-CISK activities only for the LL in Emilia-Romagna, Italy. In this LL, climate change is projected to alter the seasonal distribution and variability of rainfall/ temperature, inducing consistent variations in water availability. On the other hand, water use has recorded a consistent increase since 2003 in both the RER and the area of the LL, leading to frequent conditions of water scarcity compared to demand. Beside the frequency of extreme floods, the most relevant sources of hazard from Climate change are related to water availability (ERVET and ARPAE, 2018), which has been preliminarily identified as the main hazard for this LL. Balance between water availability and demand is, at present, in precarious equilibrium, with local criticalities. These are related to both over-exploitation of surface and underground water bodies, and recurrent water crises due to resource scarcity that occur for various irrigation areas supplied exclusively by natural rivers. The availability of resources from surface watercourses reflects the degree of torrentiality of the hydrological regimes, strong for the Apennine watercourses. Supply, leading, if anything, to a temporary over-exploitation, with the possibility of locally accelerating the piezometric lowering and the transport of contaminants. In the mountain regions, the streams and springs fed by shallow aquifers are the first affected by the drought periods that are now not only typical of the summer season, but also occur during the winter; in some situations, the drinking supply is already temporarily ensured in an emergency (e.g., with tank trucks). Drinking water uses may locally show seasonal characteristics, in proportion to the incidence of activities related to tourism. For the industrial sector, seasonality of demand affects specific sectors related to transformation for agricultural production, while irrigation uses concentrate in the late spring and summer period.

5.2.4 Heatwaves and urban heat islands in Erzsébetváros, Budapest, Hungary

Budapest has high exposure to climate change associated with heatwaves, as can be inferred from the long time series (1970-2010) meteorological data (daily mean temperature) from the CARPATCLIM-HU climate model, as shown in Figure 25. Sensitivity to heatwaves is shown in Figure 26, which is the map that has been compiled by aggregating a total of 20 socio-economic indicators to produce a complex indicator that provides information on sensitivity to the effects of heatwaves in a composite way.

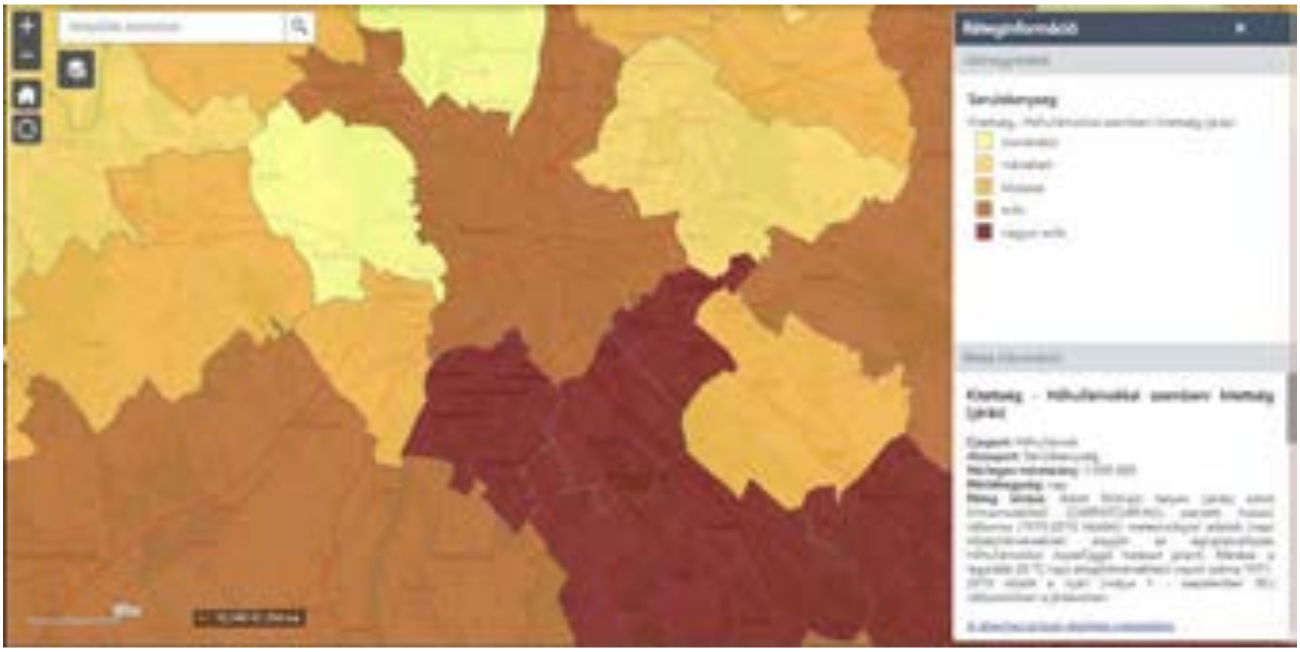


Figure 25. Exposure to heatwaves in Budapest, Hungary

(source: https://map.mbfsz.gov.hu/nater/)

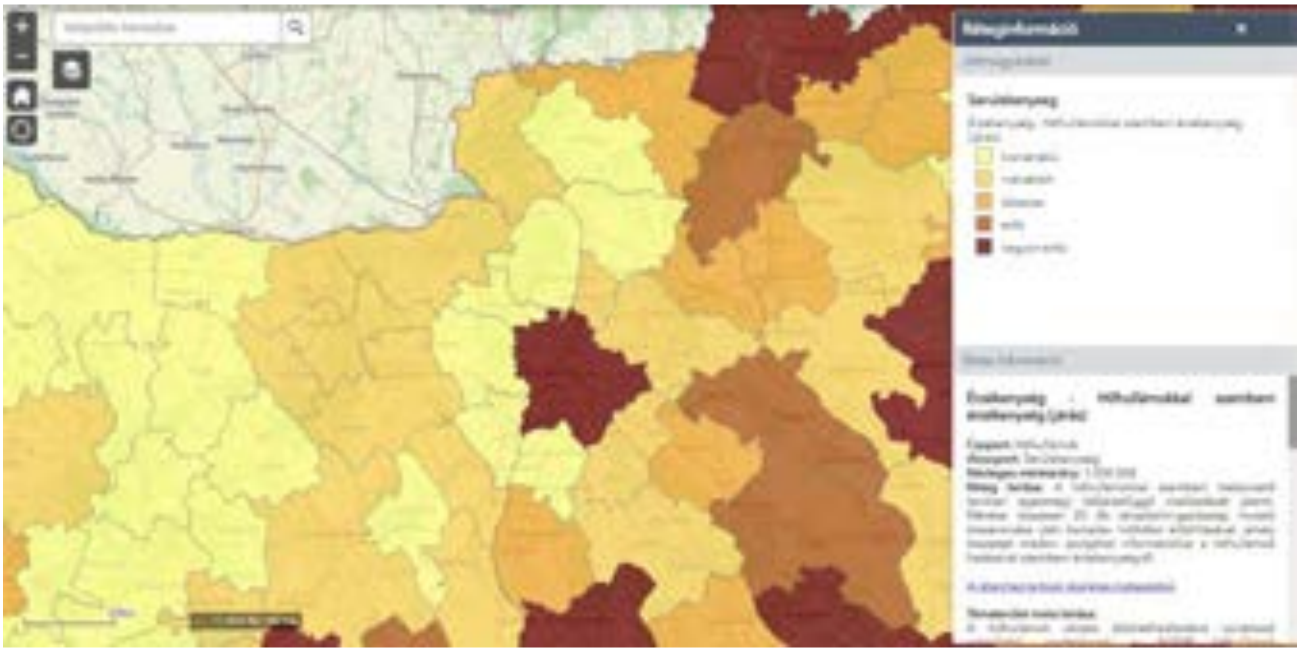


Figure 26. Sensitivity to heatwaves in Budapest, Hungary

(Source: https://map.mbfsz.gov.hu/nater/)

The main causes of urban heat islands are the too small and degraded green areas in the inner parts of the city (in Budapest, the average size of the green areas per capita is 6 m^2 in contrast to the 9 m^2 recommended by the WHO), and the inadequate operation of urban ventilation corridors. Most of the brown areas are private property which makes it difficult to establish new green areas. The green areas have a significant impact both on climate change mitigation and adaptation, especially in urban heat islands. The adaptation methods in public spaces comprise shading or the provision of drinking water (Zsombor et al., 2021). The effects of urban heat islands are extremely prominent in Erzsébetváros, which is the most populated district in Budapest. The houses are old (90% had been built before 1945), with a very low percentage of green areas (0.5 m^2 per capita) and a very high percentage of artificial surfaces. The green areas are not only small but are island-like and fragmented (Éva and Cecília, 2020). The adaptation strategy of the district aims to increase the percentage of green areas, green roofs, green walls, green backyards of the houses, shading of buildings (public and private) and public transport spots (with green roofs), and the establishing of drinking fountains, or other places to drink water during the hot waves (like restaurants providing water). It also aims to organize a heatwave alarm system and education of the public on adaptation strategies (Éva and Cecília, 2020).

6 Natural resources and socio-economic sectors impacted by climate and water related hazards

There are a number of natural resources and socio-economic sectors that are impacted by weather, climate and water related hazards in the I-CISK LL (Table 3). Multiple sectors are impacted in each LL, with water resources management, agriculture and tourism emerging as the most prominent sectors in focus under I-CISK, as these are of primary concern in most of the LL. Environment (including forestry) and health are also among the important sectors of interest, and has primary focus in at least one of the LL. The livestock and energy are of secondary concern in some LL. Water resources management is the most impacted sector, and, hence, the primary focus under all the LL except Hungary. Agriculture is the second most important sector under study, as it is the primary focus in four out of six LL. Tourism ranks third because it is the primary focus in three LL. More information about these sectors is provided in the following sections.

Table 3. Natural resources and socio-economic sectors under investigation in the I-CISK living labs

Natural resources and socio-economic sectors	Rijnland Delta, the Netherlands	Andalucía, Spain	Emilia-Romagna, Italy	Erzsébetváros, Budapest, Hungary	Crete, Greece	Alazani river basin, Georgia
Water Resources Management	Primary concern	Primary concern	Primary concern	Relevant for the LL but not in focus under I-CISK	Primary concern	Primary concern
Environment	Relevant for the LL but not in focus under I-CISK	Primary concern	Secondary concern	Relevant for the LL but not in focus under I-CISK	Relevant for the LL but not in focus under I-CISK	Secondary concern
Agriculture	Primary concern	Primary concern	Primary concern	Relevant for the LL but not in focus under I-CISK	Secondary concern	Primary concern
Livestock	Relevant for the LL but not in focus under I-CISK	Primary concern	Not of significant concern	Not of significant concern	Not of significant concern	Relevant for the LL but not in focus under I-CISK
Tourism and recreation	Primary concern	Secondary concern	Relevant for the LL but not in focus under I-CISK	Primary concern	Primary concern	Secondary concern
Health	Not of significant concern	Not of significant concern	Not of significant concern	Primary concern	Relevant for the LL but not in focus under I-CISK	Not of significant concern
Energy	Not of significant concern	Not of significant concern	Secondary concern	Not of significant concern	Secondary concern	Secondary concern

Legend of I-CISK concern for sectors	Primary concern	(dark blue)	Secondary concern	(orange)	Relevant for the LL but not in focus under I-CISK	(grey)	Not of significant concern	(white)

6.1 Water resources management

The linkages of weather, climate and water related hazards with water resources, and their management and governance are well established. The water resource sector is directly impacted by hydro-climatic hazards, and the sector also acts as transmitter of risks to other natural resources and socio-economic sectors. For example, when water resources diminish during drought, supply to water use sectors (e.g. agriculture, environment, tourism) declines, which causes adverse impacts. Therefore, management and governance of water sector becomes a major challenge in mitigating the impacts of extreme events. However, the impact of climatic and hydrological extremes is highly variably across the LL due to multiple factors such as different hazards in focus and diversity of environmental, management and governance contexts. Two examples are provided below highlighting the impact of droughts and floods on water resources management in different contexts.

For example, the Rijnland delta is a highly managed water system. Drought conditions manifest in the scarcity of precipitation and surface water (freshwater). The situation is most pressing when reduction in precipitation in the region is combined with flow reduction in the discharge of the Rijn river. Managing river water levels for navigation, controlling water quality (e.g., salinity) and providing adequate water (both quantity and quality) to meet the surface water demands of multiple uses becomes very difficult. Groundwater quantity and quality is also impacted as water tables decline and saline water intrusion increases. Groundwater use increases during drought as agriculture has to mostly rely on groundwater resources. Allocation of water among competing water use sectors becomes a challenge besides day to day operations of the system to regulate salinity levels, navigation of ships for tourism and recreation and water supply to irrigated agriculture and environmental uses. The water system, as illustrated in Figure 27, is managed by different actors representing government agencies, private sector and end users, with Rijnland Water Authority having the main role in water allocation and operational water management. The authority has developed a drought management plan after 2018 drought, which identifies water management actions under different categories of drought. The water authority views this plan as a dynamic one, which needs to be regularly updated.

