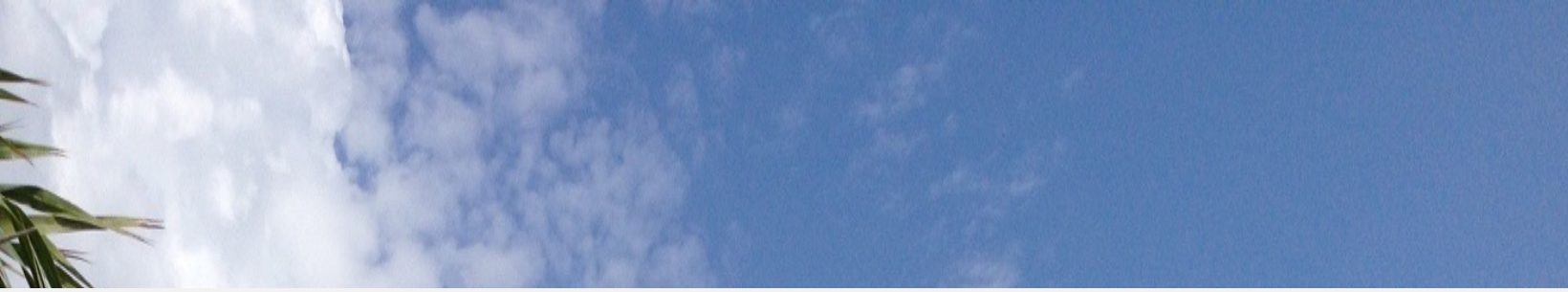
Universitat Autònoma de Barcelona

Integrated Environmental System Management Approaches and Stakeholder Chosen Visualizations for Coastal Management in the Global South

David J. Smith



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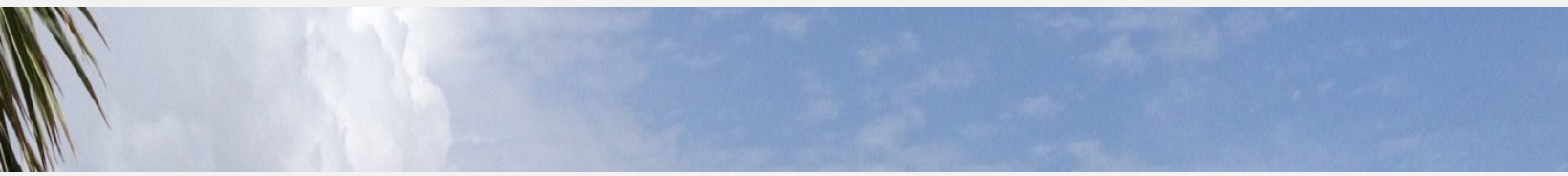

Doctoral thesis

Doctoral Programme in Environmental Science and Technology Institut de Ciència i Tecnologia Ambientals (ICTA)
Universitat Autònoma de Barcelona (UAB)

Director:
Beatriz Rodríguez Labajos (ICTA-UAB)
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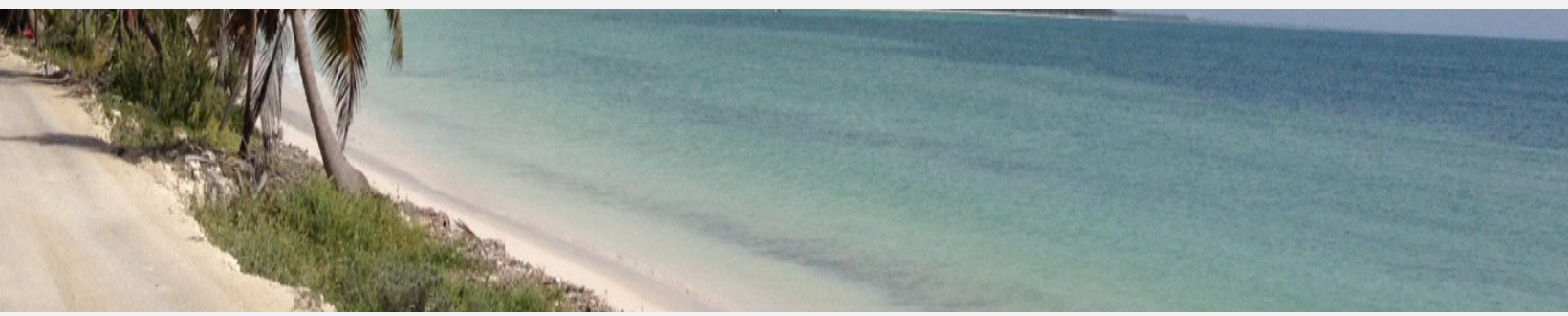
September 2022



