Climate Services 26 (2022) 100300

Contents lists available at ScienceDirect

Climate Services

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

Societal local and regional resiliency spurred by contextualized climate services: The role of culture in co-production

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ARTICLE INFO

Keywords:
Resilience
Sustainability
Climate services
Culture
Values
Risk perception
User needs
Europe
Asia

ABSTRACT

Climate information plays a foundational role in achieving a green recovery and climate neutrality in Europe, and a central one for a climate resilient Europe. This role can materialize if climate information is delivered appropriately and used effectively. Climate services, understood as the provision of climate information for use in decision making, have been created to provide climate information addressing these aspects. The utility of climate services is determined by the level of user engagement and co-design, employed during their development, while resource limitations for any of these aspects constrain their full potential. Co-design together with users is increasingly seen as a necessary good practice approach to provide efficient services that bring together supply and demand. In this paper, we focus on how climate services can contribute to climate neutrality by considering the cultural dimension of the users and their regions for whom specific climate services are co-designed. We specifically address dimensions of vulnerability and resilience to changing climatic conditions in five case studies worldwide while analysing the influence of culture on risk coping and enabling mechanism of key stakeholders and their needs for specific climate services in these regions. We found that user needs, desires and actions hinge on value prepositions formed by specific socio-cultural, climatic, spatial and bio-ecological contexts. Hence, when co-designing climate services, it is vital to understand users' needs, based on their values and experiences with climate and weather and to seek ways to influence, alter and change them.

Practical Implications

In order to allow a co-production of a particular climate service, which serves real needs of stakeholders in real world cases, a consistent and comprehensive understanding of the environmental, social and economic context of the case study need to be obtained together with the climatic parameters. It is therefore necessary to identify and analyze risk perceptions and their origins, vulnerability and adaptive capacity of stakeholders before starting with the development of any given climate service. A *Framework for Risks and Vulnerabilities Perception Analysis* can guide such information gathering to understand the demands of stakeholder and hence potential utilization of climate services. It particularly it helps to:

1. Provides background and context on the most relevant climate issues and impacts in a given case study;
2. Supports the identification of all relevant stakeholders in that case study and the collaboration with them;
3. Focuses on climate services which are sustainable, in line with the Sustainability Development Goals (SDG's) and of relevance to the needs of stakeholders;

Data to be obtained in such pre-investigations can be divided into

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https://doi.org/10.1016/j.cliser.2022.100300
Received 5 October 2021; Received in revised form 2 March 2022; Accepted 8 April 2022
Available online 21 April 2022

four broad categories:

- Context
- Water, weather and climate
- Governance
- Risk perception

In practice however, these data types will overlap. The data to be collected will also vary in format, from qualitative (e.g., text or scoring of predetermined criteria) to quantitative (statistical, numerical data) and spatial (e.g., maps) data. Data can for example be obtained through (1) desk research, (2) Consultation sessions, (3) Workshops, (4) semi-structured narrative interviews. They help to create a picture of the societal settings for which a climate service shall be produced and support to locate historical data on climatic impacts.

Through the application of this procedure policy makers and practitioners are able to understand concrete aspects of climate change risk management in relation to local and regional contexts and needs. Furthermore, it will enable to better understand needs and actions e.g., via climate services which hinge on the values formed by specific social and spatial contexts. Climate services must reflect such specific socio-cultural conditions in their respective ecological environments in order of being influential to the regions path on resiliency.

1. Introduction

The case for geo-physical and geo-ecological limitations of the Earth's resources have been recognized in the "planetary boundaries" rational (Rockström et al., 2009). The recognition of these boundaries has resulted in a complex web of policies and actions promoting sustainable futures for all people and presented in the form of the "United Nations (UN) 2030 agenda for sustainable development" and the sustainable development goals. The increasing exceedance of planetary boundaries of the earth system forms the basis for the sense of urgency which drives the change in behaviour of society towards sustainability. A key challenge is to understand how different contexts and cultures shape visions, needs and acceptance of solutions (Chabay, 2020) such as the application of climate services to support collective behavioural changes. Synthesised knowledge from more than 300 publications shows that culture is important for the aspirations of the Sustainable Development Goals (SDGs) (Zheng et al., 2021). However, and despite all the references to culture in the framework of the UN agenda for 2030, *culture* is not adequately reflected in the implementation of the SDGs. The concrete role and contribution of culture still needs to be systematically analysed (Austrian Commission for UNESCO, 2021), and its inclusion in the SDGs promoted, implemented and evaluated.

The rationale for this paper is to present empirical evidence of the role of culture for climate resilient transformation, and role of expert in supporting the inclusion of culture, notably in the co-design process of climate services. Climate services are understood as the generation, provision and contextualisation of data and information on the extent of climate change for managers, decision-makers at all levels of society. They are provided to support adaptation to climate change and variability in the world regions (Vaughan and Dessai, 2014). While there is consensus that culture matters for both transformation to sustainability in general, and risk management of climate change in particular, the knowledge about how it really matters is still under-explored and not generalized. This is owing to a large extent to the variations of cultural values and ambitions, their complex creation over time and space, and their expression in various socio-political and economic regimes of social groups and individuals (Adger et al., 2011; Brien and Wolf, 2010; Fresque-Baxter and Armitage, 2012; Barnes and Dove, 2015; Martinez, 2019). This paper aims to help closing this gap through empirical evidence of how cultural values are included in regional and local risk management and transformation processes.

As suggested in a recent paper on co-production (Norström et al., 2020), successful co-production of solutions to confront climate change or other similar challenges should be context-based, pluralistic, have clear, shared goals, and be interactive. Similarly, Clifford et al. (2020) argues that when designing climate services, it is vital to include a variety of user inputs, and to understand users' needs, based on their experiences with climate and weather. Such approaches can increase the salience, and thus the usefulness and effectiveness of climate services for their intended users. Since the effects of climate change are experienced where people live (local), many aspects related to exposure, sensitivity and adaptability e.g., of a community in a certain place are site- and context-specific. Societies and individuals construct their risk realities based on past experiences with (mis)managing risk, the magnitude of the perceived risk, and the familiarity with place-based hazardous situations. Additionally, political thinking, societal constellation and social capital play a key roles as cultural boundaries of risk understanding (Carmona et al., 2017) and transformation to resilient and sustainable systems. Therefore, culture is crucial to understanding vulnerability and resilience to climate change.

The aim of this paper is to explore the role of culture and cultural values in the development of climate services for local level application in five case study sites (termed "hubs"). The specific objectives of this paper are to examine: (1) how stakeholders for whom climate services shall be developed in the five hubs experience respond to climate change (2) what input do culturally determined narratives provide for a needs & vision analysis supportive of climate service development (3) the potential of culturally sensitive climate services to solve context-specific climate challenges (4) their potential to support transformation to greater resiliency.

This work was undertaken in the European Commission ERA4CS research project entitled INNOVA (Innovation in Climate Service Provision), which focused on the co-development of climate services for (peri-) urban areas (Swart et al., 2021). Five different "innovation hubs" were identified in different regions in Europe and European territories that were deemed vulnerable to the effects of climate change. The five hubs were: the Dutch city of Nijmegen; the Northern German coastal area of Kiel Bay; the Mediterranean coastal urban area of València, in Spain; the French West Indies islands, and the harbour metropolitan of Kaohsiung City in the Republic of Taiwan.

2. Methods and approach

To address these research objectives the research team discussed appropriate ways to gather diversity of bio-physical, climatic, spatial and socio-cultural data necessary to develop climate services. They are based on the following two concepts of culture and narratives.