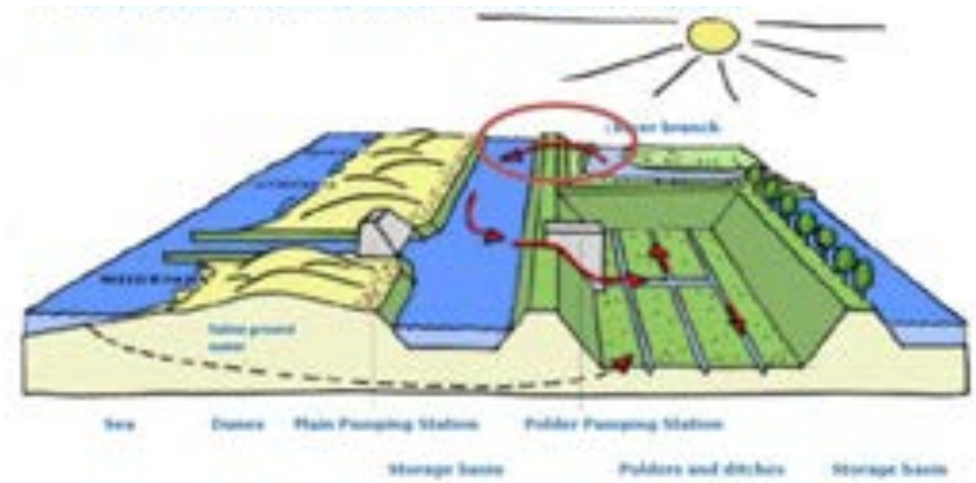


Figure 27. Surface water operation during summer half-year in Rijnland water system

(Source: Van der Zwan, 2019)

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6.2 Environment sector

The climate and hydrological variability and extremes impact a variety of unique environments present in the I-CISK LL. The water quality degradation in rivers, groundwater and lakes/wetlands has potentially negative impacts on the ecosystems, which is an important issue for the LL in the Netherlands, Italy, Greece and Georgia. As an example, water quality status of rivers in the Italian LL are presented in Figure 28. Extreme precipitation events and floods cause high rates of soil erosion and landslides/mudslides in the LL in Italy and Georgia. The reduction of environmental flows and changes in river flow regime due to drought and water scarcity impacts the aquatic environment, which is an important consideration for the LL in the Netherlands, Spain, Italy and Georgia. The increase in temperature causes environmental change by altering the hydrological cycle and climate of the LL region, which is projected to accelerate in the future under climate change.

Figure 28– Surface water bodies quality according to EU Water Framework Directive, outline of the area of interests.

(Source ARPAE, 2021)

Land use change driven by natural and anthropogenic factors is an important environmental concern in the LL in Spain and Georgia, especially degradation of forest environments. The unique land use land cover types and protected areas/national park environments are important features in the LL located in Spain and Greece, and these ecosystems are under pressure due to climatic and hydrological change. For example, the Agro-forestry ecosystem (*dehesa* landscape) in Andalucía, Spain (Figure 29) is one of the largest and best-preserved Holm oak meadows in Europe. This ecosystem, product of the intervention of the human being on the natural environment, constitutes a cultural landscape where the balance between the exploitation and conservation of natural resources prevails. This ecosystem provides several important services such as production of Iberian pigs, sheep, cattle, large and small game, firewood and charcoal, but also, to the maintenance of the landscape resource and environmental quality. The impacts on environment and ecology reported are both due to human induced and climatic factors. Human induced factors include: a) pollution of aquifers due to urban areas and intensive livestock dairies; b) the decay and lack of regeneration of oak due to a high stocking rate of cattle; c) oak tree damage due to excessive pruning for charcoal production; and d) excessive game populations in forested areas, affecting protected vegetation. Climatic factors are those such as drought and irregular rainfall. Moreover, climate hazards affecting water availability have a strong impact on forest decay Decreased herbaceous cover due to drought also affects the balance of fauna populations, like a strong decrease in rabbits, main prey for many species, including the Iberian lynx. The local actors indicated pronounced amplification of the summer season and less rainfall in the winter season, strongly affecting game reproductive cycles and phenological behaviour of both flora and fauna. In the same line, changing rainfall patterns reduce groundwater recharge rates, affecting related water bodies as well as the ecosystems depending on it.

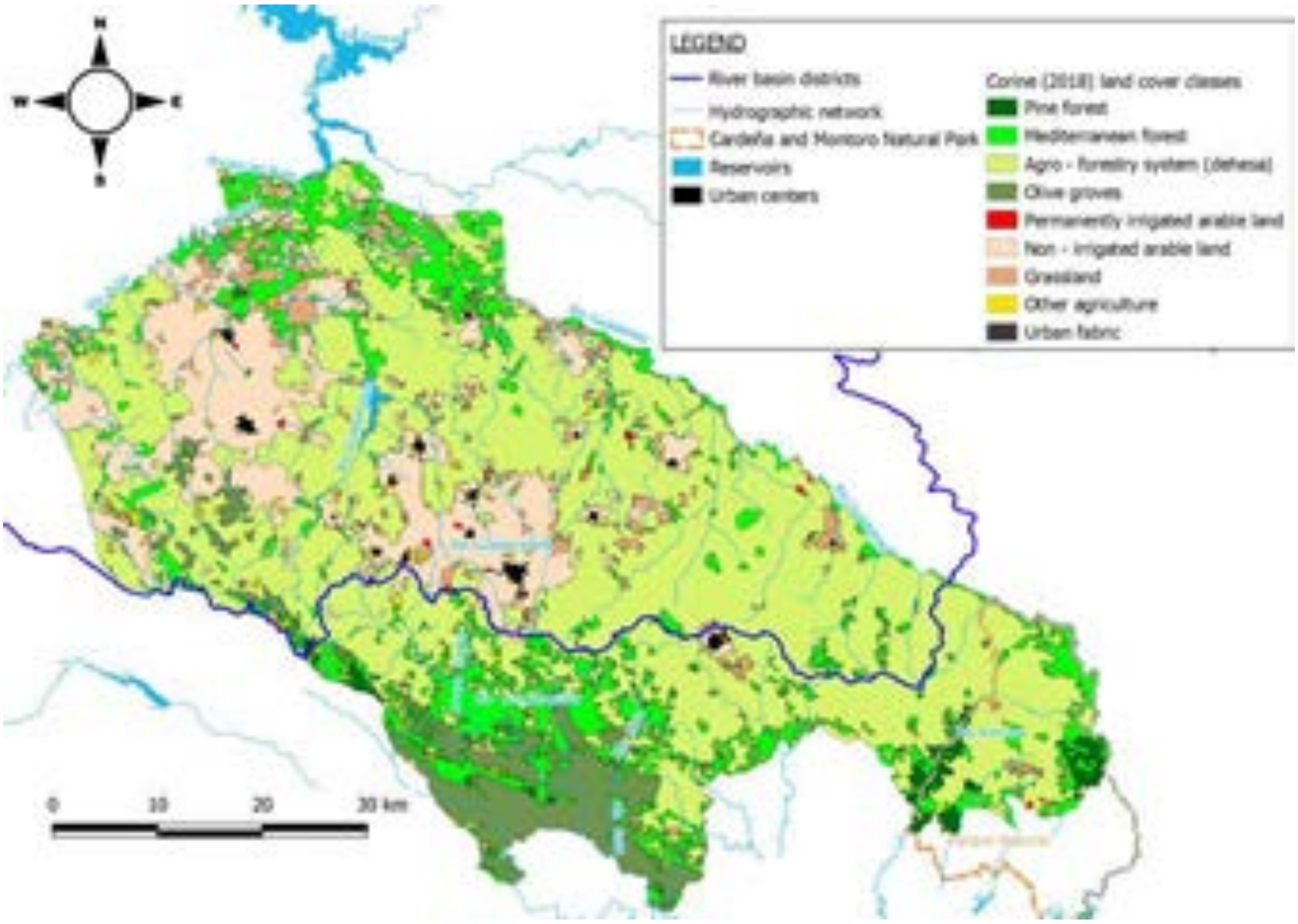


Figure 29. Land use land cover classes in Los Pedroches region, Córdoba, Spain.

(Source: Broekman et al., 2022)

6.3 Agriculture and livestock

Agriculture is the very important socio-economic sector in the I-CISK LL in the Netherlands, Spain, Italy and Georgia. The agriculture sector is closely linked with livestock, and we discuss both sectors together in this report. Drought, water scarcity and high hydro-climatic variability are identified as the major hazards impacting the agriculture sector in the LL regions. Climate change is projected to increase the negative impacts of these hazards on agriculture and related sectors of economy. For example, in the Spanish LL region, the agricultural sector and, specifically, livestock breeding and agro-industry (Figure 30 and Table 4) are the main pillars of Los Pedroches' economy. The business structure of this sector is characterized by a large group of agricultural companies producing -mainly- livestock products (e.g., Iberian pig meat products, dairy products, and other livestock meat) complemented by the olive grove, hunting and agrotourism sectors. Cooperative societies and in particular agri-food cooperatives (e.g., COVAP and Olipe) significantly contribute to the global economic value of the region. The economic activities related to agriculture sector are highly dependent on climatic conditions and in particular rainfall patterns. Drought significantly impacts agriculture sector in the region, for example, the multi-year drought of 2005-2008 in the Andalusian region significantly impacted agriculture sector productivity (especially rainfed agriculture), with an estimated economic loss of EUR 1512 million (Espinosa-Tasón et al., 2022).

Figure 30. Extensive livestock farms and olive groves products in Los Pedroches region, Spain.

(Source: Broekman et al., 2022)

Table 4. Characterization of livestock and agricultural farms in Los Pedroches region, Spain.

Economic Sectors	# of farms	Area (ha)	# of full-time jobs (total)	Total Standard Production (K€/yr)
Agricultural	2602	67723	1415	44.16
Olive groove	1661	22766	1025	29.04
Cereals	601	31729	232	7.98
Other crops	340	13228	158	7.14
Livestock	2284	152383	2956	186.43
Others	68	1710	11	0.02
Total	4954	221817	4382	230.61

(Source: Adroches, n.d.. based on data of INE 2009)

Similar to Andalucía LL, agriculture and livestock are important sectors of economy in the Kakheti region including the Alazani River basin. On a regional level, about 32 % of gross domestic product created in Kakheti region is accumulated from agriculture. Agricultural land accounts for almost half of the river basins territory (48 %), which is 40 % of the total arable land of the country (MEPA, 2019). Furthermore, the LL region is predominant in the country in all major categories of agricultural land use, namely, arable (annually cultivated, or fallow but available for annual cultivation), perennial crops (trees, shrubs, and vine crops) and pastureland, including mown land. Total size of agricultural lands used by farmers in Kakheti is 315,499 ha, including 133,099 ha of arable land, 33,117 ha of perennial crops and 149,230 ha of hay meadows and pastures. As a result of these types of land and the climate, Kakheti is the leading region in the production of cereals, melons and sheep meat (Figure 31). The largest irrigation systems of the country are located in the Alazani River basin which supplies water to the local farmers in the regions of eastern Georgia. Around 76% of the labor force within the region is employed in the agriculture sector. It should also be noted that 76% of the country's wine is produced in the Kakheti region. Kakheti also has 70 % of all Georgia's vineyards. Most of the vineyards are concentrated on the floodplains of the Alazani River and its tributaries.

Among climate-related hazards, droughts, hail storms and floods are the most damaging for the agriculture sector. The hail events occur annually and cause significant economic loss to the agriculture sector. The most severe drought occurred in 2000 and 2001, which significantly impacted the agricultural productivity. The country was affected by a severe food crisis. Agricultural production in 2000 drastically dropped as a result of the event. The drought affected all crops (https://www.fao.org/3/x8374e/pays/geo0010e.htm). Georgia lost 5.6 % of GDP due to drought (350 million in US$), much higher portions of agricultural GDP (25.5 %) were lost. Kakheti was one of the most inflicted regions along with others. Moreover, agriculture is a highly sensitive sector and climate change has the potential to lead to major effects in the region. These include changes in climate variability and water availability, which may cause direct and indirect impacts on irrigation, crop production, livestock, viniculture, agricultural supply and values chains. Due to the high dependence on the agriculture sector, the region's economy is vulnerable to weather, climate and water related risks.

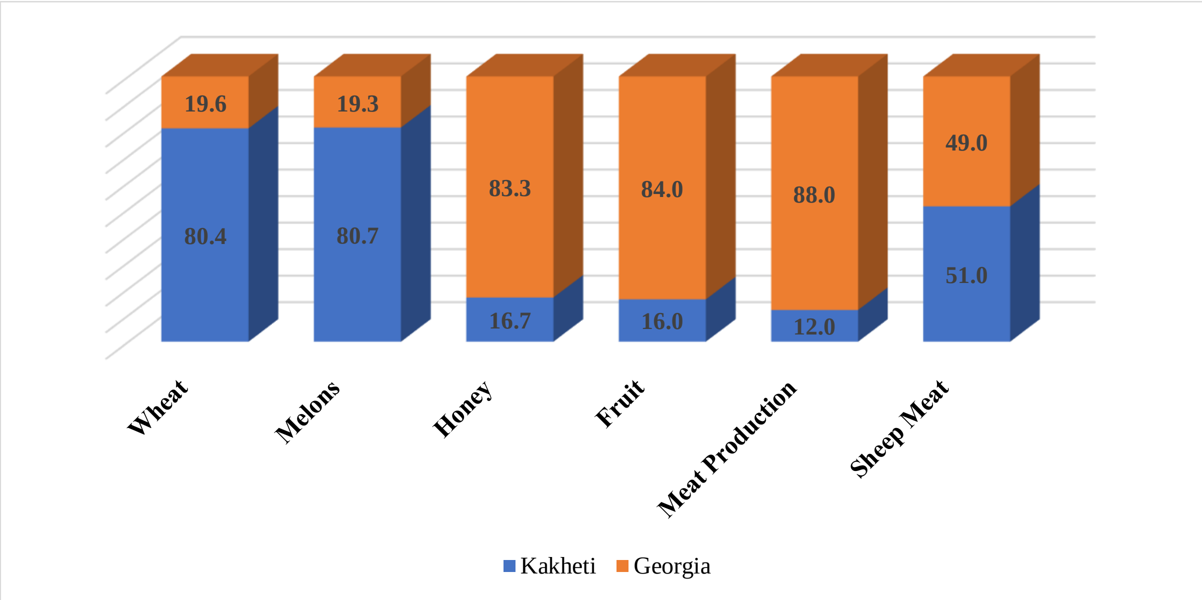


Figure 31. Share of Kakheti Region in Total Production in 2020

(Source: National Statistics Office of Georgia)

6.4 Tourism and recreation

Tourism and recreation sectors are the main focus in the LL located in Greece, Hungary and the Netherlands. It is an important sector of the economy for the Spanish and Georgian LL as well. The sector is impacted by multiple hazards, pre-dominantly by high hydro-climatic variability, heatwaves, droughts and floods. Climate change and increasing anthropogenic pressures will further aggravate the vulnerability of these sectors, as illustrated below.