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ICTA Institut de Ciència i Tecnologia Ambientals - UAB

UAB Universitat Autònoma de Barcelona

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Preface

In 2013 I started a boutique consulting company "Water, Environment and Business for Development (WE&B)" with the aim to provide specialised social and business consulting services to aid in solving local and global environmental challenges. The company motto is: local impact, global change, which is something we strive to achieve. The company has since implemented several small, medium and large scale projects across the globe for a number of intergovernmental organisations. One of these projects (WaterClima LAC) implemented across Latin America (demonstration cases in the coastal areas of Mexico (La Paz), Argentina (Mar de Plata), Haiti (Les Cayes), El Salvador (Bajo Lempa)) provided a first-hand insight into local level needs at coastal areas. At the time, WE&B was also implementing several larger scale European research projects providing new innovation lines to environmental social and economic integration. My interest was piqued in the interface between local knowledge generation and scientific investigation to solve the challenges at local level, in this case within coastal areas in developing countries. I was intrigued to discover if there could be a way that the knowledge at local level could be combined with the knowledge from the scientific literature to provide a co-developed solution. It became evident that I was in a unique position, at the intersection between bottom-up and top-down knowledge exchange. This is when I embarked on my PhD journey to begin to investigate these areas of interest. With access to local coastal community knowledge, I wondered if other researchers could follow a similar path to help advance co-creation knowledge processes to better adapt to the changing climate. These ideas were further enhanced during the implementation of the large scale European funded project AfriAlliance which had the aim to bring together African and European stakeholders to jointly tackle water and climate challenges in Africa. The co-creation processes were brought to the fore during the implementation of a United Nations Industrial Development Organisation project on the Coastal Hazard Wheel (CHW). When we finalised the project, we put forward a recommendation to include social indicators within the framework. The lack of social indicators in the CHW created an opportunity to further investigate a way to close this gap through co-creation processes. My thesis is thus driven by a desire to provide new knowledge on the ways that coastal area managers and coastal area researchers in developing countries can co-generate solutions to the socio-ecological challenges and communicate the results in a visual format matched to the target stakeholder group to effectuate change.

Acknowledgements

The country you are born in, the social setting that surrounds you and the family that envelopes you, makes your path somewhat easier or harder as you navigate through life. I have always been very conscious of the fact that I have "had it easy" and been in a privileged position in my life. Even the country I was born into only for the colour of my skin was I already on an easier path than others born on the very same day. My parents, alone in raising 4 children in a complicated social setting, did an incredible job. I am forever grateful to them and my siblings for every opportunity they afforded me, I wouldn't be at this point of my career if it weren't for the economic physical and emotional support, they provided me. Thank you, mom, dad, Mike, Fi and Kirst.

This dissertation and the entire doctoral process would not be possible without a very special person. Beatriz, you have an incredible mind and have challenged and supported my ideas and concepts. Without a shadow of a doubt, as my tutor, you have made everything I have done in this thesis possible and you have been essential in its development, for that I am eternally grateful.