2.1. Culture and its representations

Broad and narrow definitions of the concept of culture can be found in large numbers, with different emphases depending on the field of scientific research. Half a century ago Kroeber and Kluckhon collected over 100 different definitions of culture, systematized and analysed them coming to a widespread and shared definition that "Culture consists of patterns, explicit and implicit, of and for behaviour acquired and transmitted by symbols, constituting the distinctive achievements of human groups, including their embodiments in artefacts. The essential core of culture consists of traditional (i.e., historical derived and selected) ideas and especially their attached values. Culture systems may, on the one hand, be considered as products of action, on the other as conditioning elements of further action." (Kroeber and Kluckholm, 1952) More recent studies (e.g. Lemée et al., 2019; Fresque-Baxter and Armitage, 2012; Adger et al., 2011; Brien and Wolf, 2010) have emphasized that people' perception of climate change and hence their

actions are strongly influenced by the value they tribute to their surrounding environment (place), the level of risks they associate with the changes in their environment and the beliefs they hold about control and responsibility to adapt or to mitigate to its effects. Thus, cultural and ecological factors help to explain needs in order to handle impacts of climate change. Various authors discussed that preferences for measures against environmental threats, may differ between actors from different socio-cultural contexts, even if events occur under (almost) similar physical conditions (e.g., Douglas and Wildavsky, 1982; Thompson et al., 2003, Douglas et al., 2012; Martinez et al., 2012). It suggests a relationship between people and a particular local condition of human/nature relations, rather than what is conceived of as a 'purified' de-contextualized system of general/abstract formalities (Devie-Wright, 2013).

2.2. Narratives and its representations

Narratives are used in societies in various ways, e.g., as stories illustrating a plot or as imaginaries with symbolic expressions and typical characters (Jones and McBeth, 2010). Through such narratives people create meaning to explain events or circumstances but also use their past and present experiences to compile imagined futures (Niles, 1999; Fisher, 1984; Raadik-Cottrell, 2010) In addition, narratives are also used to actively try to shape a reality and thus can provide a catalyst for change (Sandercock, 2004; Baker, 2010; Rivera and Nanz, 2018). In the five INNOVA hubs we identified different narratives which evoked over time and space according to the specific interaction of stakeholders with possibilities and/ or constraints of physical existence, as determined, for example, by economic, political, geographical and historical circumstances in the regions they are based.

2.3. Framework for risks and vulnerabilities perception analysis (RVPA)

We applied the above explained concepts of culture and narratives by relating risk perception, knowledge and user needs to the cultural context in each hub to understand the underlying socio-cultural patterns that motivates for a specific climate service of a particular group of stakeholders. For this purpose, the research team firstly developed the RVPA to guide the collection of data in each case study site. Research activities were undertaken on two dimensions, i.e., in the hubs (geographically distributed case-studies with bio-physical, spatial and climatic aspects) and in a thematic work package related to culture and narratives. The hubs were the geographically bounded case-studies in the five countries. They served as "laboratories" where the research team experimented with climate services which were developed through the consultation with stakeholders. In each hub, specific local climate hazards, vulnerabilities and risks were explored, as is the governance, economic and socio-cultural conditions and requirements to produce a culturally sensitive climate service together with key stakeholders. Divided into four sections (1) context; (2) water, weather and climate; (3) risk perception; and (4) governance, the RVPA structured the collection of data to assess and explain dimensions of vulnerability and resilience in real-world contexts as a basis for the co-development of services to support transformation processes. Contextual information on the hubs were collected in the four categories of the framework (see Table 1).

As an interdisciplinary composed research teams INNOVA researcher applied multiple theoretical propositions, methods and knowledge based on different epistemologies. The team contained a proportional mix of researchers with backgrounds in natural sciences and engineering, social sciences and humanities. Based on various research team discussions lead by the project's coordinator the team developed the above described RVPA approach. The main purpose was to create understanding of the specific needs of the stakeholders in the different regions along various thematic lenses such as flood protection, management of water scarcity in agricultural regions and climate-proof urban planning.

The research team used a mixed-methods approach. This included a literature and policy review relevant to climate change adaptation programs, strategies and transformation processes, semi-structured, narrative interview, stakeholder workshops and focus group meetings. Throughout the INNOVA project, seventy-five semi-structured, narrative interviews took place in the five hubs and eight workshops and focus groups meetings, respectively one in Nijmegen, two in Eckernförde, two in Valencia, two in the French West Indies and one in Kaohsiung City. In addition to the interviews, workshops and focus groups meetings served as background information on socio-political, cultural and narrative expressions. They also provided a source for identification of further stakeholders to conduct interviews with. To understand backgrounds, motivations and rationales for the application and uptake of specific climate services, interview questions were developed which on the one hand targeted a specific stakeholder group and on the other hand took the larger societal picture into account by acknowledging views of socio-political and socio-economic importance. The interviewer allowed respondents to also tell their own stories in their own words. In general, in each hub a sample of stakeholders were identified encompassing regional and local authorities and companies, farmers, citizen, representatives of NGOs and scientists. The following stakeholder groups were especially targeted in each hub:

City of Nijmegen: Water Authorities and Planners, Scientists.
Kiel Bay: Coastal Authorities, Entrepreneurs, Citizen.
Valencia: Water Utility Companies, Authorities, Farmers.
French West Indies: Environmental Authorities, Farmers.
Kaohsiung City: Environmental Authorities, Farmers.

Interview questions (see supplementary table 3 were grouped in three categories: (1) Image of Nature & Sense of place; (2) Sense of Change & Environmental change in particular; (3) Risk Perception, Adaptive Capacity and Transformation. Three interrelated value bases (cultural identity, socio-economic values and vision) were found to be particularly relevant to the explanation and interpretation of risk behaviour, and in turn the *status quo* of resiliency of the people living and working in the hubs. These categories formed the framework to understand exposure, vulnerability, resilience, risk perceptions and demands for climate services according to the informant's cultural identity, beliefs and values. Through them the analysis focuses on the interplay between expressions of resilient futures in specific communal contexts, social identities and values of social groups from these communities as well as their perceptions of transformation towards a sustainable future.

3. Introduction of hubs

The five hubs demonstrate a range of bio-geographical diversity based on their location, i.e., coasts and islands, to mountains and plains in urban and peripheral settings. They also differed in terms of their cultural, institutional, political structures, and economies, and hence they portray how cultures—values, knowledge, beliefs underpinning actions from individual or institutional standpoints—shape local and regional responses to climate change, needs for climate services and support in turn resiliency (Fig. 1).

3.1. City of Nijmegen, Netherlands (INNOVA E-Zine 2018)

With nearly one third the country reclaimed land situated below sea-level (and protected behind dykes), the Dutch have had to rely on their ingenuity and determination to build and maintain the safety of a large part of their citizens. Given such challenging environmental conditions, it takes a collective societal effort to "keep water out of the country", which is why the centuries-old struggle against water is a feature of Dutch nationhood. In response to these enormous challenges, the Dutch worked out a series of measurements: Dikes, levees, gates, pumping stations or open areas designed to hold excess water. People in the

Table 1
Framework for Risks and Vulnerabilities Perception Analysis. Source: Louis Celliers, Grit Martinez, Maria Manez.

Category	No	Case study Parameter	Description	Type
1. Context	1.1	Summary	Narrative containing the rationale for selecting the hub, key ecological, social, political and economic features, national and sub-national administrative context etc.	Text
	1.2	Hub boundary	Absolute boundary, i.e., polygon indicating the proposed physical boundary of the INNOVA hub, as well as the rationale for the selected boundary.	Spatially explicit, polygon on a map plus a text description of the boundary
	1.3	Key features (a) Ecology and landscape (b) Social system including demography, administration etc. (c) Economic including key sectors and	Key ecological, social and economic features of the hub area described in No. 1.2 above	Text, spatially explicit layers e.g., land cover/use, administrative areas.
	1.4	Outlook	Stated environmental, social and financial outlook of the hub system. This is public domain knowledge as expressed in state of the environment reports, economic outlooks etc. What is the perceived future of the hub area and society?	Narrative
2. Water, weather and climate	2.1	Climate impacts (a) Hazards (b) Vulnerability (c) Risk	Description of the hazards, vulnerability and risks to which the hubs are subjected. What are the physical climate impacts causing vulnerability (social, ecological, economic), and the risks to the various elements of the hub?	Text, spatially explicit layers e.g., vulnerability indices, areas at risk etc.
	2.2	Realized risk	Provide key examples of how climate impacts described in 2.1 resulted in and/or contributed to the challenges described in 2.3. Refer to estimates of costs, damage, impacts etc.	Reports, publications etc.
	2.3	Problem statement	Specific problem or set of problems, brought on by the climate impacts above, and which INNOVA intends to address.	Narrative
	2.4	Sources of climate data and information	Map the hazards listed above to known and specific water, climate and weather data that is being used (pre-climate service data and information).	Data bases, reports, providers, etc.
	2.5	Existing climate services in use	A description of existing knowledge systems, or climate services, their use, uptake and origin. What are the recognizable knowledge systems that are being used for decision-making in relation to the problem statement in No. 2.3 above?	Reports, links
	2.6	Adaptation Planning and Implementation	What are the sector-based or multi-sector adaptation plans or response strategies relevant to the challenges defined in No. 2.3	Reports
3. Governance	3.1	Strategic societal and sectoral processes and plans	Key planning and operational processes which guide actions that may affect the adaptation to the climate impacts described.	Published and unpublished documents
	3.2	Societal goals	Identification and description of known societal goals, either from multi-sectoral development plans, or individual goals from sector plans.	Narratives
	3.3	Users and networks	A description and classification of users (public, private, civil etc.), institutions and stakeholders and their networks	Matrix of actors
4. Risk perception	4.1	Cultural background	INSTITUTIONAL: Description of political, societal and economic (environmental) worldviews, social identity and cultural commitments. PERSONAL: Description of world and environmental views, personal identity and sense of meaning, ancestry and personal exposure to environmental risk.	Narrative
	4.2	Socio-political backgrounds	INSTITUTIONAL: Social values, relations and trust, scientific knowledge, organizational constraints, economic and political structures. PERSONAL: Personal values and trust, personal knowledge, media influence	Narrative
	4.3	Cognitive-affective factors	INSTITUTIONAL: Risk perception, attitudes, risk management, perception and utilization of climate services. PERSONAL: Risk perception, personal beliefs, emotional affections, self-management and spontaneous actions.	Narrative