In Crete, the tourism sector is growing and the related demand motivated significant investments in hotel units, resulting in the quantitative and qualitative upgrade of the hotel infrastructure. At the same time, it faces structural problems which focus mainly on the intense seasonality and the limited diffusion of tourist traffic to the inland settlements, as the hotel infrastructure is concentrated mainly on the north coast and in small outbreaks in the south. Additionally, the sector's economic performance is greatly affected from exogenous, uncontrolled conditions, which contribute to fluctuations. A significant competitive advantage of the tourism industry on the island is the high percentage of high-quality hotel infrastructure. In Crete, various forms of tourism are developed: Conference Tourism, Urban Tourism, Coastal and Maritime Tourism, Cultural Tourism, Ecotourism - Agritourism, Fishing tourism and others. The tourism sector of Crete constitutes ~50 % of the GDP of Crete and about 2.5 % of the GDP of the country (data 2018, 2019) (Ikkos and Koutsos, 2019 & 2020). Based on the climate projections until 2040, the vulnerability of tourism sector climate change estimated as moderate for both the intermediate and the worst-case scenario (GRRoC, 2021). For the mid-century (up to 2060), the vulnerability is estimated as high and extreme in several areas of Crete (Figure 32).

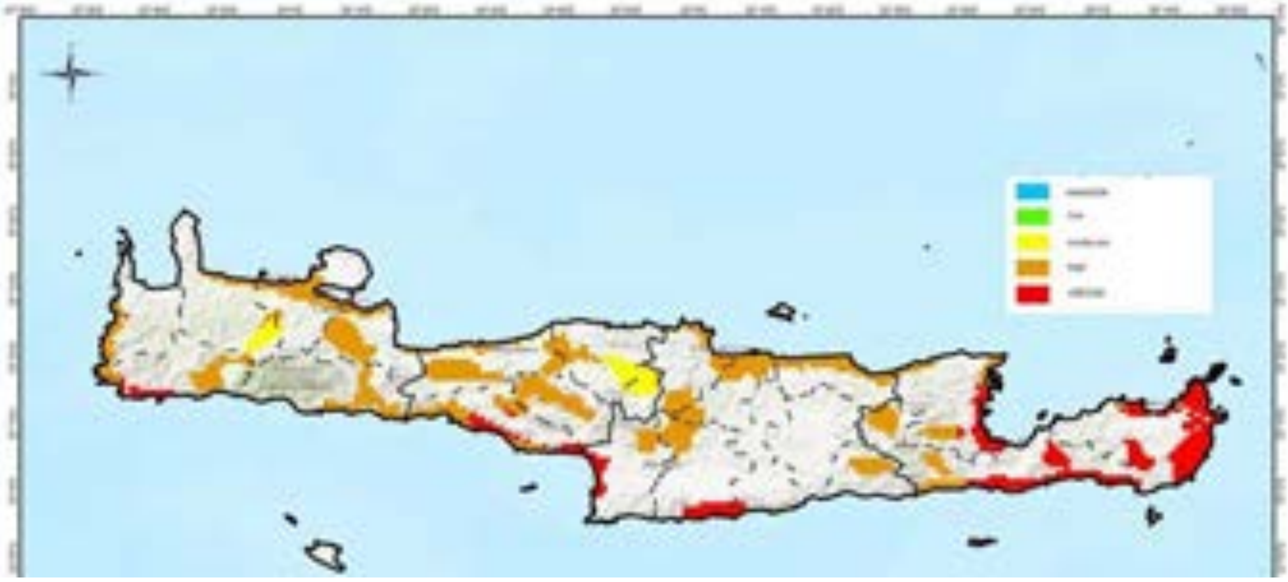


Figure 32. Tourism sector vulnerability to climate change for 2041-2060, RCP8.5 in Crete, Greece

(Source: adopted from GRRoC, 2021).

In the case of Budapest, climate change has, and will continue to have, a strong impact on tourism, and urban tourism will be negatively affected by heatwaves and urban heat islands (Csete et al 2013). Erzsébetváros is an inner-city district, where small businesses dominate the economy. Its economy is highly based on tourism, cultural services, and food services. Tourism is mostly based on the cultural heritage of the district. The urban heatwaves had already (moderately) affected tourism in the district (Éva and Cecília, 2020).

Water tourism is an important economic sector in Rijnland Delta region, the Netherlands. Droughts may strongly limit navigability for recreational shipping because counter measures taken by the water board include limiting the operation of ship-locks. Interest from the water tourism sector is whether drought alerts could be provided by the water board further in advance than is currently available in order to improve planning. For the long term, the water tourism sector representatives expressed interest in information on potential changes in drought frequency. Increase of this frequency may require a change in their business strategy. The water board of Rijnland has expressed the objective to come to an informed and lively discussion with water tourism and agricultural stakeholders in the region on climate change outlooks for expected drought frequency and characteristics. Thus, Rijnland expressed the need for informative and attractive CS with tailored climate change outlook information.

6.5 Health

Health is the primary sector in Focus for the LL in Hungary. The impact of extreme temperature is an important health risk in the study region, which causes increase in the mortality rates (Figure 33). According to the

National Centre for Public Health (Országos Közegészségügyi Intézet) (NCP) forecast, the frequency of heatwaves is expected to increase further in the future, doubling by 2050, significantly increasing the excess heat-related deaths by ~150 %. Between 2071 and 2100, climate change will increase the current excess mortality by a factor of six, based on current demographic and socio-economic conditions.

The LL region (Erzsébetváros municipality) is significantly affected by the urban heat island, it is considered highly exposed, highly sensitive, highly vulnerable, and moderately capable of adaptive measures due to the low density of green areas and the lack of ventilation (Éva and Cecília, 2020). The most significant effect of heat waves in Budapest is concerning the health sector, as the heat waves can cause health problems, hospitalizations, and in some cases death. The heat waves are causing heart and circulation problems, breathing problems, heatstroke, dehydration, and kidney failure. The main vulnerable groups are the elderly, children, pregnant women, people with chronic health issues, and those who are working outside. The age distribution of the population shows that 23 % of the population is elderly, and the number of families with small children is increasing in the district, therefore, Erzsébetváros has a fairly significant vulnerable population (Éva and Cecília, 2020).

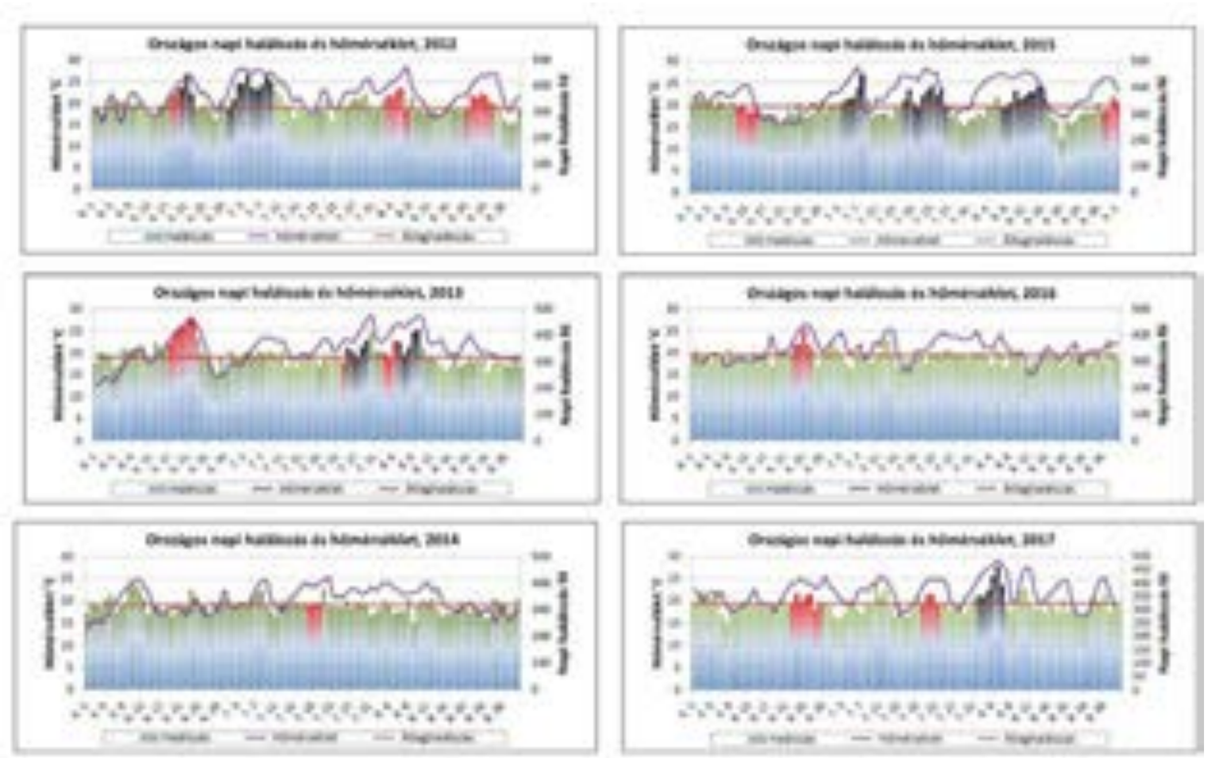


Figure 33. National daily mortality and temperature trends 2012-2017, June-August

(source: Páldy, n.d.)

6.6 Energy

The energy sector is important consideration in the three LL: Emilia-Romagna, Italy; Alazani River Basin, Georgia; and Crete, Greece. The energy sector represents an economic sector particularly vulnerable to climate change in these regions. In general, a significant increase in electricity consumption is expected in the summer season. The production and supply of energy will also be affected by the probable reduction in the availability of water resources for hydroelectric production or for the cooling of thermoelectric plants. Other possible impacts may occur following the variation in energy demand, the availability of natural resources (water, wind, etc.) and the vulnerability of the territory (instability phenomena, etc.); these will have direct repercussions on the location of energy plants and infrastructures. Furthermore, for the hydroelectric sector, increasing attention will be required to protect the ecological conditions of watercourses, guaranteeing a suitable release from the plants throughout the year, and to conflicts related to other uses of the resource.

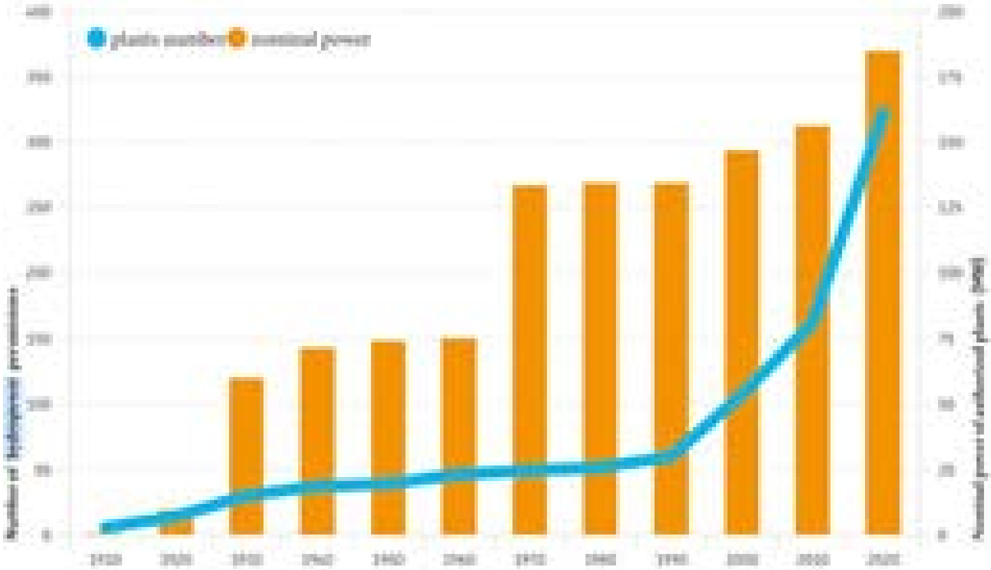
Hydropower is the main focus in Emilia-Romagna, Italy and Alazani River Basin, Georgia considering its importance in these regions. Figure 34 shows some facts and figures on hydropower production in the Emilia-Romagna. According to ARPAE (2020), the hydropower sector grew in the last decades (in number of new authorized plants) and the overall relative contribution to energy production is lower ~9 % (Figure 34).

Currently, 12 run-off-river type hydropower plants (HPP) operate in the Alazani River basin (Table 5). Most of them were commissioned over the last decade. The region has the potential to expand the number of HPP, and there are several HPP planned in the Alazani River basin. The energy sector in the Alazani River basin is also highly exposed to climate change. Primarily, changes in the seasonal and sub-seasonal patterns of precipitation and temperature can lead to alter overall annual runoff and hydropower generation. Also, due to intensified extreme events (floods, landslides, debris flow) the infrastructure of the generation systems is under increased threats.