I am also very thankful to all the stakeholders that made this research possible. Specifically, to Ken Kenny the CEO of the Development Institute that has been a long-time collaborator and friend. Apart from your reliability, responsibility and professionalism, you manage so well the gathering of the stakeholder groups in Ghana – thank you. I am also very grateful to Lucia Frausto, the director general of Como Vamos La Paz, on short notice and tight budget you managed to bring together some key players in the water sector in La Paz, thank you. In making these projects possible and making sure that these contacts could be made, thank you to the coordinators of the project Dr. Uta When (AfriAlliance) and Dr. Laura Benjejas (WaterClima LAC).

Knowing that the survey was long and somewhat tedious to fill out, to all those that took the time to meticulously run through it and answer the questions, I am very appreciative.

I would also like to thank a very special person, Beatriz Medina. You have provided me the space away from work so that I can focus on the writing of this thesis. Without that space none of this would have been possible. You are an incredible person that I am very grateful to have as partner at WE&B.

Finally, thank you Nadine, you provided me the time, support and motivation to keep going when things were looking a bit difficult. Thank you to Noah, for holding out and allowing your dad to finish his thesis before you were born – it helps more than you know right now.

Abstract

Integrated Environmental System Management Approaches and Stakeholder Chosen Visualizations for Coastal Management in the Global South

Coastal communities, especially those in the Global South, are increasingly at risk to the impacts of the changing climate. The Anthropocene has accelerated the environmental degradation, removing the protection offered by the environment and further impacting the socio-ecological systems at coastal areas. However, it is precisely the human behaviour towards the environment that can be managed. This thesis is motivated by the desire to manage these behaviours with the aim to enhance coastal management by improving the integration of knowledge into environmental systems management approaches pertaining to local coastal communities**.** Coastal area management frameworks require co-creation with all stakeholders that includes bottom-up and top-down knowledge. Hence, research is still required into the role of "Boundary Organisations" that can combine bottom-up and top-down processes. To manage these human behaviours, the inclusion of social indicators into coastal area management frameworks, specifically within the well-used Coastal Hazard Wheel, remains a research gap. Even when knowledge is integrated and appropriate indicators are included within the coastal management frameworks, visualising the data and matching it to stakeholder groups is still an exciting and open line of research. In this thesis, the systematic literature research and analysis provided the theoretical basis and analytical dimensions for the qualitative empirical studies that took place in the coastal areas of Accra, Ghana and La Paz, Mexico between 2017 and 2018. The engagement processes during the field studies involved a varied and complete group of bottom-up and top-down knowledge holders (i.e. stakeholders) from both sites. A survey launched across the African continent (2020) provided quantitative analysis in matching stakeholder types to visualisation tools and techniques.

The results show that even as ICT technologies advance in the Global South, face-to-face interaction and participatory processes are currently the better methods to identify, capture, exchange and validate local knowledge and needs. This can be achieved through the establishment, enhancement or use of Boundary Organisations. These Boundary Organisations / multi-stakeholder partnerships that bridge the gap from local level to policy making level hold a potentially important key in finding solutions to the current and future impacts of climate change at coastal areas. In terms of the indicators for systemic coastal area management three scenarios were characterised. The first scenario (a co-occurrence of the literature analysis with the identified needs from local Ghanaian coastal stakeholders) is the one we promote to be incorporated within the current coastal indicator monitoring frameworks (for example by upgrading the CHW – the framework advocated for use in developing country contexts). The research has also provided a clear direction for the types of visualisation tools and techniques for each type of coastal community stakeholder group and area of expertise. Thus, a stakeholder that wants to convey a message for coastal area management, our research demonstrates to which target audience a specific communication tool or technique is most suited. This thesis prepensed to contribute to enhanced coastal management, specifically in the Global South, by advancing the science of knowledge integration in the approaches to socio-ecological systemic management. In such, the thesis concludes with a contribution to the theories of knowledge integration processes. In particular, the new coastal knowledge integration process proposed here (SHAPES: **S**ystemic **H**ybrid Knowledge Integr**a**tion **P**roc**es**s) is conceived to provide opportunities for coastal managers to enhance local coastal management.