Netherlands always had good reasons to work together, in order to take collective responsibility for the financial means to design and build large-scale protective infrastructure. This process already began in the Middle Ages, when floods where a common occurrence in the Netherlands, killing thousands of people and reshaping the country. In the case of the "Room for the river Waal" project (Schut et al., 2010; Warner and Buuren, 2011), the intensive and substantive cooperation between designers, researchers, citizens and governmental bodies in Nijmegen also resulted in a renewed identity of the city, nowadays known as a flood safe and resilient place. In 2018, Nijmegen was selected "European Green Capital" of the year.

The municipality Nijmegen as University City traditionally has a green and innovative background. As a consequence, Nijmegen paid lots of attention in sustainable development throughout the last decades. It was a front runner, which culminated when Nijmegen was the "green EU capital" in 2018, based on its strong efforts on sustainability, green and liveability, based on public participation. So far Nijmegen traditionally has strong ambitions on transformations towards sustainability, as realized for the first time in the Waalsprong plans (Structuurplan Land over de Waal, 1996) and in sectoral environmental plans (Milieubeleidsplan). The "Room for the River Programme" emphasized a joint project along the river Waal bringing together the national government (responsible for the rivers system), the Water Board (responsible or regional water systems) and the municipalities (responsible for spatial planning and liveability). As a result of this multi-level collaboration numerous joint actions were executed to lower the rivers water levels, the "Mirror Waal Project" being one of them. In 2020 the new Nijmegen "Omgevingsvisie" ("Ambient View") was discussed which main goals are stronger participation of citizen's, entrepreneurs and businesses. The "Omgevingsvisie" aims to develop a new strategic vision on Nijmegen, integrating aspects of traditional spatial planning, and liveability with sustainability aspects such as energy transition and. Plans for housing and working areas along the Waal are in progress which coincide with long term river water level forecasts based on climate services. As a next

step Nijmegen works on integrating the old city centre, with the Lent Island and the Waalsprong center into one overall city centre of the future, including shopping areas, restaurants. Developments in the field of cultural manifestations, e.g., recreation and water sports are central strategic actions of the "Omgevingsvisie" (Fig. 2).

3.2. Bay of Kiel, Germany (INNOVA E-Zine 2018)

The Bay of Kiel is located in the southwestern Baltic Sea. Impacts of climate change and the consequences of human activities on the oceans are already clearly visible in the Baltic Sea. Some of the more serious changes already include an increase in serious storm floods, warming, acidification, eutrophication and a depletion of oxygen levels. These processes are more pronounced and faster in the Baltic Sea. While oceans had warmed by an average of 0.5 degrees Celsius over the past 30 years, measurements of the Baltic Sea over the same period indicated warming of around 1.5 degrees Celsius. Together with changing wind patterns, rising sea levels, and changing rainfall patterns, this can have impacts on the coastal areas. Expected impacts from these changes are an increasing erosion of the beaches, changes in the amount of beach wrack washed on shore, but also an increase in the tourism sector due to warmer air and water temperatures, and prolongation of the season in spring and autumn.

Kiel Bay contains smaller bays and inlets. Apart from the state capital Kiel, the coastline is mostly populated by smaller and middle-sized communities such as the town of Eckernförde. In its history Eckernförde has suffered severe damage from coastal storms (Kiecksee, 1973). It also has been a well-known spa and holiday resort for century's hence coastal tourism remains the main economic driver. For instance, in 2017, the coastal area of Kiel Bay area accounted for over 23 million overnight stays and days of stay (Kiel-Marketing, 2019). The quality of beaches is an essential factor for the decision of tourists to stay in the area. A negative tourist perception or beach experience has direct consequences for the local economy. Examples of such negative experiences includes the perception of pollution of the Baltic Sea, or the loss of the beach space due to erosion. Therefore, coastal managers of Baltic Sea communities strive to prevent or minimize possible adverse effects and perceptions.

For coastal communities, whose primary economic driver steams from the touristic sector, dealing with coastal risks has different aspects. The beaches have to be maintained for tourists, which can go against/threaten coastal protection efforts. Therefore, the coastal managers strive to prevent or minimize possible adverse effects. While rising temperature provide opportunities to increase the number of tourists and extend the touristic season, risks can arise when the quality of the beach will be impaired. For example, these impairments can arise from erosion of the beaches but also from changing amounts of beach wrack washed on shore (Mossbauer et al., 2012).

In the Bay of Kiel area, the appearance of beach wrack (a mixture of seagrass and algae) on the shores is irregular and seasonal, and depends on its growth and health under water, as well as wind and water movement in the Bay. During storms, which raises water levels, and strong wave action, seagrass and algae are torn off the seabed and washes up on the coasts. For example, between May and October 2017 approx. 4.900 tons of beach wrack were deposited on the shores of the German Baltic Sea coast. Once deposited on the shoreline, it is a very visible element of the beach. Other than the 'waste-like' appearance, the smell of decomposing organic material also pronounces it presence. Tourists often associates the appearance of breach wrack with low water quality, especially once it starts decomposing and smelling. In Eckernförde, plans are now under discussion on how to improve coastal defences. A practical solution tested recently by the community is the use of seagrass for building a natural dike made up of beach wrack. Helped by the knowledge that in the past beach wrack had played a major economic role for Baltic Sea communities, local authorities and scientists started a research project investigating forms of sustainable utilization of beach wrack. The use of beach wrack to create and stabilize dunes seemed promising in light of the different scenarios of rising sea levels and increased coastal erosion (Ahrendt, 2019; Packschies, 2019). Such beach wrack dunes could be vegetated with typical dune plants and serve as an inexpensive 'nature-based' coastal defence structure (Fig. 3).

3.3. City of Valencia, Spain (INNOVA E-Zine 2019)

The Valencia Region is located in a territory very vulnerable to climate change. Some of the main risks associated with climate change are general increase in temperatures, decrease in rainfall, aridification of the territory, rise in sea-level, emergence of new invasive species and new diseases and increased intensity of extreme events like heat waves and droughts (GVA, 2018). Sea-level raise and marine intrusion to the La Plana de València aquifer are also perceived as risks for agriculture located in the coast. The quality of the raw water is also affected by

Fig. 1. Location of Hubs. Source: https://www.innovaclimate.org/hubs/.

Fig. 2. Map of Nijmegen and its regional area.

floods, as content of solids and material that will react with the disinfectant will directly affect the efficacy of all disinfectants. Climate change has an impact on the quantitative and qualitative state of the available water resources on the Valencian region (Rubio-Martín et al., 2019, Llario-Sempere et al., 2019). This negative impact will suppose a technical and economical challenge for the company responsible of urban water purification. To anticipate the future requirements of the available water, and to prepare for the future scenario, scientific knowledge aims to estimate the quantitative and qualitative state of the future water to support a transformation to sustainable water utilization.