Energy production in Crete is mainly composed of steam electric station production, accounting for up to 73% of total production, followed production by Renewable Energy Sources (wind and solar), which accounts for ~27% (data from GRRoC, 2021.), as shown by Figure 35. Regarding climate change impact in terms of energy demand (for cooling), in the short term (up to 2040) in both the intermediate and the worst-case scenario, most areas of Crete show moderate vulnerability (GRRoC, 2021). Higher vulnerability is estimated for the Heraklion R.U. (regional unit). In the mid-century (up to 2060), for the intermediate scenario, the projections show a vulnerability ranging from moderate, in most of the island, to high in the Heraklion R.U.. In the worst-case scenario, the average vulnerability of the island is projected to be high.

a)

b)



c)

Figure 34. Some facts and figures on hydropower production in the Emilia-Romagna Region, Italy: a) a run of River hydropower plant along upper Secchia River, b) growth of hydropower plants and production, and c) overall gross energy production

(Source: ARPAE, 2020)

Table 5. Operational Hydropower Plants in Alazani River basin.

N	HPP	Installed Capacity (MW)	Type	Commissioning Year
1	Khadorhesi	24	Run-of-River	2004
2	Akhmetahesi	9.2	Run-of-River	2014
3	Alazanhesi	6.1	Run-of-River	1942
4	Alazanhesi-2	6.1	Run-of-River	2013
5	Khadorhesi-2	5.4	Run-of-River	2012
6	Shildahesi	5	Run-of-River	2013
7	Avani HPP	3.5	Run-of-River	2019
8	Lopotahesi	2.5	Run-of-River	2021
9	Pshavelhesi	1.9	Run-of-River	2010-2015
10	Kabalhesi	1.5	Run-of-River	1953
11	Instobahesi	1.5	Run-of-River	1998
12	Shildahesi-1	1.2	Run-of-River	2018
	Total	**67.8**		

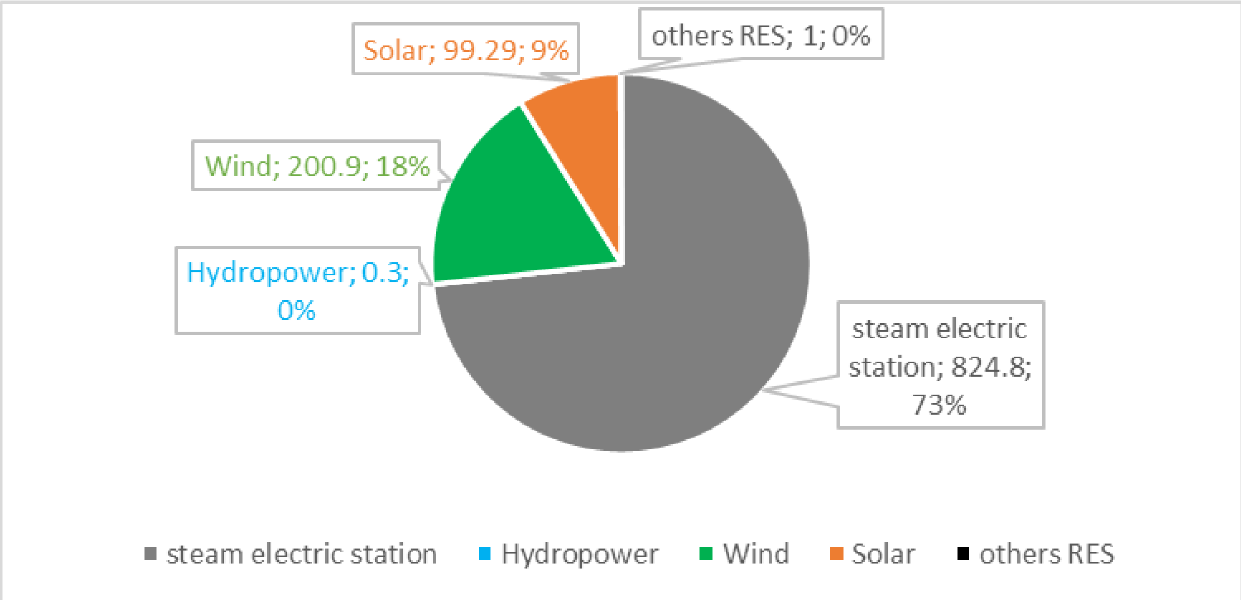


Figure 35. Energy production mixture in Crete, Greece.

7 Stakeholder involvement in co-creation of human centred climate services

7.1 Stakeholder Analysis to establish Multi Actor Platforms

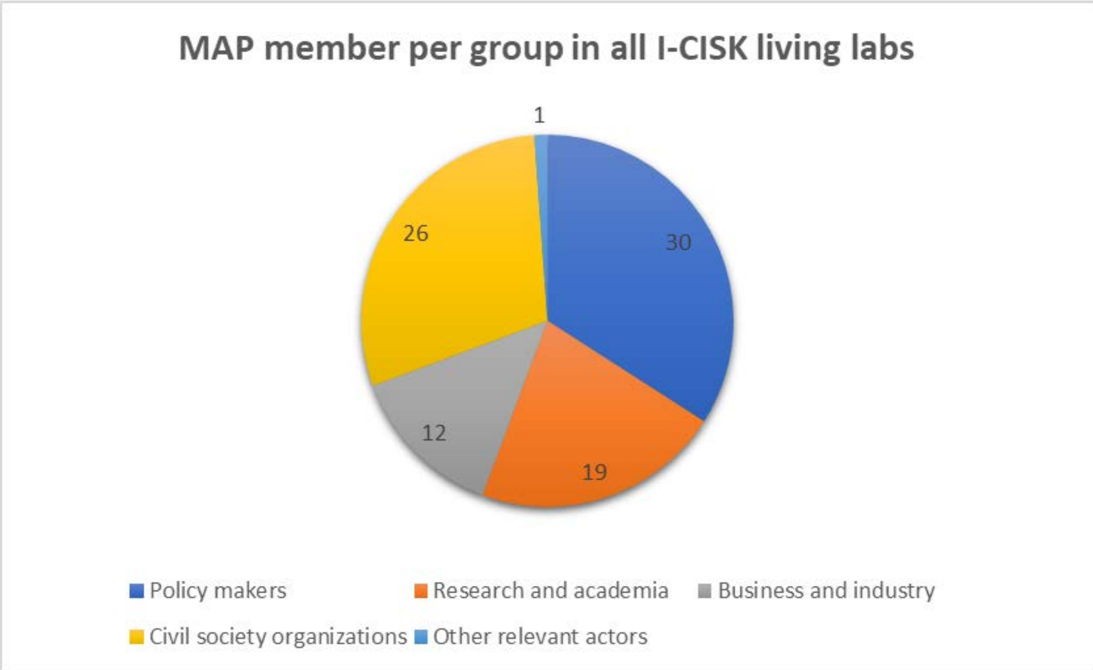
A snowball sampling approach was followed in identifying the key actors, starting with those actors who confirmed their support during the I-CISK project proposal development phase. The number of participating organizations and individuals vary per LL, and in general, they represent policy and decision makers, research and education, business and industry, end users like farmers, tourists and citizens, and civil society organizations. These stakeholders also represent the whole value chain of actors involved in the CS sectors: Providers, Purveyors and End-Users. The stakeholders' roles and responsibilities were examined and mapped using interest-influence matrix, which helped to formulate the stakeholder involvement strategies in the LL. For example, the stakeholders with high interest and high influence were considered as key actors involved in the co-creation process, whereas those with low interest and low influence could be kept informed through communication and dissemination activities. The details on stakeholder analysis for each LL are provided in the individual LL reports (Netherlands- Van Andel et al., 2022; Spain-Broekman et al., 2022; Italy-Mazzoli et al., 2022; Hungary Bela et al., 2022; Greece-Ziogas and Tzimas, 2022; and Georgia-CENN, 2022). A summary is presented below. In total, ~90 key actor organizations are expected to participate in the I-CISK MAP established across the six LL (Figure 36a). In general, the distribution of these key actors aligns very well with the recommendations of RRI and MAA approaches, and also represents the different actors in the climate value chain well. The composition of MAP for each LL are discussed in the following sections, while a summary of different types of organizations participating in the MAP is shown in Figure 36b.

The established MAP in the different LL fulfill core values of RRI by representing a way of thinking that balances commercial and other goals with those concerned with wider wellbeing. A key part of RRI is concerned with people's engagement and participation in the research process. This is directly implemented in the living lab and associated MAP by the formation of a stakeholder group that is actively engaged in planning and drafting the next generation CS, which will support the stakeholders' needs. By including the participant stakeholders in planned meetings and workshops throughout the whole project, the LL applies an approach of anticipation and assessment of potential implications and societal expectations with regard to research and innovation, with the aim to foster the design of inclusive and sustainable services, within the frame of responsible research and innovation.

The RRI approach is taken into consideration in all activities and interactions within the LL. All the aforementioned societal actors, researchers (project partners), policy makers (local authorities), business, third sector organisations (NGOs), etc, will work together during this research and innovation process in order to better align both the process and its outcomes with the values, needs and expectations of local society. Further, the participant stakeholders represent members of the LL and society with access to the wider audience and means to promote, share and make public the results of the current effort, increasing the chances of scientific results uptake and supporting the RRI principle for Open Access.

To address issues regarding gender balance and social inclusion in the LL, a set of actions are foreseen, from the formation of the LL and during the project. As such, during the formation of the multi-actor platform and the initial conversations with the candidate stakeholders, an inclusive environment where all genders are encouraged to participate is carefully supported, in cooperation with the stakeholders. During the development phase of the new CS, the participation of women will be encouraged, especially in the planned demonstration actions of the CS. Further, the business opportunities which will arise from the project, will be oriented towards openness and gender equality. In case of capacity development activities, these will be planned based, among others, on a gender criterion in the selection of participants, acting towards inclusion and against gender biases. These actions taken under the LL will be monitored by the leader of the LL as well as the WP1 leader of the I-CISK project.

a)



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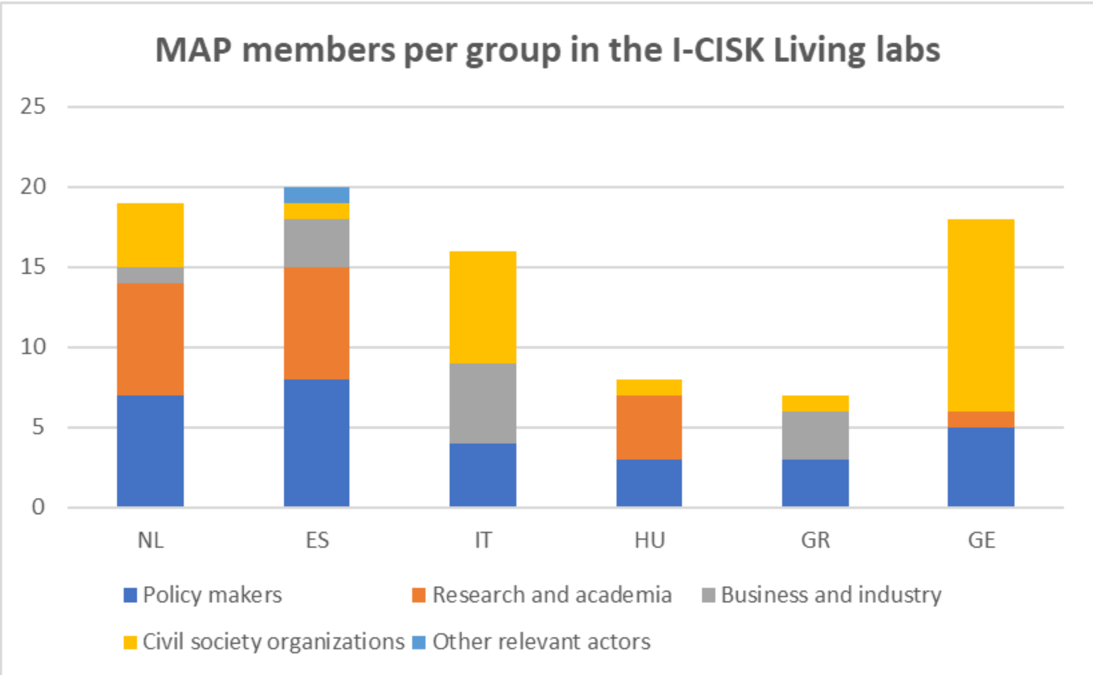

Figure 36. Key actor organizations represented in I-CISK Multi Actor Platforms: a) all I-CISK living labs; b) individual I-CISK living labs

7.1.1 Multi Actor Platform: Rijnland Delta, the Netherlands

The composition of the Rijnland Delta MAP is given in Table 6. The key actors voluntarily participating in this MAP represent policy makers and institutional actors (4 organizations), research and academia (2 organizations), business and industry (2 organizations), and civil society organizations (2 organizations). The core group of actors representing water management, tourism and agriculture sectors has already confirmed their participation in the MAP. The water board of Rijnland (Hoogheemraadschap van Rijnland) is the main stakeholder with highest level of interest and influence in the region. The water board sets policies and investments on climate change adaptation together with stakeholders in their area. The water board is responsible for the operation of regulating structures of the water system of Rijnland, and as such is the key actor to balance conflicting interests among stakeholders in the area, especially during drought periods. The water board works both short term (drought preparedness and management) and long term timescales (ranging from 5-year target water level agreements to 50 year plans taking into account climate change outlooks).