Keywords: Bottom-up; top-down; hybrid knowledge; Boundary Organisation; data visualisation; social indicators; CHW; knowledge integration process; socio-ecological systems; stakeholder participation; Global South; Integrated Coastal Zone Management.

Resum en Català

Aproximacions integrades de gestió del sistema ambiental i visualitzacions triades per les parts interessades per a la gestió costanera al Sud Global

Les comunitats costaneres, especialment les del Sud Global, estan cada vegada més amenaçades per a l'impacte del canvi climàtic. L'Antropocè ha accelerat la degradació mediambiental, eliminant la protecció que ofereix el medi ambient i afectant encara més els sistemes socioecològics de les zones costaneres. No obstant això, és precisament el comportament humà cap al medi ambient el que es pot gestionar. Aquesta tesi està motivada pel desig de gestionar aquests comportaments amb l'objectiu de millorar la gestió costanera mitjançant la millora de la integració del coneixement en els enfocaments de gestió de sistemes ambientals pertanyents a les comunitats costaneres locals. Els marcs de gestió de l'àrea costanera requereixen cocreació amb totes les parts interessades que inclou el coneixement de baix a dalt i de dalt a baix. Per tant, encara es requereix la investigació sobre el paper de les Organisationorganitzacions frontereres" que poden combinar processos de baix a dalt i de dalt a baix. Proporcionar un conjunt d'indicadors socials als marcs de gestió de la zona costanera que l'ajuda en la gestió del comportament humà és una bretxa específica i coneguda en la literatura, específicament dins de la roda costanera de Hazard. Fins i tot quan el coneixement està integrat i s'inclouen indicadors apropiats en els marcs de gestió costanera, la visualització de les dades i la seva adequació als grups interessats continua sent una línia interessant i oberta de recerca. En aquesta tesi, la investigació i l'anàlisi de la literatura sistemàtica van proporcionar la base teòrica i les dimensions analítiques per als estudis empírics qualitatius que van tenir lloc a les zones costaneres d'Accra, Ghana i La Paz, Mèxic entre 2017 i 2018. Els processos de compromís durant els estudis de camp van implicar un grup variat i complet de titulars de coneixement de baix a dalt i de dalt a baix (és a dir, parts interessades) d'ambdós llocs. Una enquesta llançada a tot el continent africà (2020) va proporcionar una anàlisi quantitativa en els tipus de parts interessades corresponents a les eines i tècniques de visualització.

Els resultats mostren que fins i tot a mesura que les tecnologies de la informació i la comunicació avancen en el Sud Global, la interacció cara a cara i els processos participatius són actualment els millors mètodes per identificar, capturar, intercanviar i validar coneixements i necessitats locals. Això es pot aconseguir mitjançant l'establiment, la millora o l'ús d'organitzacions frontereres. Aquestes organitzacions de fronteres / associacions multipropietats que satisfan la bretxa des de l'àmbit local fins a l'àmbit de la política, tenen una clau potencialment important per trobar solucions als impactes actuals i futurs del canvi climàtic a les zones costaneres. Pel que fa als indicadors per a la gestió sistèmica de la zona costanera, es van caracteritzar tres escenaris. El primer escenari (una coaparició de l'anàlisi de la literatura amb les necessitats identificades de les parts interessades locals de la costa de Ghana) és el que promovem que s'incorpori als marcs de control de l'indicador costaner actual (per exemple, mitjançant l'actualització del CHW – el marc proposat per al seu ús en contextos de països en desenvolupament). La recerca també ha proporcionat una direcció clara per als tipus d'eines de visualització i tècniques per a cada tipus de grup de participació de la comunitat costanera i àrea d'especialització. Per tant, una persona interessada que vol transmetre un missatge per a la gestió de la zona costanera, la recerca demostra a quin públic objectiu és més adequat una eina o tècnica de comunicació específica. Aquesta tesi prepensava per contribuir a una millor gestió costanera, específicament al Sud Global, mitjançant l'avanç de la ciència de la integració del coneixement en els enfocaments de la gestió sistèmica socioecològica. En aquest cas, la tesi conclou amb una contribució a les teories dels processos

d'integració del coneixement. En particular, el nou procés d'integració del coneixement costaner proposat aquí (SHAPES: Procés d'Integració del Coneixement Híbrid Sistèmic) es concep per proporcionar oportunitats als gestors costaners per millorar la gestió costanera local.