València is a city of 795,000 habitants, about 1,600,000 considering its surrounding towns and cities (INE, 2019). The city of Valencia, its metropolitan area within the Júcar River water resource system located in a semi-arid region that suffers from long and frequent droughts due to its Mediterranean climate. Extreme events typical of the Valencian region, such as droughts and floods have a very well-known negative effect on water quality (Hrdinka et al., 2012). The increasing frequency of these events demand a reaction of the companies and institutions responsible of the water treatment and supply. In addition, its touristic sector draws millions of visitors to the region every year. For that reason, predicting the impact of climate change on the water quality for the region is a critical topic for the future (Fig. 4).

Water-use in the Valencian region is intense, often competitive between landowners, and is a complex social, economic and ecological issue. Decisions on water management, allocation, are made at the highest political level. Other water-use stakeholders often do not accept norms and values of one party, e.g., decision-makers. Therefore, management changes and interventions are similarly complex, often disputed and rather slow. Hence, the authorities of València are challenged with establishing an equilibrium, which guarantees water supply to more than 1.6 million people in and around a city already affected by climate change while satisfying the demands for agricultural usage. However, when the focus is narrowed from the larger basin to specific uses and users, the actions of individuals can be managed for faster and appropriate changes to achieve sustainable water use. For example, València is famous for its historic Water Tribunal. Every Thursday at noon, since times immemorial, the tribunal meets at the Apostles' Gate of the Valencian Cathedral to decide on irrigation disputes. Praised by experts as a model of procedural law, the process for reconciliation of water disputes is rooted in a few simple ingredients: the judges hold local knowledge; their decisions are made promptly and transparently (vocally and publicly); they do not receive financial compensation; and the disputing parties incur no costs to be heard. Do these historical principles for irrigation management have potential to be applied to other water-management issues? The supply of potable water is managed at the municipal level (city administration) using basin-wide regulations and permits to distribute water. Over the past decade the company identified patterns of water consumption by its users which helped creating bottom-up approaches for changing citizen's behaviour and consumption of domestic water accomplished by incentives and education. (Martinez et al., 2018).

However, the predicted effect that climate change will have on the region and city of València has motivated the development of adaptation plans and strategies.

3.4. *French West Indies, France (INNOVA E-Zine 2019)*

The territory of the French West Indies (France) extends over the archipelago of Guadeloupe and the island of Martinique. It is part of the so-called 5th worldwide hot spot of biodiversity, and it is highly exposed to climate change. The main economic sectors of both islands are tourism, followed by agriculture. Moreover, farming remains historically, socially and culturally important to the identity of the islanders. About one-third of the land is occupied by crops which are highly sensitive to pests also influenced by the tropical climate. Building resilience to natural disasters and committing to the agro-ecological transition from mainly large commercial-scale monoculture (sugar and banana) to a better balance with more diverse and sustainable farming for local use are two main challenges in the French West Indies. Moreover, food sovereignty is one of the main issues as the islanders depend on more than 80% of imported food, generating, at the same time, a huge ecological footprint. Like other Caribbean islands, the French West Indies, are shaped by its colonial heritage. Today's economic structures are a legacy of the colonial era. Against this background, governmental support for an agro-ecological transition has emerged in the last decade. For example, a new legislative framework (Economic Development Scheme of Regional Communities) underlines the ambitions for a green economy, a shift away from the current monoculture to the production

Fig. 3. Map of Kiel Hub with the town of Eckernförde.

of crops and vegetables for local consumption and food sovereignty. Recent national policy (Loi d'Avenir on Agriculture and Food: 2014, and the strategic plan for the agro-ecological transition in Guadeloupe carried by the Territorial Collectively and acted upon in November 2020) is supporting diversification towards multifunctional agriculture, focusing on small-scale family farming as a possible vector for agricultural development in light of the challenges of the 21st century, such as adaptation to climate change, food sovereignty, agro-ecological and bio-economic transition. In addition, grass root initiatives promoting small-scale farming/urban gardening are currently spreading over the islands. This could open up new, fairer opportunities for agricultural production and consumption for the Creole and non-Creole population in the French West Indies under the changes new climate regime dictating to seasonality, timing and volume of rainfall.

Key planning and operational processes which guide actions that may affect the adaptation of the climate impacts are slowly evoking. For instance, at the initiative of regional councils, regional plans being currently developed such as schemes on "Climate, Air, Energy" aiming to strengthen actions around mitigation and adaptation to the impacts of climate change, land management defining guidelines for sustainable development, land development and environmental protection or green growth program based on a roadmap for agro-ecological transition (Fig. 5).

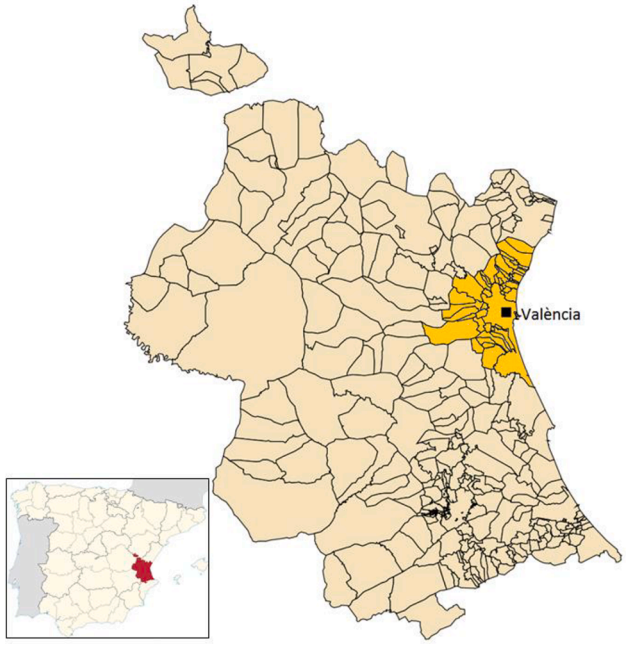

Fig. 4. City of Valencia and its metropolitan area.

3.5. *Kaohsiung City, Taiwan (INNOVA E-Zine 2020)*

Kaohsiung City is a centre for industries in the south and is one of the three major cities in Taiwan. With its rapid expansion and development, Kaohsiung as a heavy industry city is faced with problems such as air pollution, river pollution, groundwater pollution, traffic congestion, and overcrowding of buildings. In addition to traditional industries and agriculture, tourism has also become an emerging industry of Kaohsiung City. Under the impact of climate change, the city will face more complex disasters, such as heat waves, cold waves, floods, droughts, and other extreme weather events. Days of huge downpours starting e.g., in 2018 inflicted damage on leafy vegetables. High temperatures and frequent rainfall in summer are unfavourable conditions to grow leafy vegetables. However, during winter from the end of 2018 to the beginning of 2019, the weather was abnormally warm. Kaohsiung was also in the middle of a dry spell at that time, and the amount of rain was only 20% of that in the same period last year. Droughts damaged local agriculture, and the agricultural loss reached NT$74 million. Crops affected included major high-value crops, such as lychees and green-gages. The government had to provide cash relief for natural disasters on agriculture and loans with low-interest rate to help farmers overcome this disaster. On the other hand, if there is not enough rain between May and October, which is the rainy season in Taiwan, farmers planting rice in the first season of the flowing year will face water shortages. In addition, the water resource will be restricted if reservoirs are at low water levels. The government will first prohibit farmlands which need over 70% of water resource from irrigating. Farmers will have no choice but to fallow their farmlands due to a lack of water for irrigation, stopping production activities and affecting their income.

The metropolitan area in Kaohsiung is brimming with concrete buildings, with all kinds of asphalt roads crisscrossing in the city. In addition, local people usually move around using motor vehicles, and internal combustion engines emit waste heat. Furthermore, since Kaohsiung is located in a tropical area, households frequently use air conditioners, which also emit waste heat. Therefore, the average temperature in the metropolitan area is usually higher than the surrounding suburban districts, which leads to a more intense heat island effect. The hot and humid environment in Kaohsiung makes it easy for mosquitos that transmit dengue fever.