The Rijnland MAP platform is established with water board of Rijnland holding the coordinating role together with IHE Delft, the Netherlands. The communication with the potential members was carried out through emails, phone calls, online and face to face meetings (Figure 37). In total, nine organizations have agreed to participate in the MAP. The participating members are identified in most cases, and discussions are ongoing with those organizations who have confirmed their participation but still need to delegate staff to participate in the Rijnland MAP activities. The agreements of voluntary participation are confirmed through different means: email confirmation, verbal commitment, and signing the I-CISK MAP platform framework letter or I-CISK voluntary participation consent form. The composition of the MAP remains flexible, as more actors will be contacted in future who may also join the platform. For example, Rijkwaterstaat is an important stakeholder in the region who represents policy as well as operational water management at the national level. They also provide useful CS (e.g. hydrological information and forecasting). Similarly, the Royal Netherlands Meteorological Institute (KNMI) is an important climate service provider for the Netherlands including for the Rijnland Delta. These stakeholders will be contacted in coordination with the water board and their involvement in the project will be explored. At the very least, they will be kept informed about the project activities as part of I-CISK communication and dissemination activities. The details on the role and activities of the Rijnland MAP are currently under discussion and will be outlined in the coming months. For example, it is planned to at least have two meetings per year of the MAP members. These meetings will provide an opportunity to discuss the progress and way forward on participation in the I-CISK co-creation process. Additionally, the individual MAP members will be contacted to participate in different co-creation activities (e.g. surveys, workshops, participatory modelling sessions) during the project implementation period.

Table 6. Composition of the Multi Actor Platform: Rijnland Delta, the Netherlands

Actors involved in the MAP	Role	Sector	Climate value chain actor	# MAP members		
				ns	Male	Female
Policy makers						
Hoogheemraadschap van Rijnland (Water Board)	Water managemen and safety	Water	Provider/End-User		2	
The national Netherlands association for water sports South-Holland		Water / Leisure	End-User		1	
The national Netherlands association for water sports North-Holland-South		Water / Leisure	End-User		1	
Agricultural sector organization LTO Haarlemmermeer		Agriculture	End-User		3	
Research and academia						
IHE Delft	I-CISK, lead LL	Water	Purveyors		2	2
UVA	I-CISK, co-lead LL	Water	Purveyors			3
Bussiness and Industry (e.g. companys including consultancies)						
Horticultural farmers Rijnland	Horticulture (flower bulbs) production in Rijnland	Agriculture	End-User	tbc		
Tree nurseries Boskoop	Tree saplings production (drought sensitive)	Agriculture	End-User	1		
Civil society organizations						
Sail and motor boating clubs Spaarndam and Haarlem		Leisure	End-User		4	
Other relevant actors						

Note: ns refers to not specified.

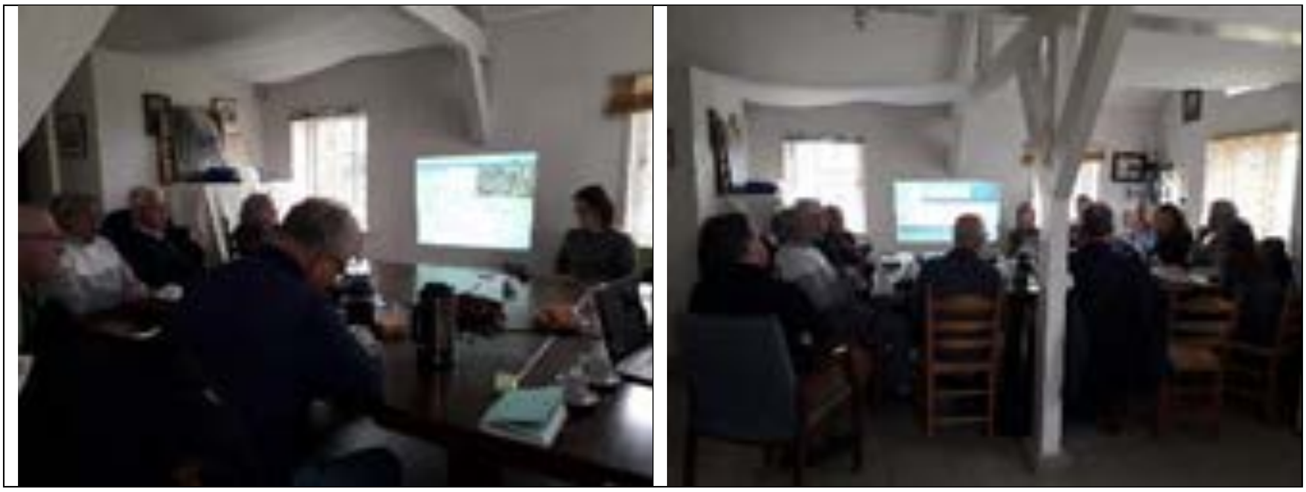

Figure 37. Meeting of key actors represented in the Multi Actor Platform in the Rijnland Living Lab held during April 2022

7.1.2 Multi Actor Platform: Andalucía, Spain

The Andalucía MAP is composed of members from 12 different organization (Table 7), representing policy makers (4 organizations), education community (1 organization), research and academia (3 organizations), business and industry (3 organizations), civil society organizations (1 organizations) and other relevant actors (1 organization). A series of online and face-to-face meetings were coordinated by the I-CISK LL leaders (UCM and CREAF) to establish the LL and associated MAP (Figure 38). The established MAP reflects the focus on the agricultural sector, both rainfed olive production and extensive livestock farming, and on the management of natural forested areas. An effort has been made to identify key actors in each of these sectors and in the production of CS with a particular focus on the management of drought risks, alongside the most relevant decision makers at the policy level.

The MAP actors have been divided into three categories in terms of their involvement in the co-creation process (Table 8):

1. High: Those who will actively participate in the MAP identifying necessary CS and participating in the co-creation process
2. Low: Those that will collaborate providing information and data and helping validate outputs.
3. Informal: Those that will participate informally without a written agreement.

The division has been made according to their representative role in each of the three primary sectors identified - agriculture, livestock farming and forestry and natural areas - and their availability to participate actively in the co-creation process. The latter responds as much to their interest in the project as to their position as family farmer, public sector employee or responsible for an organization that has representational or research duties as part of their job.

The format and the intensity of the involvement of stakeholders in project activities (workshops, surveys, participatory modelling, etc.) has not yet been discussed. In our first field visit in February 2022 several stakeholders agreed to sign commitment documents with I-CISK. However, all have asked for moderation and adequate time management to be able to participate within their time constraints. Based on this, we will modulate the intensity of stakeholder involvement according to the evolution of the project needs and requirements and the availability of the actors.

The MAP developed for this Living lab will follow the principles of RRI, which helps to fulfil the needs for both qualitative and ethically sound research projects. A key part of RRI is concerned with people's engagement and participation in the research process. During the process of building the map of actors engaged in the different living lab activities, the MAP team will actively seek to align both the process and its outcomes with the values, needs and expectations of local society, as well as to foster the design of inclusive and sustainable services. The profiles of people engaged will cover a broad range of fields of interest, ensuring transdisciplinary of the perspectives included in the outcomes produced. Profitable partnerships will be promoted, thanks to the networking activities in the Los Pedroches area, as well as with stakeholders engaged from other territories.

During the project implementation, the living lab team will ensure reporting and communication of results are shared with participants and each step is handled with transparency. The living lab team also will invest efforts to promote, share and make public the results of the project, increasing the chances of scientific results uptake and supporting the RRI principle for Open Access. Gender balance is also a key dimension of RRI, and equal participation of women and men will be carefully encouraged, in cooperation with the stakeholders. Furthermore, project activities developed in WP 2 towards the creation of "A prototype framework on co-creating end-user centered climate services" will provide monitoring and evaluation tools to ensure the highest standards of stakeholder interaction and engagement into the building of next-generation CS.

Table 7. Composition of the Multi Actor Platform: Andalucía, Spain

Actors involved in the MAP	Role	Sector	Climate services value chain actors	# MAP members		
				ns	Male	Female
Policy makers						
Guadalquivir River Basin authority	Water management and planning	Water	Provider/End-User		1	
Guadiana River Basin Authority	Water management and planning	Water	Provider/End-User		3	1
REDIAM (Environmental Information Network of Andalusia)	Environmental Information Network of Andalusia	Environment	Provider/Purveyor		1	
Sierra de Cardeña and Montoro Natural Park	Nature conservation park	Environment	End-User		1	1
Research and Academia						
CREAF	I-CISK partner, LL lead		Purveyor		1	2
UCM	I-CISK partner, LL lead		Purveyor			3
IFAPA – Instituto de investigación y formación agraria y pesquera	Agriculuture & Fisheries Research and Training centre	Agriculture	Purveyor			1
Business and Industry						
Cooperativa OLIPE	Farmers cooperative on olive production	Agriculture	End-User		1	
Cooperativa COVAP	Farmers cooperative on milk production	Agriculture	End-User		1	
Asociación ADROCHES para el Desarrollo Rural de la Comarca de Los Pedroches	Support development rural areas	Environment	End-User		1	
Civil society organizations						
WWF Spain	Environmental protection	Environment	End-User			1
Other relevant actors						
CCEFC (Centro de capacitación Centro de Capacitación y Experimentación Forestal de Cazorla)	Forest management Research and Training of Cazorla	Forestry	Purveyor		1	

Figure 38. Some snapshots taken during the field visits in February 2022 to Andalucía living lab region, Spain (Source: Broekman et al., 2022)

Table 8. The expected level of involvement of different actors in the co-creation activities, Andalucía LL, Spain

MAP Actors	Sector	Public/ private	Gender	Involvement	Confirmed	Role in CS production
Guadalquivir RBD	Water	Public	Male	High	Yes	Producer & consumer & decision maker
Guadiana RBD	Water	Public	Male	High	Yes	Producer & consumer & decision maker
REDIAM	Water / climate/ protected areas	Public	Male & female	High	Yes	Producer & consumer
Sierra de Cardeña and Montoro NP	Forestry and protected areas	Public	Male & female	High	Yes	decision maker
CCEFC	Forestry	Public	Male	High	Yes	decision maker
IFAPA	Agriculture and forestry	Public	Female	Undecided	Yes	Research & education
COVAP	Livestock	Private	Male	High	Yes	decision maker
OLIPE	Agriculture	Private	Male	High	Yes	decision maker
ADROCHES	Rural development	Private	Male	High	Yes	decision maker
MIO-1898	Livestock	Private	Male	Informal	Yes	decision maker
WWF	Environment	NGO	Female	Low	Yes	decision maker

(Source: Broekman et al., 2022)

7.1.3 Multi Actor Platform: Emilia-Romagna, Italy

The core group of actors participating in the Emilia-Romagna living lab and associated MAP are presented in Table 9. The MAP is composed of representatives of the main actors with interests in the Water sector for the selected study area, mainly represented by policy makers, business and industry, and civil society organizations. The regional government is represented by the *Directorate General for The Care of The Territory and The Environment, Service for The Protection and Remediation of Water, Air And Physical Agents* that, across the entire region, oversees the action of the regional government of water resources, towards a sustainable future. The Service defines guidelines and priorities for the planning and verification of the effectiveness of territorial water policies, with a focus on climate change (developing the Regional Water Protection Plan and contributing to District Management Plans) management and verification of water resources policies (by developing the regional Water Protection Plan and contributing to water resource management plans WRMPs). The main Regional multiutilities companies are well-represented in the Italian Living Lab, thanks to IRETI Spa that manages integrated water service in 242 municipalities of Emilia Romagna (provinces of Parma, Piacenza, and Reggio Emilia). Multiutilities are responsible for water exploitation from surface bodies, with a mandate to manage the withdrawals for human consumption and industrial usages as well. Land Reclamation and irrigation Consortia are the major actors in water provision to agriculture, an economic sector of major relevance in the region. The Burana Consortium, with more than 240’000 ha of territory and 50 municipalities is a crucial entity in flood risk management and planning, water resource management and irrigation. The *Emilia Centrale Consortium*, similarly, ensures the correct management and distribution of surface water for the protection and development of territory, including drainage of rainwater, through their channel systems, for the protection of the flatlands from flooding coming from upstream. During summer, the Consortium distributes water for irrigation and environmental purposes, to an area of ~120,000 hectares. They also manage the hydropower plant over the Castellarano Weir with an estimated average energy production of 6 GWh/year.

The private sector is also represented, by *Aren Electric Power*, a company active at national level in energy production using natural, renewable, and sustainable resources (wind, solar and hydro) for over 85 megawatts of installed power. In the LL area they manage the hydropower plant upstream of the Castellarano catchment (near the Regional monitoring station named "Lugo"), with installed capacity of 3.2 Mw and expected annual clean energy production around 11 GWh/year.

The *Regional Environmental Agency* ARPAE is another relevant actor in the water sector, maintaining the monitoring network, including hydrological and meteorological gauging stations, and producing climate projections for the regional government. The ARPAE representatives have consolidated experience in climate data production, analysis and in CS. ARPAE is involved in the Regional Observatory on climate change mentioned before. Finally, ARPAE is responsible for releasing and revising, when necessary, withdrawals permissions to all users.

Decision making processes in small rivers often follow complex pathways, being frequently focused on long term planning and policy making rather than changing operational management; more frequent shortages lead to "conflict" for water usage that shall nonetheless be managed even in the short term. In the case of irrigation for example providing irrigation advice through further downstream services directly to farmers and planning infrastructure investment through local CS; in the case of multiutilities tools for resilience towards climate change have been experimented. Most of the selected users have access to communication networks (including press releases and networking with twin services and organizations departments) that shall be explored to disseminate and communicate project results.