Paraules clau: Inferior; top-down; coneixement híbrid; Organització de Fronteres; visualització de dades; indicadors socials; CHW; procés d'integració del coneixement; sistemes socioecològics; participació de les parts interessades; Global South; Gestió integrada de les zones costaneres.

List of abbreviations

AfWA	African Water Association	**IWRM**	Integrated Water Resource Management
ACA	Automated Content Analysis	**IPCC**	Intergovernmental Panel on Climate Change
CSOs	Civil Society Organisation	**IPBES**	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
CTCN	Climate Technology Centre and Network	**LEK**	local environmental knowledge
CHW	Coastal Hazard Wheel	**MOOC**	Massive Open Online Courses
SARS-CoV-2 virus	Coronavirus disease (COVID-19) caused by the SARS-CoV-2 viru	**M&E**	Monitoring and evaluation processes
EA	Emergy Analysis	**NGO**	Non-governmental Organisations
EST	Energy Systems Theory	**OECD**	Organisation for Economic Co-operation and Development
GWP	Ghanian Global Water Partnership	**SHAPES**	Systemic Hybrid Knowledge Integration Process
GIDA	Ghanian Irrigation Development Authority	**AfriAlliance**	The Africa-EU Innovation Alliance for Water and Climate
WRC	Ghanian Water Research Commission	**UNEP**	United Nations Environment Programme
GGE	Greenhouse Gas Emissions	**UNIDO**	United Nations Industrial Development Organisation
IKH	Indigenous Knowledge Holders	**SDGs**	United Nations Sustainable Development Goals
ICT	information and communication technology	**WASH**	Water, sanitation and hygiene
ICZM	Integrated Coastal Zone Management	**WaterClima–LAC**	Watershed and Coastal Management in the context of Climate Change in Latin America and the Caribbean

CHAPTER 1

INTRODUCTION

1

Introduction

1.1 Coastal socio-ecosystems are on the verge of multiple crises

By the year 2060 there could be more than a billion people living within coastal areas across the globe (Hauer et al., 2021). The environmental and ocean systems provide these coastal communities with a basis for their livelihoods (Karani & Failler, 2020). Fishing, tourism, farming, housing and leisure activities, coupled with the organisation of these activities including policies, laws, customs, norms, and cultural behaviours, constitute the human and environment systems at coastal zones (Adger, Hughes, et al., 2005) or, using the term coined by Hopkins et al., (2012), the coastal *socio-ecological system*.

Yet, these same human activities, combined with the effects of the changing climate, are increasing the challenges faced by the socio-ecological system (Field & Barros, 2014). Coastal communities are specifically vulnerable to the changing climate (Hauer et al., 2021), not least due to increased extreme weather events and rising sea levels (He et al., 2000). Further, a new debt crisis intensified by the global pandemic (Lustig & Mariscal, 2020) has intersected with the climate dynamics, limiting the options for coastal adaptation and resilience (Fresnillo Sallan, 2020). This disruptive combination is disproportionately affecting developing countries (Phillips et al., 2020). As the world starts to emerge (albeit slowly) from the global pandemic, a shift in focus to abate the health crisis is hindering the achievement of the United Nations Sustainable Development Goals (SDGs) set by the Agenda 2030 (Water JPI, 2021). Indeed, the SARS-CoV-2 virus and the debt crisis, together with climate change, are seen as threat multipliers to the socio-ecological systems at coastal zones (Keulertz et al., 2020).

These aforementioned crises can either be exacerbated or reduced depending on the human activities that have so far been the main drivers impacting the coastal ecosystems (Pörtner et al., 2022). Even more troubling is that the vulnerability of coastal areas continues to increase through accelerated environmental degradation and natural resource depletion (Lagacherie et al., 2018). Social change is therefore essential to protect coastal environments and to reduce the risks faced by the socio-ecological systems in general (Dacks et al., 2018).