Recently, the city government has been building detention basins to solve flooding issues during typhoons. Fifteen detention basins have been constructed so far, with two more expected to be completed at the end of 2019. In addition, the municipal government has established the Green Building Autonomy Regulations, stipulating that plants should be planted on roofs and water reservoirs collecting rainwater should be established as well, so buildings can also serve as micro detention basins by absorbing rainwater. This is a city-led initiative on green buildings to work with private sectors and citizens from the city. A subsidiary policy was also initiated in 2016. So far, the area of greenified buildings has reached 350,000 square meters. Planting vegetation on buildings can not only preserve water, but also help lower the temperature of buildings, lessening the heat island effect.

Furthermore, different departments in the government are now implementing a series of measures with citizens to restore wetlands and mangroves to what they were before industrialization and urbanization. Combined with reservoirs, aqueducts and farmlands, these wetlands and mangroves will form a vast wetland environment, presenting an "ecological corridor", a place for a wide variety of species to live, in order to restore ecological diversity. So far, the city has constructed 21 wetlands, with a total land area of more than 1,000 ha. Each wetland has its characteristics and functions (Fig. 6).Fig 7.

4. Results from semi-structured interviews

Interview responses were grouped in three categories (Image of nature & Sense of place; Sense of change & Environmental change in particular; Risk perception & Adaptive capacity) to understand exposure, vulnerability, resilience, risk perceptions and demands for climate services according to the informant's cultural identity, beliefs and values. Through these categories the interplay between expressions of visions of aspects of resilient futures in specific community and the social identities and values of social groups from these communities as well as their potential for transformation towards sustainable futures became visible shaping the development of particular climate services. Table 2 captures quotations from the interviews (highlighted in italics) which are meant to be representative, illustrating the principal direction of expressions.

4.1. Image of nature & sense of place

One of the most commonly expressed justifications for being concerned about the environment in which the interviewees live, in particular and 'nature' in general, is that it forms part of the identity of personal life and economic activities. The interviews revealed that informants across all hubs were motivated by a diversity of values, ranging from the conviction that "nature has a right in itself", to the idea that "nature exists for human utility" and as the "provider of economic livelihood". Most of the informants thought of nature as being sensitive to intervention despite having a genuine resilience.

The represented samples of Tables 2–4 illustrate that these interviewees had a clear model of interdependencies in nature. They had already observed that our changing climate is causing significant changes that are connected to their personal life and economic circumstances. The main changes for these interviewees in the five locations are connected to floods, storm surges and droughts affecting water quality, agricultural production and human safety. They also had a clear model of interdependencies in nature as they observed that our changing climate is causing significant changes that are connected to their personal life and economic circumstances. The main changes for the interviewees in the five locations are connected to floods, storm surges and droughts affecting water quality, agricultural production and human safety. Naturally, risk perception across the case studies differ according to the special circumstances. While in the French West Indies (hurricanes, earth wakes, tsunamis, volcanic eruptions and massive pollution) risks seems to be perceived widely and across all levels of societal life, in other cases risks are rather associated with specific topics such as floods or droughts. Interviewees confirmed the application of a variety of adaptation strategies. They range from early stages of the assessment of impacts of climate change (e.g., on the agricultural sector in the French West Indies) to visions of dikes made of beach wrack in the case of the Baltic Sea region. In the region of Valencia, profound adaptation studies to the already extensively researched climate risks are on its way and in the Dutch city of Nijmegen new perspectives for investigations in risks that are newer to the Dutch such as droughts are on the horizon.

5. Discussion

Communalities and differences of the hubs and the implications for "climate services"

Climate change is a global environmental threat which manifests in different ways in the world regions. Nonetheless, it has taken a similar path although with specific variations in all cases studied. It is apparent in the increase in high-impact extreme weather events such as storm surges, sea-level rises, flash floods, heavy rain, increase of water pollution due to ocean warming, droughts with its effects on water availability, biodiversity, species etc.

Communalities

The economies in all the hubs have already been suffering or are likely to do so in the future, but with some variations. For instance, businesses, tourism and security of residents in shore areas (Hubs: Kiel Bay, community Eckernförde; French West Indies) are affected by damage resulting from climate extremes and ecological problems, and both inland and shore case studies show a decrease in options for making a living. Tourism holds a prominent position in most of the case studies. A comparison suggests that travel and leisure activities are expected to be most vulnerable to climate change because of their direct dependence on weather conditions. Tourism based on a particular climate element (e.g., sunshine), location (e.g., beach areas), or a physical characteristic (e.g., built-up infrastructure) is particularly at risk (Hubs: Kiel Bay, community Eckernförde; French West Indies, Valencia, Nijmegen).

The crucial role which state and public administration plays in all cases is evident although the extent to which administrations are taking actions seems to depend on a variety of factors. In the case of the

Fig. 5. Map of FWI.

Fig. 6. Map of Kaohsiung (Source: TUBS, CC BY-SA 3.0, via Wikimedia Commons).

Fig. 7. Five-hubs-in-adaptation-cycle-diagram. Source: https://www.innovaclimate.org.

Netherlands (Hub: Nijmegen) for instance, experiences with and traditions of handling the risk of flooding are clearly above average, they are deeply rooted societal habits as well as participatory planning processes involving civil societies which had been necessary for centuries to secure the survival of the country against the forces of water. The case from Germany (Hub: Kiel Bay, community Eckernförde) equally demonstrates an advanced development of participatory planning processes grounded in development trajectories which not only contribute to a culture of trust in climate science but also in firm beliefs administrations in environmental policies and action programs of (Bray and Martinez, 2011). The vast experience with management of water scarcity is also deeply engrained in societal memory as demonstrated in the case of Spain (Hub: Valencia) and hence led to pronounced program around the distribution of water. On the other hand, the hubs in the French West Indies and Taiwan (Kaohsiung City) rather indicate an absence of long-established traditions of handling environmental risks and fully developed administrative environmental and risk management programs. However, in the last decade both countries as evidenced by the hub description have seen improvements. It is obvious that municipalities, regardless of their size, political and economic strength, need a robust legal decision-making framework, and a clear implementation strategy. Hence, commitment at the local level to address climate change seems to depend mainly on a broader, possibly national, level in each of the cases. Considering these observations, several factors could be identified that facilitate and hinder the transition process in the hubs such as risk perception at local, regional and national levels; the degree of public investment in risk management; the level of community coherence; or the duration of a tradition of living in a challenging environment including the level of risk exposure.

Table 2
Examples of "images of nature" and "sense of place" expressed by respondents (n = 75) of semi-structured interviews, workshops and focus groups on cultural values and climate change in the INNOVA project.

Hub	Image of Nature	Sense of Place
The French West Indies	"For me nature is tolerant. In French we have a name, nature is resilient, yes…. Nature is resilient, but the action of humans can make it difficult to return in the resilient state, so I think we have a level here of the human action where nature has difficulties to return in the resilient state." (Interview, March 2017)	"I would say a splendid environmental potential, but people have you know degraded a lot of some places, but the potential is marvellous, and we have beautiful landscapes and the positive thing about Guadeloupe is that we have all of the lesser Antilles in the archipelago." (Interview, March 2017)
Kiel Bay (community Eckernförde)	"I think "sensitive nature" comes closest. All the effects of the hole in the ozone layer, pollution, climate change will be felt by future generations." (Interview, May 2018)	"Eckernförde is a place at the Baltic Sea Bay and in the fjord a very varied landscape. So, here you have the Baltic Sea, various coastal sections, beach and coast, very dense agricultural areas, moors, etc. everything basically to reach by bike. Quite different from for example the North Sea coast where you have a lot of flat land and dikes and a North Sea that is not always there. Well, here everything is always there." (Interview, May 2018)
Valencia	"Every intervention affects the original status quo, so I think nature is ephemeral." (Interview, April 2018)	"The city of Valencia is surrounded by what is known as the "Valencian orchard" or "l'Horta", an agricultural landscape with deep cultural significance." (Interview, April 2018)
The city of Nijmegen	"We as Dutch know that our natural system is very sensitive to changes, especially from rising sea levels." (Interview, January 2018)	"We need to live with the water instead of mastering it…however, this does not mean we cannot enjoy it." (Interview, January 2018)
Kaohsiung City	"Yuhebau is a type of lychee, named 'Jade Purse', and it is sensitive to the natural environment around it, especially temperature. The flowering of lychee requires cold temperature roughly 17 degrees Celsius and optimally for four weeks." (Interview, November 2019)	"Dashu is the biggest area for lychee yields in Taiwan, with size of 2500 ha. The main reason why net houses are used in Dashu is because the farmers are mostly old and if the net houses could reduce the pesticides use and workload, as well as increase the yields, then this might be able to attract more young farmers to come back here for farming." (Interview, November 2019)

Differences

Despite the above classified communalities between some hubs, differences amongst them are equally important to notice as they path the way for better understanding of the specific cultural conditionalities leading to a certain demand for adaptation and mitigation actions as in the case of the INNOVA project climate services. Climate services were initially developed to hand over to the public the vast amounts of

Table 3
Examples of "sense of change" and "sense of environmental change" expressed by respondents (n = 75) of semi-structured interviews, workshops and focus groups on cultural values and climate change in the INNOVA project.