The co-creation process will happen thanks to the interaction and engagement with Stakeholders in the platform. At this early stage of interaction, it is nonetheless possible to identify key actors who will be involved in this process and outline the interaction. The Actors involved in the platform are spread through a wide set of stakeholders' groups, both collaborating and competing in the water resource allocation. According to EU public engagement in research and innovation policies RRI[6], the main goal of this interaction will be to foster multi-actor dialogues and exchanges, mutual understanding, co-creation of research and innovation outcomes, and providing input to policy agendas. All the users are quite familiar with the topic and share a common understanding of the problems and the possible triggers from CC on water resource availability. Also, a positive attitude towards innovation adoption (such a new CS) has been identified, although at a very varying level across actors; the public sector (with its role of policy maker and its double mission to provide water resource for users and to protect the environment) can be active in fostering adoption of CS in other sectors.

First contacts have been carried out in indirect (phone call, mail contacts) and direct (virtual and face to face meetings) ways (Figure 39). Moving on with the interaction, a structured approach towards co-creation will be applied in line with RRI. Thanks to the guidelines developed in the project (I-CISK WP2, MS10, 2022), it will be designed as a two-way process with feedback loops, so that the outcomes of the engagement processes are usefully fed back into the service development. As many of the stakeholders participate actively in other research projects on the water resource topic, in which the LL leader is also involved, joint initiatives may be a good opportunity to keep stakeholders engaged, build capacity and team attitude, and enlarge the platform.

Willingness and commitment of key actors to contribute in I-CISK activities has been reached through both formal (most Stakeholders from the beginning) and informal engagements (initial contacts to be tuned to

[6] https://ec.europa.eu/programmes/horizon2020/node/766

formal later on). Depending on each organization's way of working, a couple of representatives per organization were asked to ensure their presence and participation in the various events, including surveys, workshops, online and live meetings. All organizations actively participated in the first meeting, confirming their engagement in this way.

Interaction will proceed through indirect tools (particularly at this stage surveys, to start the co-creation process); more agile development methods and tools to feed the co-creation process are under development inside the project consortium, based on Lab leader and partners' previous experience online and live meetings (roughly twice a year). More complex type of interactions (such as serious gaming, training, and impact storytelling) are envisaged later, when co-development is in a mature stage.

It shall be noted finally that, besides obvious public functions played by Regional Government and Environmental Agency, also the final users (Multiutility and Consortium) are recognized by law to operate in the *public interest*, deploying essential services to final users (related in this Lab to water provision). They are thus provided with specific ethical rules that they strictly follow when dealing with third parties including R&D partners, despite being a player on the private market (as Multi-utilities companies), thus familiar with the necessities of for-profit entities as well. Furthermore, the regional government shows interest towards innovative CS for all water users, public and private, underlying the necessity for users to be equipped with advanced tools such as resource forecasting systems and CS in general, to demonstrate that they have made every effort for the optimal management of the withdrawal and support the strategies of water savings. This is a rewarding element in the event of conflicts for resource allocation during periods of scarcity and revisions of permissions in areas of water deficit.

All these elements set a favourable ground for agreeing on core values of the MAP during the Lab activities. Some examples are the resilience need towards climate change effect for the relative activities; trust towards the produced knowledge and the providers; flexibility; adaptability to user's needs and exploitation (openness of the solution up to the extent of Small Medium Enterprise needs, to make also commercial employment of results).

Table 9. Composition of the Multi Actor Platform: Emilia-Romagna, Italy

Actors involved in the MAP	Role	Sector	Climate services value chain actors	# MAP members		
				ns	Male	Female
Policy makers						
RER	Regional government	All	Provider/End-User		1	1
ARPAE	(Regional Environmental Agency	Environment	Provider/Purveyor		1	1
Research and Academia						
Business and Industry						
Gecosistema	I-CISK partner, LL lead	Water	Provider/Purveyor		2	1
AREN	Private energy company	Energy	Provider/End-User		2	
Civil society organizations						
IRETI	Multi-utility company (water exploitation)	Water	End-User			2
CB_Burana	Land reclamation authority - water provision to agriculture	Water	Provider/End-User		1	1
CB_Emilia Centrale	Land reclamation authority - water provision to agriculture, hydropower	Water	Provider/End-User		1	2
Other relevant actors						

Figure 39. Meeting of key actors represented in the Multi Actor Platform in the users meeting held in February 2022

7.1.4 Multi Actor Platform: Erzsébetváros, Budapest, Hungary

The MAP of Erzsébetváros, Budapest LL (Table 10) is formed by actors representing policy makers (2 organizations), academia and research (2 organizations) and civil society (1 organization and citizens). The most interested and influential stakeholder for this LL is the *Municipality of Erzsébetváros*. The municipality (and also the municipality of Budapest) prepared a climate strategy/action plan, that contains the actions that are necessary for climate mitigation and adaptation. An important part is the improvement of green infrastructure in the district (and in Budapest, especially in the inner parts), in public and private spaces. Although the establishment of green areas would be the main force in the adaptation to climate change and urban heat exposure, the district has limited space for increasing green infrastructure. The financial possibilities of the adaptation incentives are also limited. New green areas are generally created when a new building is established by a private investor. *The municipality of Budapest* has also developed a climate strategy/action plan, that contains the actions that are necessary for climate mitigation and adaptation.

The *National Public Health Institute* (OKI- Országos Közegészségügyi Intézet) is monitoring the health consequences of heatwaves and is also instrumental in the operation of the national heat alarm system. Heat alarms are issued when in three consecutive the daily average temperature is more than 25°C. They are not participating formally in the MAP, they rather expressed the desire to participate informally in the co-creation process by occasionally sending background information.

Eötvös Loránd University, Department of Meteorology, has great expertise in the field of urban heat exposure, the department had research projects on urban climate models and gathered data on urban surface temperature in Budapest. *Clean Air Action Group (*Levegő Munkacsoport) is a green NGO, that specialized in air quality and energy/climate issues, mostly functioning as think-tanks, consultants, and sometimes watchdogs. *The local population* in general considered the heat waves and the improvement of green areas the most important issue in climate change according to the survey conducted by the municipality. Despite the results of the survey the measures launched by the municipality to tackle the negative health effects of heatwaves (like cool buildings available for the people), were not generated significant interest among the local population.

In this LL, a special emphasis is given on the involvement of the needs and perspectives of women, as in this geographic region, they bear the responsibility of reproductive work, which means they are mainly responsible for care work: for children, for elderly. The MAP will serve to initiate a dialogue between decision-makers, NGOs, the research community, and the residents of Erzsébetváros, to foster multi-actor dialogue, mutual understanding of climate change and CS, and co-create research outputs for policy initiatives. The Municipality of Erzsébetváros, especially the Climate Cabinet, is going to be a main actor in the process as a decision-maker and policymaker in the field of urban heatwaves. After a meeting of with them and a couple of experts, the main areas were identified that can be of interest for the project concerning urban heatwaves/heat islands and CS. The MAP members will work on finding suitable ways to reach out to the members of the local population. For example, it is assumed that a snowball method can be followed in this context to identify other members of the public or local communities who can participate in the co-creation process. As a next step of the co-creation process, an online survey will be conducted among the residents, to test/modify the areas that were identified, foster multi-actor dialogue, and help mutual understanding of the topics around urban heatwaves. The survey is also aimed at finding stakeholders who can participate in the co-creation process.

Table 10. Composition of the Multi Actor Platform: Erzsébetváros, Budapest, Hungary

Actor	Role	Sector	Climate services value chain actors	# MAP members		
				ns	male	female
Policy makers						
Municipality of Erzsébetváros	Local authority	all	Provider/End-User		2	1
Municipality of Budapest	Local authority	all	Provider/End-User			
Research and Academia						
Ideas Science Ltd.	I-CISK partner, LL lead	Environment	Purveyor		1	2
Eötvös Loránd University (ELTE)	University	Environment	Purveyor			1
Business and Industry						
Civil society organizations						
Clean Air Group	ThinkTank - NGO focus on air&climate	Environment	Purveyor			1
Local residents	Advocating greener city for heat stress	All	End-User	tbc		
Other relevant actors						

7.1.5 Multi Actor Platform: Crete, Greece

Six different stakeholder groups form the MAP of the LL in Crete (Table 11), and represent policy makers (3 organizations), business and industry (2 organizations) and civil society (1 organization). The MAP comprises national and local authorities responsible for planning (policy makers), authorities responsible for implementing infrastructure projects as well as local business actors of various levels and different aiming. For example, the Greek National Tourism Organisation (http://www.gnto.gov.gr/) was founded in 1929. It is a body governed by public law, under the supervision of the Ministry of Tourism. Its main mission is to organise, develop and promote tourism in Greece by utilizing all the capabilities of the country. It aims to enhance the value of Greek tourism products, in collaboration with the tourism industry and all stakeholders in order to increase tourism revenue. The Organization for the Development of Crete S.A. (O.A.K. S.A., https://oakae.gr/). is a governmental organization with responsibilities, among others, to support the development of the countryside through projects and Community Initiatives with the aim of contributing to the development of the region of Crete. The Regional Development Company of Crete S.A. aims, among others, to support a managed, well planned, development of the tourism sector under high quality standards. Further, Elounda SA Hotels & Resorts is a tourism company which has received awards and distinctions and has established a strong brand in the luxury hotel industry. Elounda SA's CEO joins the MAP in that capacity as well as in the capacity of a member of the governing board of the Greek Tourism Confederation (SETE, NGO). SETE is an organization established in 1991, which represents the national unions of tourism enterprises, as well as individual businesses operating within the broader tourism industry and covering the entire range of the sector’s activities.

The six stakeholder groups represented in the Crete MAP have given their formal/written consent to participate in the activities of the MAP of the Crete LL and provide the necessary data regarding surveys, workshops, trainings, capacity development, role plays and/or participatory modelling. The expected meeting frequency which was discussed and agreed during the first MAP meeting is 3 to 5 meetings per year, as well as some supportive telephone or web communications when needed.

Table 11. Composition of the Multi Actor Platform: Crete, Greece

Actors involved in the MAP	Role	Sector	Climate services value chain actors	MAP members		
				ns	male	female
Policy makers						
The Greek National Tourism Organisation	Organize and promote tourism	Tourism	End-User			1
The Municipal Port Fund of Rethymno	Port authority	Port	End-User			1
The Organization for the Development of Crete S.A	Support development rural areas	Economic dev.	End-User		1	
Research and Academia						
Business and Industry						
The Regional Development Company of Crete S.A	Regional development	Economic dev.	End-User			1
EMVIS	I-CISK partner, LL Lead	Environment	Purveyor		2	
Civil society organizations						
Elounda SA Hotels & Resorts	Hotel group	Tourism	End-User		1	
Other relevant actors						

7.1.6 Multi Actor Platform: Alazani, Georgia

Fifteen different actor groups form the MAP of the Alazani River Basin Georgia (Table 12 and Figure 40): civil society (9 organizations), Policy makers (5 organizations) and research and academia (1 organization). Most of these actors represent agriculture, water management and environment sectors. For example, MEPA and NEA represent policy actors from the government side, and are mainly responsible for water management and environment besides providing CS. The main provider of CS in Georgia is the National Environmental Agency (NEA) of Ministry of Environment Protection and Agriculture of Georgia (MEPA). The Department of Hydrometeorology under the Agency mandated to provide meteorological and hydrological information and warning services to the government and public. Governmental structures at national, regional and local levels and public are most important customers for NEA. The agriculture sector users are represented by several civil society organizations such as Georgian Farmers' Association (GFA) and Association of Women Farmers. The environmental sector is represented by MEPA, NEA and CENN. Civil Society organizations are an important source of information for both citizens and government. They monitor government policies and actions and hold government accountable. One of the MAP members- the Regional Center for Sustainable Development and Kakheti Regional Development Foundation (KRDF) has a thematic expertise in climate and environment.

Development of the state policy in the sphere of water protection and use as well as the adoption of legislative acts concerning water use and protection and control is the responsibility of the Ministry of Environment Protection and Agriculture of Georgia. Implementation of water monitoring and assessment of the water quality of inland and coastal waters, as well as provision of meteorological and geo-morphological observations, and maintenance of respective records is the responsibility of the National Environment Agency of the Ministry of Environment Protection and Agriculture. The established MAP in Alazani will be the main driver of the co-production process proposed in the I-CISK project. The members will actively participate in the I-CISK activities, which will include regular meetings, workshops, conferences, surveys, demonstrations, knowledge sharing and capacity development. The MAP will meet at least 2 times per year. The capacity building activities will be organized based on identified needs.