1.2 Unbridged knowledge types for coastal management

Changes in human behaviour in relation to the environment are possible (Aswani, 2011), but require knowledge exchange and sharing. The changes in human behaviour and the associated adaptation solutions to the environmental challenges must be tailored to the needs of the local coastal communities since this is where climate change impacts are already being experienced (Leiter, 2016).

To provide solutions to climate change adaptation, evidence continues to emerge of the importance of the inclusion of indigenous knowledge or local environmental knowledge (LEK) (Petzold et al., 2020). Indeed, there has been a substantial move away from exclusive and authoritarian "top-down" professional and scientific "expert" knowledge to a growing acceptance of "bottom-up"

knowledge. The bottom-up approach typically encourages participation of, and engages with, local people including marginalised groups such as women, youth, and people with disabilities integrating their local knowledge, diverse perspectives, skills, needs and experiences into environmental management approaches (Harris, 2014; Smith, 2008). Documenting local knowledge or LEK has gained considerable interest in social environmental research to better integrate these local level needs and perspectives into the development agendas (Alessa et al., 2016; Saito, 2017). Consequently, the integration of local knowledge to tailor the adaptation solutions to the local conditions is considered essential (Makondo & Thomas, 2018).

The interface between bottom-up and top-down knowledge generation can result in new "hybrid knowledge" (i.e. the combination of local and scientific knowledge) (Nguyen et al., 2014). Specific tools, approaches, methods, and processes are still required to successfully integrate bottom-up and top-down knowledge (Gaillard & Mercer, 2013), specifically in the development of knowledge integration processes (Raymond et al., 2010). Bottom-up and top-down knowledge integration within socio-ecological systems has gained a lot of recent attention in the scientific literature (Adams et al., 2014; Ainsworth et al., 2020; Butler et al., 2015a; Coffey & O'Toole, 2012; Hiwasaki et al., 2014; Homsy et al., 2018; Lopes & Videira, 2019; T. P. L. Nguyen et al., 2014; Shirk et al., 2012). However, scientists and local coastal managers are still faced with challenges in finding processes that can integrate the hybrid knowledge into practical coastal management solutions (Albuquerque et al., 2021).

The potential to integrate this hybrid knowledge can be enhanced through what is known as "boundary organisations" (Nguyen et al., 2014). Boundary organisations in terms of co-learning or "social learning" (Reed et al., 2010) have ensured that communities' concerns and voices are heard to adapt to the stressors affecting people, and to establish co-learning groups (Cundill, 2014). The social learning process is therefore not only focussed on climate change, but also on the contextualised vulnerabilities that are identified as important. Effective organisational mechanisms that facilitate communication, translation and mediation across various stakeholder groups enhance the salience and credibility of the information produced (Cash et al., 2003). The inclusion of local stakeholders in managing the environment consequently results in more "socially inclusive environmental policies" (Ferro-Azcona et al., 2019).

1.3 Data monitoring, integration, and visualisation to effectuate change in the age of holism

A systematic approach to data monitoring, integration and visualisation requires a holistic thinking style where the tendency is for communities to perceive different environmental elements to be interconnected and interdependent (Ito & Li, 2019). Through the lens of their cultural setting, local communities can interpret and construct climate change trends using local indicators and adaptation strategies (Adger et al., 2013). Developing countries have a greater challenge in this regard, since data, capacity, expertise and economic resources are limited. Further, coastal populations in these countries are generally growing more rapidly and haphazardly (Rosendahl Appelquist & Balstrøm, 2014). To make sense of these changes, and to provide information to the relevant stakeholders to manage the coastal socio-ecological system, coastal area indicators provide the ability to gather and present data in a relatively straightforward manner. Thus, the complex system can be appreciated in a way that is reasonably simple to understand by coastal zone managers (Choobchian

et al., 2015). Indicators are useful for sharing the results of technical analyses or for monitoring the characteristics of the socio-ecological system. They also enable comparisons across sustainability criteria or indeed across regions.