Hub	Sense of Change	Sense of Environmental Changes
French West Indies	"I have noticed changes for the time I've been here. I also know how it was before, because of my family, my family history, I see that it has been many changes from the social, how can I say this, life in society. It changed for example, before, for the last 30 years, people were really linked, family was important in the society for example, and the neighbourhood was important. Now it has been changed. Therefore, this is one important change within the society here. (Interview, March 2017)	"We have real problems with our quality of water, soil and air… you know we have these issues of chlordecone. Also, the degradation of our terrestrial or submarine land and the endangerment of our biodiversity… "(Interview, March 2017) "And we also speak a lot about climate change, because some people who were here forty years before who were little, who were kids at that time, used to go to one point of the island by walking but now this specific point is in the sea. So, it is not possible to walk there anymore. So there has been some changes, and some really important changes, yes of course." (Interview, March 2017)
Kiel Bay (community Eckernförde)	"There's a lot of things there. So, there are a lot of areas that were drained in the past. What has become worse is that the inhabited areas themselves have been built more densely and also not necessarily more beautifully built. In recent times there has been a tendency towards graveling and concreting gardens. So that's an absolute counterpart to what I've been fighting for the past 30 years and that's sometimes quite frustrating." (Interview, May 2018)	"In the area of the natural conditions a predicted sea level rise which has already had a strong impact because the coastal breaks have intensified here and coasts have got more in motion, so it seems at least as it was the case earlier, also because storms come at other times from other directions, so the system of coastal development is a bit in upheaval here." (Interview, May 2018)
Valencia	"For example, when I was a child Valencia was a dirty city with many pollution…all the traffic from eh north to the south of Europe and Africa came across the city of Valencia…and there were no many water treatment plans—the river Turia was grey and it smelled so bad….I think from the 1990ths on many policies of the city changed and as a result the city is much more green today." (Interview, April 2018)	"The most important are the water issue… Many policies we are trying to do are helping the environment, but they don't have in the background a good social project." (Interview, April 2018)
The city of Nijmegen	"We took a lot of time to understand what the river wants, how it works and changes…This was a very interesting, insightful dialogue." (Interview, January 2018)	"The attitude of people and the city towards climate change increased a lot over the last years. Hopefully the stamina of the people can be used for other important issues such as mobility and energy…" (Interview, January 2018)
Kaohsiung City	"The ability to foresee the future changes in the market is very important for researching new crops. For example, no one predicted the change in the family sizes and very low birth-rate nowadays and therefore picked the crops for quantity, but not for quality." (Interview, November 2019)	"The lychee yields could cover 80–90% of the market share and therefore is a representative product. The yearly lychee yields used to be roughly 20,000 tons and it is to be distributed and consumed in 2–3 weeks on the market. Later, due to climate change, the warming of winter significantly reduced the yields and therefore the farmers started to worry and reconsider whether lychee should be the main crops." (Interview, January 2020)

projection and climate data to support mitigation and adaptation actions. However, the differences in perceptions, values, knowledge and skills of users worldwide made it difficult to provide just THE climate service (Swart et al., 2021). In addition, the framing of climate services according to the needs of users are paramount for the utilization and uptake of them. Amongst the five hubs there are also several fundament differences which are in the following part discussed along the main axis of the RVPA and explained by their cultural developments (Table 5 culturally sensitive climate services).

Water, weather, climate/governance/risk perception

The most obvious differences amongst the hubs are the exposure to climatic changes which can be divided into two broad groups: (1) Water born (e.g., flooding, erosion) and (2) temperature/precipitation born (e.g., droughts, water scarcity and increase in surface and water temperatures). Secondly, the existing knowledge systems and hence positioning in the adaptation cycle to handle climatic changes and their impacts can be also clustered in two groups: (1) Beginning level (French West Indies and Kaohsiung City) and (2) advanced, well advanced and matured (Eckernförde/Bay of Kiel, Valencia and Nijmegen). While in the French West Indies and Kaohsiung City sector-based or multi-sector adaptation plans or response strategies relevant to climate challenges are only very recently being developed and party implemented, in the other three hubs (Eckernförde/Bay of Kiel, Valencia and Nijmegen) these are clearly advanced due to the long lasting exposure to risks such as flooding (Eckernförde/ Bay of Kiel and Nijmegen) and droughts (Valencia) as well as the from this circumstances developed broad sensitivity leading to governmental, non-governmental and citizen initiated policies, programs and activities to mitigate and/ or adapt. In the Netherlands, a country which lies 50% below sea level, for centuries land was wrested from the water. This is a vital part of the Dutch identity and hence programs such as "giving room to the river" are directly coupled with a strong developed risk perception and culture to act. Likewise, in Germany (Eckernförde/Bay of Kiel) the cultural memory of storm surges is very high. For example, even more than 150 years of the devastating Baltic Sea storm surge of 1872, the water levels are still used as design criteria for coastal protection (Hofstede and Probst, 2002), memory marks are placed along the entire German Baltic coastline and as result of the 1872 storm surge coastal protection became part of the state duties (Martinez et al., 2020). Finally, in Valencia availability and accessibility of water has been always a principal issue in the region for irrigation and human consumption alike. For the 1.6 million city dwellers of Valencia sufficient quantity and quality of potable water is a major concern nowadays where climate projections forecast an increase in dryer and hotter seasons.

On the contrary, although the French West Indies and Kaohsiung City frequently experienced hazards such as strong tropical cyclones in the winter season (French West Indies) and extreme weather events such as typhoons or heavy rain (Kaohsiung City), the adaptive capacity as an indication of adaptation and mitigation policies, regulations and activities are rather less developed. However, both hubs are in the initial phase to prepare for climate change adaptation and learns to mainstream adaptation measures in the policy planning and implementation.

In the five INNOVA hubs different bio-physical, spatial, climatic and socio-cultural developments produced special needs of stakeholder groups documented in Table 5 (The needs for culturally sensitive climate services).

The climate services co-developed within the INNOVA project reflect the special local demand brought onto the surface by the RVPA, the interviews and workshops and the background research. In all project hubs culture, language and terminology associated with the specific environmental challenges were seen as of importance to understand which specific climate information is needed and how it should be framed and produced to integrate climate risk management effectively into the broader development process in general and the climate service in particular (SWART et al., 2021). Thus, specific climate services being co-developed with stakeholders in the five hubs are presented in Table 6.

Table 4
Examples of risk perception and adaptive capacity expressed by respondents (n = 75) of semi-structured interviews, workshops and focus groups on cultural values and climate change in the INNOVA project.