Table 12. Composition of the Multi Actor Platform: Alazani River Basin, Georgia

Actors involved in the MAP	Role	Sector	Climate services value chain actors	# MAP members		
				ns	male	female
Policy makers						
Climate division of Ministry of Environmental Protection and Agriculture (MEPA)	Climate - Environmental governance	Environment	Provider		1	
National Environmental Agency (NEA) of MEPA	Environmental governance	Environment	Provider		1	
Regional Administration of Kakheti	Regional government	all	End-User			1
Tusheti Protected Lanscape managed by akhmeta municipality	Local environmental protection (municipal)	Environment	End-User		1	
Information Consultation Centre in Kakheti region	Information provider		Purveyor		1	
Research and Academia						
Lakob Gogebashvili Telavi State University	Research and education	Environment	Purveyor			1
Business and Industry						
Civil society organizations						
Kakheti Regional Development Foundation (KRDF)	Regional development	Economic dev.	Purveyor/End-User			1
Regional Center for Sustainable Development	Sustainable development regional	Economic dev.	Purveyor		1	
Akhmeta Innovation Centre, NGO "Kakheti"	Innovation	Innovation	Purveyor			1
Shepherds Association of Georgia	Sheperds association	Agriculture	End-User		1	
Georgian Farmers' Association (GFA)	Farmers' association	Agriculture	End-User		1	
Association of Women Farmers	Women rights advocacy in agriculture	Agriculture	End-User			1
Chaduna/Women Council	Women rights advocacy	Agriculture	End-User			1
Individual farmer	Farming	Agriculture	End-User			1
CENN	I-CISK partner, LL Lead	Environment	Purveyor		1	3
Other relevant actors						

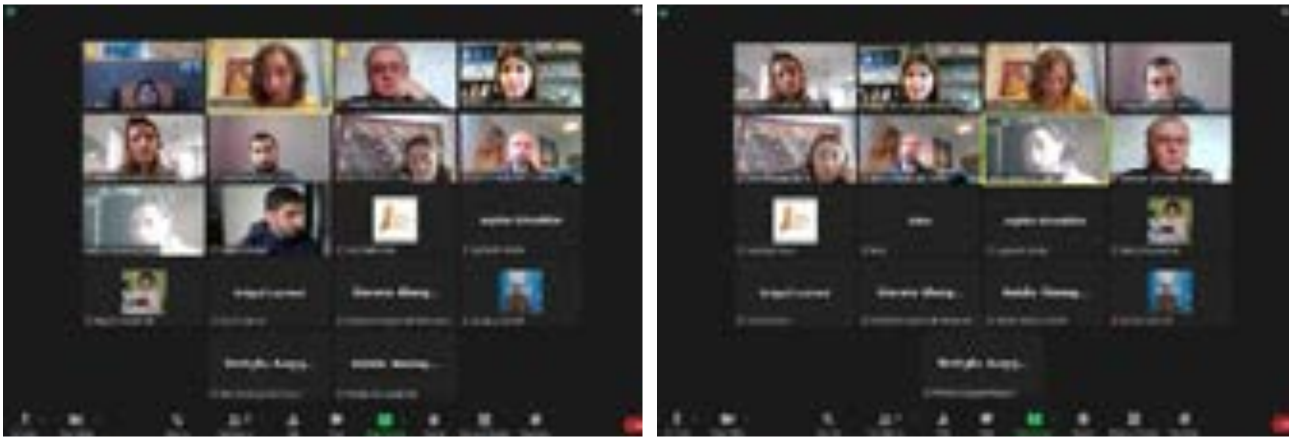

Figure 40. Some snapshots taken during the first online meeting with MAP, Alazani River Basin LL, Georgia

8 Innovating climate services in the I-CISK living labs

8.1 Climate services use and needs

This section is mainly based on the I-CISK Deliverable D2.1 – Preliminary Report: Climate Service Needs & Gaps (Moschini and Emerton, et al., 2022). A summary of currently available CS, barrier to effective use and CS needs is presented in Table 13. It is important to note that these are preliminary findings based on limited information available at this point in time. The information on CS use and needs will be updated during the course of the project following an iterative process. The established MAP will play an instrumental role in providing this information as part of the I-CISK's co-creation process.

Reflecting on the current situation, it can be stated that there are a number of CS available in the LL (Table 13). However, the use is limited and the available services do not reach their full potential value. There are a number of barriers to effective use such as lack of tailored information (e.g. to users and sectors), limited lead time, lack of access, unsuitability in terms of required spatial and temporal resolution, unreliability and uncertainty of the forecasts. There were specific needs identified in each LL, such as improved spatio-temporal resolution; sub-seasonal, seasonal and climate projections; multi hazard forecasting and early warning systems; and sector-tailored information. The needs will be further explored and prioritized in each LL, and through the proposed co-creation process, the next generation of CS will be developed.

8.2 Expected outcomes and impacts

Some of the expected outcomes and impacts of developing the innovative CS were also identified based on the initial discussions with the key actors involved in the co-creation process. These impacts are summarized in Table 13, and some of them are highlighted below, which could be applicable to most of the LL.

- Increased awareness of climate change and drought
- Multiple stakeholders transform their processes from reacting to drought to being proactive
- Better planning of agricultural strategies; reduction in agricultural production losses or increase in agricultural production
- Contributing to build a culture of proactive decision making, based on up-to-date evidence-based information and integrating scientific data
- Improved information on water availability leading to better water allocation decisions and reduced water shortages
- Strengthening of the adoption of European climate change policies
- improved information contributing to building resilience of society to multiple weather, climate and water related risks

Table 13. Overview of the types of CS currently available used in each LL, barriers to their use, and CS needs.

Living Lab	CS currently in use	Barriers to effective use	CS needs/ potential ambition under I-CISK	Expected outcomes and impact of providing needed climate service
The Netherlands	Drought monitoring system (including medium-range forecasts), streamflow predictions	Stakeholder engagement with CS and lack of tailored information, limited lead times	Longer timescales, including sub-seasonal, seasonal and climate projections, strengthen stakeholder engagement and communication	Increased awareness of climate change and drought; short to long term adaptation strategies by sector but also across multiple sectors
Spain	Climatological data, reservoir management support, seasonal forecasts, climate projections, forest fire risk management plans, climate scenarios viewer, drought monitoring, meteorological forecasts, river basin monitoring	Effective dissemination to target audiences, lack of tailored information, forecast uncertainty, insufficient spatio-temporal resolution, lack of access to historical data	Sector-tailored information (e.g. forecasts of rainfall patterns, seasonal distribution, start of summer and winter seasons), impact-based forecasts, improved spatio-temporal resolution, longer-range forecasts (sub-seasonal, seasonal and >6 months), historical data access	Reduced vulnerability to climate risks; strategies for sustainable management of agriculture and environment; improved information contributing to building resilience of society to multiple risks; counter rural exodus and abandoning of agricultural activities; contributing to build a culture of decision making, based on up-to-date evidence-based information and integrating scientific data; strengthen the adoption of European climate change policies.
Italy	Regional climate projections, historical and current hydro-meteorological observations, agriculture water demand forecasts	Forecasts aggregated at weekly timescales causes challenges for decision-making, data accessibility, lack of information on uncertainty and skill	Improved spatio-temporal resolution, integration of local data, river discharge forecasts, effectively communicated uncertainty information	Improved information on water availability leading to better water allocation decisions and reduced water shortages; better planning of agricultural and industrial activities; reduction in agricultural production losses
Hungary	CLMS Urban Atlas, green areas monitoring, biodiversity monitoring, historical global land surface temperature, meteorological data, air quality monitoring and information module	Lack of useful variables, limited information on potential of green infrastructure	Tailored CS and wider range of variables related to heatwaves, including health impacts	Improved knowledge on urban heat island exposure leading to improved adaptation policies; adaptive behaviour; decrease in heatwaves related deaths, illness, discomfort and economic loss
Greece	Weather forecasts, climate change impact assessments and vulnerability analysis, hindcasts, short-term forecast service for reservoir water quality and quantity	Current CC-scale CS focus on single sectors and lack cross-sectoral links, other CS are not tailored for sectoral use, accessibility for non-exert users	Sector-tailored information and sector-specific indicators, improved spatio-temporal resolution, hazard severity indicators, uncertainty and reliability information, compound hazard CS	Improved touristic planning contributing to change the seasonal character of the tourism product, and to diversify destinations and widen the spatial coverage of the touristic product in the Mediterranean; promote and support better informed and more agile, short term and long term, planning of tourism related policy and business activities; Climate information provided through I-CISK CS in Crete LL, directly contributes to improve water resources planning and water use efficiency (target SDG6–Clean water and sanitation).
Georgia	Meteorological observations, local knowledge, meteorological and hydrological forecasts, extreme event warnings & advice, agrometeorological bulletins, frost early warning service, seasonal outlooks, climate projections	Service discontinuity (CS produced on-demand rather than continuously) and lack of long-term national strategy for user-driven CS, language barriers for local decision-makers and end users	Multi-hazard early warning system, impact-based forecasts, maintenance and integration of observation network and data, sector-tailored information	facilitate planning and implementation of integrated management of the Alazani River basin based on the EU Water Framework Directive; improve the resilience of the local communities and economic sectors; increase the food production, improve access to the clean drinking and irrigation water, better exploit the renewable energy and in general, enhance the prosperity of the population; The new CS will provide a useful contribution to energy management decisions and relevant policymaking to achieve an optimal balancing of supply and demand, as well as to drive behavioural changes in energy saving.

(Source: adopted from Moschini and Emerton, et al., 2022)

The I-CISK project has a dedicated task on impact analysis (Task 1.3 under WP1), which will detail the impact assessment process, applying theory of change approach. Under Task 1.3, theory of change will be developed for each LL and also for the whole I-CISK project. Key components of the theory of change include identification and description of inputs, activities, outputs, and outcomes that lead to impacts. The implementation of a theory of change model will facilitate systematically monitoring the transformational process contributing to achieving the expected outcomes and impacts. The model will be based on carefully selected indicators and criteria, which will help to assess and monitor the project's expected impacts within the LL. Suitable indicators will be organized in the form of Key Performance Indicators (KPIs), which will better help to identify the changes happening to the LL, in relation to the co-development and application of the next generation CS, and will support the application of the Theory of Change model. A simplistic overview of the theory of change approach tailored to the LL in Hungary is presented below as an example (Figure 41), which provides a good base for further development.

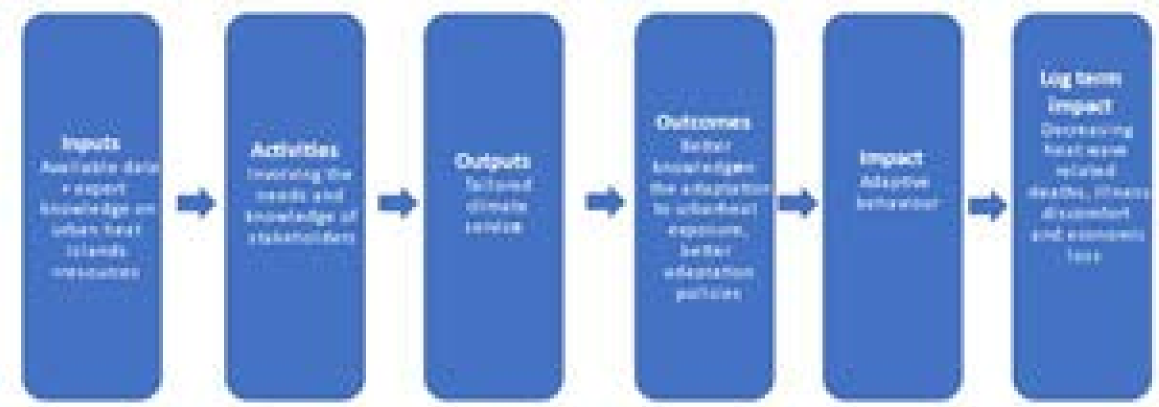

Figure 41. An example of potential elements of theory of change application in the Hungarian living lab

(Source: Bela et al., 2022)

8.3 Exploitation and Upscaling

As noted in the I-CISK project proposal, the project aims to generate several exploitable assets including pre-operational CS. At the end of I-CISK, in each LL a pre-operational CS will have been established that has been tested with partners, and which can be adopted for future use in the LL and potentially upscaled to similar regions and sectors. Business stories detailing the CS value proposition and viable business models appropriate to institutional and governance context will be developed to stimulate exploitation and upscaling.

The exploitation strategy will be developed under WP6 Task 6.4 'Exploitation strategies for end-user CS' during M12-46, which will be detailed in deliverable 6.7 'Exploitation and Sustainability plan' due in M46. This plan will also consider the exploitation opportunities of the individual project partners. Several pathways to maximize exploitation and ensure sustainability of project results will be developed by: (1) examining market potential and value proposition of Human Centred CS; (2) participating in CS Brokerage events; (3) actively engaging and contributing to existing Communities of Practice; and (4) capacity building and cross learning from the LL

Communication and dissemination have an important role in facilitating exploitation and upscaling process as outlined in I-CISK Communication and Dissemination Strategy and Plan (Kikvadze, 2022). For example, indirect Beneficiaries (Public/private organisations, businesses, NGOs, CS community, public/private CS developers etc.) will be addressed through specific exploitation and communication channels such as business sector publications and mini documentary videos. I-CISK will develop a set of publications addressing the water management, environment and forestry, agriculture and livestock, energy, tourism, and health sectors. These publications will address potential of upscaling the CS developed in the LL. The sectoral publications will be complemented by short documentary videos, directed at a non-specialist audience to convey the concept of human-centred CS and their impact potential. These "mini documentaries" will be based around storylines from selected LL, and will be especially attractive for sharing in social media, as well as in the Massive Open Online Course (MOOC). I-CISK's ambition is to develop at least 3 such mini documentary videos. In addition, a climate talk video (TEDx type) on CS and the co-production process to human-centred CS will be developed. These documentaries will serve to raise awareness of non-specialist audiences to convey the concept of human-centred CS and their impact potential. The LL have already started reflecting on possible avenues for exploitation and upscaling potential for the innovative CS to be developed under I-CISK. Some of these initial insights are summarized below.

Rijnland the Netherlands: When successful, the developed CS and the co-production approach can be upscaled to areas in the Rhine delta facing similar drought challenges, with the aim to contribute to climate adaptation in European, and ultimately world-wide, deltas. The Netherlands has 21 regional water authorities, such as Rijnland. Especially the neighboring water boards in the western part of the Netherlands often face similar challenges and may have an interest in taking-up the services ideas developed in Rijnland, for customisation to their own water board and regional actors.