Hub	Risk perception	Adaptive capacity
French West Indies	"I think we are at risk, because we have a lot of risks here. So, we live with risks, everything." (Interview, March 2017)	"There is an assessment for trying to re-establish small agriculture which allows farmers to live on their work and to increase their self-sufficiency but it's not so easy… One reason it is that we are here living like our parents. Therefore, people are not very ready to consume local produce. Sometimes they say we must consume because there is revivification [sic] of African culture. Nevertheless, at the same time they are European. It is known that the three first years of people are very important to give the preference in matter of food. So, if you give European products to young children, you will have a problem". (Interview, February 2017)
Kiel Bay (community Eckernförde)	"Stronger storms, increased flooding, increased coastal erosion (beaches). This is already very noticeable at our beaches." (Interview, May 2018)	"The most beautiful thing would be, of course, if we could use all the sea grass that floats here directly on the beach. If we find a system not only in small sections like we have now to install the sand with the sand and leave there, but that really all the quantities that accumulate just as groynes or whatever can obstruct, it is coastal protection, so you have to know that with every load of sea grass that is removed, a lot of beach sand is also removed. It doesn't all come back after processing when it's sifted through. So, you constantly lose sand and seaweed that stays on the beach and also raises the beach up and leads to even more on it and eventually it decomposes. So, we have to find the possibility to leave it on the beach, but this is not disturbing the bathers. If you can really do this in the foreseeable future but I did not give up the hope that you really don't have to leave anything." (Interview, May 2018)
Valencia	"Climate change is a major concern for regional and local administration on the Valencian region. However, the main risks and vulnerabilities are profoundly studied … So, the focus is now shifting towards the best adaptation strategies available for the region." (Interview, April 2018)	"Water consumption is a priority. So, restriction policies are applied when the droughts plan affects supply. If agricultural use needs to be restricted, maybe temporarily, it is established in the droughts plan. In the supply of Valencia, for example, policies for a reduced consumption are covered, but they are general aspects." (Interview, IMPREX project 2016)
The city of Nijmegen	"Water problems are the business-as-usual issues in the Netherlands…but e.g., health issues due to higher temperatures are less a focus yet." (Interview, January 2018)	"The Mirror Waal can be seen as a typical Dutch approach, rooted in centuries of guiding and fighting the rivers…. Individuals (e.g., a strong mayor and engaged citizens) played an important role in the process. The Room for the River Project was not just about climate change. It is also solving our regular river water problem." (Interview, January 2018)
Kaohsiung City	"We would like to aim for two directions to reduce and avoid risks and disasters. For reducing risks and disasters, to invest in infrastructure to help farmers for the irrigation, resilience and information communication. For avoiding risks and disasters, to experiment to find the new crops to be prone to extremes like droughts and floods. These are worth us considering." (Interview, January 2020)	"New crops could provide more variety for future opportunities and markets. For example, to adapt to future climate change and market, new crops are researched and developed." (Interview, January 2020)

As a result of the INNOVA project, in the **French West Indies**, decision makers are starting to prepare the ground for adaptation to climate change by assessing risks and vulnerabilities. The specific vulnerability of the agricultural sectors to the impacts of droughts and changing seasonality coupled with the culturally sensitive topic of food sovereignty is currently developing into an agroecological transition. Hence, building a knowledge repository to store, search and visualize various pieces of information and knowledge about the impact of climate change on agriculture processes on the islands became a meaningful solution to facilitate local understanding of the climate, to support climate-related risk assessment and to deliver pieces of knowledge extracted from a local repository to develop a climate service. In the **Bay of Kiel**, where local authorities and citizens are keen to transform the burden of marine waste (beach wrack) into a gain benefiting the tourism industry and costal protection alike, predictions about prolongation of the beach season in light of climate change and hence the potential financial investments needed to remove beach wrack from the shores are vital information. They support decision-makers on their path towards neat solutions for re-usage of marine waste while identifying further adaptation options. In **Valencia**, an area plagued by drought, there is an urgent need to support the equitable distribution of portable water to users while at the same time encouraging water savings and responsible consumption of domestic water. The climate service developed will support this fundamental objective. The company responsible for the water supply in Valencia combines this service with local knowledge, to improve decision making and to support the implementation of its decisions. It is to be hoped that these two factors, which were conceptually "borrowed" from the activities of the Water Tribunal, will assist urban water supply in a different future climate. In the city of **Nijmegen**, climate-related data on the Rhine River discharge was a vital component in making the decision to move the former Waal dike and construct an ancillary channel in the flood plains; to develop a robust 'climate diké along the river Waal in a recent urban development that transforms former working and harbour into residential areas and to integrate climate adaptation in the Nijmegen strategic 2040 vision. The approach is out rolled and further developed in other Dutch municipalities and regions. Finally, in **Kaohsiung City**, the public sectors are mainstreaming climate change adaptation in their policy and practice to co-identify the problems and co-develop the solutions together with the local stakeholders, including young farmers and agricultural co-operatives.

6. Conclusion

The aim of this paper was to explore the role of cultural values in the development of climate services for local level application in five hubs placed in different world regions. We found that understanding the socio-cultural construction of user realities, their risk perception and their knowledge and to make use of it, is important to make progress with both development, acceptability and utilization of climate services. The INNOVA project supports growing evidence, that users are not only the consumers of products and services, but they co-design these services because they have exclusive information about their own needs, knowledge and the way they want solutions. We categorized users according to key stakeholder groups in each hub we were developing the climate service with and for. This helped us to contextualize our

Table 5
The needs for culturally sensitive climate services.

Hub	Climate Service
French West Indies	In the French West Indies (FWI), consulted stakeholders (agricultural authorities and farmers) expressed a vision rooted in the socio-cultural identity of the so-called "creole garden" being a synonym for sovereign agricultural production. Quotes such"There is an assessment for trying to re-establish small agriculture which allows farmers to live on their work and to increase their self-sufficiency…" (Table 4, FWI, Adaptive capacity) are a representative for illustration of such cultural narrations and visions. In the French overseas departments Guadeloupe and Martinique, most of the groceries consumed at the islands are still imported from France. Moreover, the current large commercial-scale monoculture is vulnerable to the effects of climate change. Thus, climate services are being understood as highly supportive for development of a self-sufficient diverse agricultural production. Against this background, regional government supports an agro-ecological transition away from the current monoculture (i.e., sugarcane (for rum production) and banana, mainly exported to the French market to the production of crops and vegetables for local consumption and food sovereignty. Based on values and expressions offered during interviews and workshops key stakeholders from authorities (e.g., agronomy research institutes as INRAE, regional chamber of agriculture, and farmers) it became evident that a web application predicting crop vulnerability regarding future climate trends in terms would be beneficial to stakeholders in the agricultural sector connected to the narrative of the "creole garden".
Kiel Bay (community Eckernförde)	For coastal communities, whose primary economic driver steams from the touristic sector, climate change induced risks are severe if they keep away coastal visitors. Therefore, coastal managers strive to prevent or minimize possible adverse effects such as changing amounts of beach wrack washed on shores since its texture is seen as less esthetic and tend to keep visitors away from the beach. In the past, seagrass was a major source of income for coastal communities as it was used to produce matrices, packaging material or insulation for houses. However, half a century ago, the utilization was gradually displaced from the markets. During the interviews and workshops with coastal authorities, entrepreneurs and citizen it became evident that reviving this tradition could save costs in dealing with the unwanted amounts of beach wrack washed to the shores. Thus, the socio-cultural and economic values and visions of these stakeholders lead to the development of a climate service addressing the aspect of alterations in the amounts of beach wrack washed to the shores in a changing climate. Quotations such as "The most beautiful thing would be, of course, if we could use all the sea grass that floats here directly on the beach", "…We have to find the possibility to leave it on the beach …. "are exemplary for the idea developed by authorities and the community of Eckernförde to manage beach wrack in a manner that helps protecting shorelines while not conflicting with touristic desires. (Table 4, Eckernförde, Adaptive capacity)
Valencia	Availability and accessibility of water has been always a concern in the region of Valencia for irrigation and human consumption alike. For the 1.6 million city dwellers of Valencia sufficient quantity and quality of potable water is a major concern especially at current where climate projections forecast an increase in dryer and hotter seasons. In Spain, potable water supply is managed at the municipal level. In Valencia, the Júcar River Basin Authority grants the concessions to distribute water to the municipality. During interviews with water utility companies, water managers, local administrations and farmers the necessity to managing water resources wisely has been frequently mentioned as on the one hand a traditional cultural habit especially with regards to irrigation pattern in the region od Valencia and on the other hand an economic necessity demanding behavioral changes in water consumption patterns, e.g. public consultations with the city dwellers of Valencia based on their consumption patterns. During droughts in the region of Valencia, water quality problems are frequently experienced. The concentration of organic and an-organic particles in the water sources is increasing, thus making the treatment of water costly. Knowing the amount of the water resources available to purify in advance of a drought is thus important for the water planning and management authorities and thus lead to the development of a climate service that helps to support assessment of the climate change effect on raw (untreated) water available in the Valencia region in terms of both quality and quantity and allows to search the best strategies to treat and manage this resource. Quotations such as "Water consumption is a priority. So, restriction policies are applied when the droughts plan affects supply. If agricultural use needs to be restricted, maybe temporarily, it is established in the droughts plan." (Table 4, Valencia, Adaptive Capacity)
The city of Nijmegen	For centuries, the Dutch have erected dikes to protect the country from the water of the river Rhein. Whenever the feeling prevailed that the protection was not adequate, they were raised and modernized. Recently new measures such as changing the course of rivers are also being discussed and implemented e.g., in the city of Nijmegen. In interviews and workshops with authorities, engineers and landscape architects these experts expressed that climate-related data and other information were a vital component in making the decision to move the former Waal dike and construct an ancillary channel in the flood plains. Nevertheless, they also emphasized that, the story behind the data is more important than the data itself. Understanding the perspectives and needs to enable innovative solutions requires situational and problem analysis that take cognizance of the interests of different stakeholder groups. Initiated by the national government, the execution of Nijmegen's "Room for the River" program was a community-led process in which local desires for water safety met national mandates for coupling flood protection with spatial quality. Also, data and other information unfolded their powerful forces only on the grounds of historically grown convictions and entrepreneurial visions. Tourism and recreational businesses emerged from the "Room for the River" program. Since the Dutch have demonstrated the ability to stay ahead of their river flood problems thanks to deep understanding of the specific spatial conditions of the country and its socio-cultural context, the interviewees expressed the need for climate services which offer a spatial urban planning approach that is based on knowledge of the natural landscape system. The developed climate service became thus combination of both climate projections to help with the risk of flooding but also allowing the outlook to other so far non-typical risks such as droughts. It thus supports climate adaptation strategies and measures at all relevant levels of scale. The quotation "The Mirror Waal can be seen as a typical Dutch approach, rooted in centuries of guiding and fighting the rivers…. the "Room for the River Project" was not just about climate change. It is also solving our regular river water problem." represents a common vision related to the success of the recent strategy "living with water" instead of "fighting it". (Table 4, Nijmegen, Adaptive Capacity)
Kaohsiung City	Currently, Kaohsiung City is leading an initiative on greenified by planting vegetation on buildings, restore wetlands and mangroves as preventive risk measures to the effects of climate change. During the workshop with municipal agricultural authorities and local farmers the need for climate projection on temperatures especially in the winter terms became evident.The culturally narrative in Kaohsiung City is based on the very deeply rooted traditional knowledge about crops. With this knowledge local stakeholders were able to express their demands on conversation issues but also their willingness to invest in suitable changes for more climate resistant crops with key stakeholders such as municipal agricultural bureau, insurance industries and research institutes. The mutual consultation process helped to raise awareness for the needs to find new crops prone to altered seasonal temperatures. The climate service developed reflected this need by providing climate projections and systems analysis. Quotations such as: "For avoiding risks and disasters, to experiment to find the new crops to be prone to extremes like droughts and floods. These are worth us considering." represent vision and desires alike (Table 4, Kaohsiung City, Adaptive Capacity).

departing point for the development and analysis of the existing knowledge and aspirations. The analysis of the users' perception on the risk, they are facing and the cultural values and vision they have for confronting this risk allowed us better to understand the setting in which the climate service will be used and finally to develop the specific climate service in collaboration with the specific stakeholder group. In relation to the four research objectives - (1) how stakeholders for whom climate services shall be developed in the five hubs experience and respond to climate change (2) what input do culturally determined narratives provide for a needs & vision analysis supportive of climate service development (3) the potential of culturally sensitive climate services to solve context-specific climate challenges and (4) their

Table 6
Climate Services developed for each hub.

Hub	Climate Service	Target Group
French West Indies	The climate service, as a web application, provides support for decision making in agriculture in relation to climate change in the typical Caribbean Island of Guadeloupe. It addresses crop vulnerability regarding future trends in terms of drought risks. It uses a geographic information system, and it displays risk rates as projections for a given future year and each agricultural plot in the island.	Agronomy research institute as INRAE, regional chamber of agriculture, local decision makers in agriculture, farmers.
Kiel Bay (community Eckernförde)	The climate service is a guiding document addressing the aspect of beach wrack in a changing climate. It addresses the different impacts of climate change that could influence the amount and composition of beach wrack. Additionally, it also presents aspects of using beach wrack in relation to circular economy leading to a wise management of beach wrack.	The Kiel Bay /Eckernförde coastal community, coastal/beach managers (key users), including entrepreneurs working with beach wrack, locals and tourists.
Valencia	Assessment of the climate change effect on the raw —untreated— water available in the Valencia region in terms of both quality and quantity. It supports the search for the best strategies to treat and manage this resource.	Water utility companies, water managers and regional/local administrations.
The city of Nijmegen	The developed climate service is a combination of both climate projections to help with the risk of flooding but also allowing the outlook to other so far non-typical risks such as droughts. It thus supports climate adaptation strategies and measures at all relevant levels of scale (Van Rooij et al., 2021).	Regional and municipal administrations and water boards, scientists, planners and landscape architects.
Kaohsiung City	Tailor-made climate information is provided: climate projection on temperature in winter until 2100. Furthermore, an analysis of system dynamics based on interviews with all stakeholders showing interrelations of environmental, socio-economic, climatic variables.	Lychee farmers, local farmers coops, municipal agricultural bureau, insurance industries, research institutes.

potential to support transformation to greater sustainability. We found (1) that all stakeholder groups in the five hubs are concerned about the effects of climate change but have different degrees of knowledge and routine dealing with them according to their socio-cultural-political, bio-physical, geographic and climatic contexts; (2) that their culture understood as (traditional) ideas and attached values (Kroeber and Kluckholm, 1952) are encapsulated in particular narratives such as "The Creole garden" (French West Indies), "Marine waste is a treasure" (Kiel Bay), "Fair water disputes lead to sustainable water management" (Valencia), "Living with water secures our future" (Nijmegen), and "Agricultural adaptation to extreme temperatures is our path to the future" (Kaohsiung). These narratives fulfil two crucial functions: Firstly, they structure, prioritize, and ascribe meaning to experiences and beliefs and secondly, they facilitate sense making and decision making in highly complex social-ecological systems by representing core values and ideas; (3) that producing culturally sensitive climate services helps to solve context-specific climate challenges and (4) giving that mitigation and adaptation actions are taken in accordance with stakeholders needs, they are contributing to the potential to support transformation to greater resiliency.

Although the impetus for contextualized user centered needs of climate services is gaining momentum, attempts to put this into practice often remain unsatisfactory. There is also a lack of standardization in how to contextualize climate services (e.g., the types of questions to ask, types of information to collect, stakeholders to co-produce with). This means the results of attempts to contextualize climate services are scarce and difficult to compare, and suggests a lack of clear, shared goals and interactivity. It would therefore be pertinent to establish a set of principles for effective contextualization of climate services approaches as they are possible important to guide transformations to sustainability. The paper tried to contribute to closing this gap but also likes to propose a research project that aims to develop and evaluate a set of standardized principles for co-producing contextualized culturally sensitive climate services while testing them in specific regions.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We thank the interview partners in the project hubs for openly sharing their perceptions, knowledge, and wisdom with us. We also would like to thank Environmental Protection Bureau and Agriculture Bureau of Kaohsiung City Government for the support for conducting the interviews and collection of information from local stakeholders.

Author contributions

Grit Martinez designed the study focus, undertook ethnographic based research in the five INNOVA hubs and wrote the research paper. Louis Celliers, Rob Swart and Maria Manez commented and edited the manuscript. Jo-Ting Huang-Lachmann acted as principal investigator for Kaohsiung City, Harry Ozier-Lafontaine and Martine Collard for the French West Indies, Adria Rubio-Martin, Alberto Garcia Prats, Ferran Llario and Manuel Pulido-Velazquez for Valencia, Nico Stelljes and Grit Martinez for Eckernförde and Tim Wimmermann and Fokke de Jong for Nijmegen.

Financial support

We acknowledge the ERA4CS project INNOVA (Grant Agreement number 690462) for the financial support of this research.

Conflicts of interest declarations in manuscripts

The authors declare no Conflicts of Interest of the manuscript.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cliser.2022.100300.

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