Andalucia, Spain: The CS developed for Los Pedroches region will allow improvement of business and strategic planning in agriculture and forestry management in the face of adaptation to climate change, as well as improve the governance practices needed to sustain the transformation processes towards increased resilience. To facilitate the interpretation of available data as well as the integration of this information into protocols and planning exercises, a set of user-friendly tools and products will be developed and incorporated in online, GIS based applications. These innovative information formats will increase the exploitability of climate information for management both in the private sectors, such as farmers as well as for public administrations, such as municipalities or regional authorities. The opportunity offered by the I-CISK project to directly engage end-users will allow to gradually refine the scope and scale of the CS, resulting in increased exploitability of the results. In order to boost exploitation of the I-CISK CS produced, a tailored knowledge transfer program will be developed. Indeed, to ensure full understanding and enable the transmission of concepts and methods, it is key to increase awareness of the importance of the use of climate data for decision making in an inter-sectoral view.

Emilia-Romagna, Italy: Generalization is the key for results exploitation besides tailoring the new CS to local users' needs it is essential to reflect during the co-creation process on using resources and solutions that shall easily translate to other context and/or upscaled to wider areas. Also interacting with multiple Stakeholders means that each of them may have core interests in different areas. Showcasing is necessarily limited to a geographical area, but if during development attention is paid to replicability of the service this certainly will facilitate exploitation and upscaling to other contexts and users.

A realistic expectation is thus to create a Prototype that shows on one side a good degree of adaptation to local users' needs and data (in this case use of local data on water availability and withdrawals), but in the same way relies on upstream data to feed the service that is available also in other areas. For example, Figure 42 puts together the (local -ARPAE) river monitoring network with the (upstream) operational river discharge at coarse resolution from CDS forecast services. The same data are available both along Secchia river and Panaro river nearby, where some of the Stakeholders also have assets of interest; it shall thus be possible, in principle, to replicate the prototype in other areas.

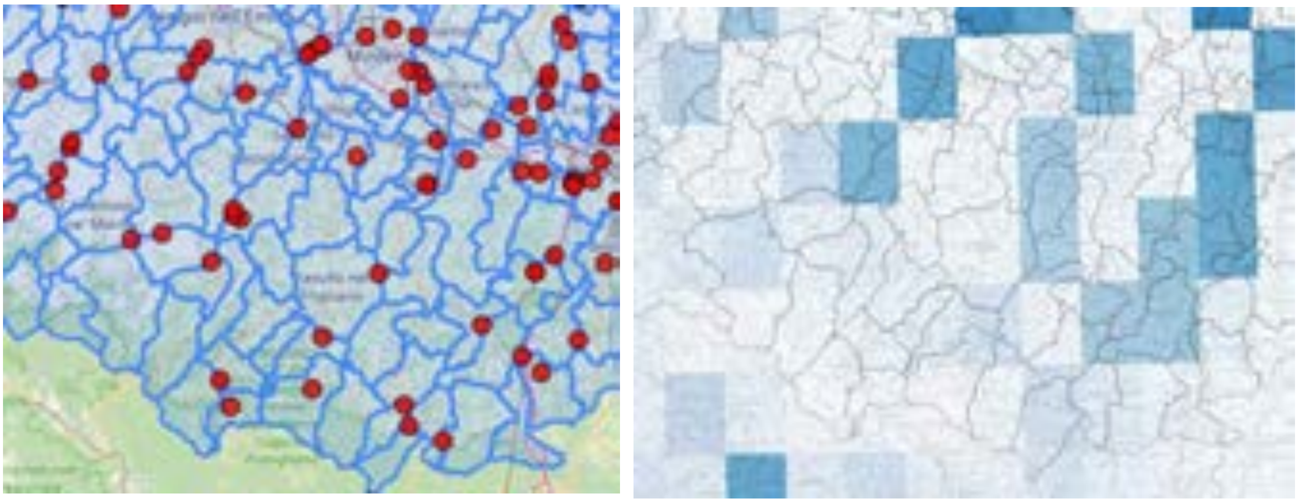

Figure 42 - local data from river stations (left) and upstream services output (CDS gridded forecasts, right) that could be used to foster upscaling and exploitation towards other contexts of the service prototype.

(Source: Mazzoli et al., 2022)

Crete, Greece: Crete LL is addressing the needs of a Mediterranean island in the tourism sector, in combination with related, cross-sectoral challenges such as the water availability, the energy needs and the infrastructure threats due to flooding events. Those needs and challenges are common to a large number of Mediterranean islands, within Greece but also in the wider Mediterranean area shared by the surrounding countries within and outside EU. However, they are not limited to island locations. The climate and land morphology have created the conditions for tourism development, mainly under the sun-sea-sand model, all around the coastal Mediterranean area. Common challenges are also arising in the scope of resources over-exploitation and climate change impacts. Therefore, the conditions which shape the tourism related challenges and the developed CS to address those challenges in the Crete LL, are the linkage which leverages the upscaling potential of this LL. On top of this, the cross-sectoral challenges identified, based on a water, energy and infrastructure nexus, make the developed CS relevant for a wider range of climatic challenges and, therefore, augmenting the upscaling potentials of the CSs. Adding to the above, the results of this LL could be easily transferred to other regions in Greece and beyond, based on easy-to-use products (e.g. mobile application) that provide access to climatic information and are connected to sustainable databases and established services from Copernicus and GEOSS.

8.4 Sustainability of climate services developed under I-CISK

Sustainability of I-CISK results highly depends on the project's ability to raise a clear demand for CS in the LL and beyond. The new CS and tools developed under I-CISK will have the capacity to become a reference CS/tool and information source for the planning and implementation authorities and actors, and become an integral part of these plans and procedures. These CS address a wide range of issues relating to climate change adaptation and mitigation. Therefore, they are directly linked to the application of a series of management, adaptation and development plans, national and regional, in the relevant thematic areas in the long-term. In general, the sustainability of I-CISK results will be ensured by making progress on the following core elements of sustainable use of the new CS. ***These key elements for sustainability include: (1)*** **Engagement with relevant**

actors in the co-creation process*; (2) business models for newly developed CS; (3) Capacity development; (3) Policy and institutional change; and (5) Networking and partnerships*

Engagement with relevant actors in the co-creation process: In all the LL, a core group of actors is involved in developing the new CS relevant for the required spatial and temporal scales and needs of the end-users. The diverse group of actors represent multiple actors representing policy makers, academia and research, business and industry, and civil society organizations who are an integral part of the CS value chain (e.g. as providers, purveyors and end-users). The engagement with relevant actors in the co-creation process will ensure ownership of the I-CISK results during and after the project. This is substantiated by two examples, from the Netherlands and Greece.

The CS to address drought issues in Rijnland Delta the Netherlands will be developed together with Rijnland water board, sector organizations and end-users representing tourism and agriculture sectors. The successful delivery of new CS has a high likelihood of sustained use by inclusion in the available portfolio of CS contributing to short and long-term decision-making process. For instance, there is the potential to incorporate the CS in the already ongoing information provisioning during the summer season, from Rijnland water board to the water tourism and agricultural sector representatives and individuals.

In case of the LL in Crete, Greece, the developed CS and accompanying tools are a product of co-planning and co-creation between climatic experts, knowledge purveyors (i.e. consultancies) who form a bridge between the experts and the end-users, and the stakeholders. During the co- creation phase, the participant stakeholders will be engaged in CS application, enabling them to acquire a better and deeper understanding of the climatic data available, their potential and limitations as well as the ways to incorporate them in their operations. The developed tools will facilitate this incorporation. The participant stakeholders in the Crete LL are representatives from their sectors, well connected and active. This enables them to act as a bridge and become themselves communicators of the knowledge acquired and the CSs developed during the implementation of I-CISK and their part in the LL.

Business models for newly developed climate service: The business models will be developed and promoted in each LL as well across LL and beyond. These business models will be underpinned by the impact stories and market analysis. The clear business objectives for addressing market needs will be formulated during the project implementation, which will consider: (i) the targeted problems the proposed services aim to solve, (ii) the current practices in place and the need for having an advanced solution to these problems, (iii) the proposed services and the advantages of I-CISK proposition compared to current management practices, (iv) the targeted users of the developed services, and (v) the benefits from adopting I-CISK CS. The business/impact stories will be documented to underpin the business models. Each LL will co-develop its own unique Business Story demonstrating the potential business opportunities. A strategy will be developed to carry out market communication, with key objectives as: (a) raise awareness about the offering, (b) promote a deeper understanding of the product, (c) generate interest in the product, (d) persuade a favourable attitude towards the product, (e) engage the audience into testing the product, and (f) convince the audience to adopt the product.

Moreover, to ensure long term provision of the climate service to potential users (and customers), analysis of the needed resources will be carried on (in the business model development phase). So far both hardware (cloud space, computing power) and human (maintenance and operationalization) resources can be envisaged as necessary for setting up the service in other contexts in the long term.

Capacity Development: To stimulate the development of the CS sector in Europe and internationally I-CISK will establish a comprehensive programme to build and strengthen the capacity of the CS sector in human-centred CS. This programme will be directed both at the capacities of the partners in the project and the stakeholders collaborating with the project in the LL, as well as the community of CS users from the public sector (e.g. NHMS, basin authorities, hydropower and irrigation companies, forestry managers, tourism and recreational agencies, municipal authorities) and CS researchers, developer and providers, including SMEs. Operational prototype, based also on previous experiences of stakeholders in developing and running CS, can be effectively used for training and capacity building sessions development towards Stakeholders and new potential users, for example organizing serious gaming sessions during the meetings.

The capacity developed programme will be developed around three key activities.

I. ***Facilitated cross-learning*** between the stakeholders in the LL and the project partners to benefit from the knowledge and experience across the multiple-sectors and the multiple hazards, time scales and institutional settings. Cross-learning events will be organised in conjunction with the project General Assemblies. The project will provide (limited) support to stakeholders to attend these events, which will also foster collaboration with the project partners other than those they directly work with.

II. **Climate Services Brokerage events** will be organised to provide opportunity for CS providers and users, both from the public and the private sector to explore the business potential of the outputs of I-CISK for developing CS to meet their needs and the opportunities these outputs may provide to CS developers and providers, in particular SMEs. We will organize these at key events that convene the CS community to attract broad participation, including annual Copernicus C3S and GEO events.

III. ***A Massive Open Online Course (MOOC)***. An online course will be developed, allowing unlimited and free participation, This will be developed on the outputs and outcomes of the project in co-producing human-centred CS from WP1, WP2, WP3, WP4 & WP5, and will build on the stakeholder experiences and stories developed in the LL. The MOOC will include filmed lectures, quizzes, and assignments, videos (developed by I-CISK) as well as interactive elements such as forum and links to the social media discussions (including those established by the project) and scientific publication (open access). The MOOC will be hosted on the IHE Delft Open Course Ware Platform, which will be linked from the project website. The MOOC will be advertised through various communication and dissemination channels including relevant networks of the consortium partners. For example, IHE has established MoU in Capacity building with UNFCCC and WMO and will use these to increase the outreach of the MOOC. Participants to the MOOC will be issued a certificate on completion.

Policy and institutional changes: The results of I-CISK will contribute to policy and institutional changes across multiple scales such as at local, national and EU levels. For example, the new CS will contribute to local and national strategies for climate change adaptation and mitigation in the LL regions. For example, in Spain, the new CS will contribute to the application of a series of management, adaptation and development plans, national and regional, in the relevant thematic areas, in line with the aims and scopes of the National Strategy for Adaptation to Climate Change (PNACC), which sets out the general objectives, guidelines and means for implementing a modern, effective and developmental adaptation strategy within the framework of the UN Convention on Climate Change and the EU Directives. Moreover, the living lab coordination team will engage the Andalusian Network for Environmental Information from the Department for Environment of the Andalusian Junta (REDIAM), as to streamline I-CISK outputs into the CS publicly provided. Furthermore, in this preliminary stage of the project it is foreseen that the regional authorities and the Guadiana and Guadalquivir river basins could be actors potentially interested in the sustainability of the co-developed CS that could be offered as a public service. There is a strong interest to amplify current climate change related aspects into water management planning exercises, confirmed as well by the European policies, underpinning I-CISK' efforts.

Networking and partnerships: The multiple stakeholder engagement within the LL arena, as well as with the local actors and members of the I-CISK consortium will support the establishment of partnerships at different scales (regional, national and international) through agriculture and/or forestry related networks focusing on innovation through knowledge sharing, thus contributing to target SDG17 – Partnerships for the goals. The LL will explore options to participate and where feasible join relevant networks such as European Network of LL (https://enoll.org/), Water Europe initiative (https://watereurope.eu/), and Green Deal Project Support Office established by EU commission to facilitate coordination and build synergies across 73 projects funded under the Green Deal Call. Moreover, I-CISK will contribute in building partnerships between EU region and beyond through the networks developed in the LL in Georgia and Southern Africa regioins. For example, in the *EU-Georgia Association Agreement* signed in 2014, the following is indicated: “the Parties shall develop and strengthen their cooperation on statistical issues, thereby contributing to the long-term objective of providing timely, internationally comparable and reliable statistical data.” Cooperation between the European Union and Georgia in this field aims to:

1. Further strengthen the capacity of the national statistical system, focusing on the sound legal basis, production of adequate data and metadata, dissemination policy and user friendliness, considering various groups of users, in particular public and private sectors, the academic community and other users;
2. Fine-tune data provision to the EU, considering the application of relevant international and European methodologies, including classifications. Collection of European statistical data is carried out through subdivisions of countries as defined by the Nomenclature of Territorial Units for Statistics standards describing several administrative levels (NUTS1, NUTS2, NUTS3) and Local Administrative Units (LAU1 and LAU2) in a descending order of size.

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