Over the years, a plethora of indicators and frameworks have been developed to provide insight, monitor, and manage coastal areas. One such framework is the Coastal Hazard Wheel (CHW) (Appelquist & Balstrøm, 2015) which is an indicator-based framework that has raised significant interest at the practical level for its ease of implementation. As a rapid assessment tool to coastal hazards, it has the benefit of requiring low or no primary data collection and thus makes it a useful framework to implement in developing countries (Appelquist & Halsnæs, 2015).

To effectuate behaviour change and to articulate the holistic options made available through the generated hybrid knowledge or coastal management frameworks, data visualisation offers an advantage to communicate the consequences of climate change (Sheppard, 2012). The visualisation of data is the process of making something seeable (Grainger et al., 2016), an "exemplification" (S. Glaser et al., 2008) a representation and presentation of data to facilitate understanding (Kirk, 2016). Thus, visual communication lessens language and disciplinary barriers, while helping to convey essential information (Vogiatzakis et al., 2006).

Bringing local stakeholders together with data is critical to close the gap between scientific knowledge generation and societal goals, and to understand which communication tool and channel works best for local stakeholders (digital or not) and which visualisation method can bring greater engagement (Grainger et al., 2016). However, the generated knowledge does not always influence, or even reach, applications in non-scientific audiences (Fisher et al., 2020).

As data and visual science communication advances, new opportunities for the transmission of ideas and information go beyond written communication (Finkler & León-Anguiano, 2019). Data visualisation helps non-scientific audiences to make informed decisions with regards to environmental management (Grainger et al., 2016). Clearly, computer-supported, visual representation of data has great potential to shed light on environmental issues (Sadiku et al., 2016), especially the rise of social media and web applications changed the scale of stakeholder participations and interactions (Voinov et al., 2016). However, the widespread use of new information and communication technology (ICT) is not always the best option. For instance, Stenchly et al. (2019) show the limitation of ICT tools in rural farming areas in developing countries. Incomplete mobile phone coverages, slow internet connections, and people who have only recently confronted internet-ready devices were seen as common limitations. Unsurprisingly, more "traditional" visualization tools appear to communicate scientific knowledge better to local communities than mobile phone technologies in this case.

The abilities to provide visual information is advancing from singular knowledge products towards knowledge integration processes within environmental management, which was first advocated by Raymond et al., (2010). Knowledge processes look to provide an enabling environment for multiple views and multiple methods to be considered in relation to an environmental management problem (Djenontin & Meadow, 2018). Within coastal management this encompasses networks of "multiple knowledge sub-systems" where the idea of a knowledge system in Integrated Coastal Zone

Management (ICZM) is fundamental to improved understanding of the socio-ecological challenges (Coffey & O'Toole, 2012).

This thesis thus provides an advance in the research on the barriers to bottom-up and top-down knowledge integration at local coastal communities and a new understanding of the evidence of knowledge integration. Furthermore, new research is provided to coastal zone managers through locally chosen social indicators to advance the CHW coastal adaptation framework. Finally, the matching of stakeholder groups to data visualisation options provides coastal zone managers with new pathways for generated hybrid knowledge to be targeted to local coastal communities that can provide impetus for social change and adaptation.

1.4 Research gaps

The renewed interest in co-created processes for systemic environmental approaches, specifically at coastal areas, has opened exciting new research spaces (Conway et al., 2019; Fet & Knudson, 2021). In line with my own interests, the changing climate coupled with the influences of the Anthropocene is further driving the need for new approaches and research to overcome the impacts at local level (IPCC, 2022). As introduced above, local coastal communities can provide valuable local level knowledge for coastal management.

However, to co-create coastal area management frameworks that include the needs of the local costal community, research is required into the role of boundary mechanisms and organisations that are able to combine bottom-up and top-down processes (Clark, Tomich, et al., 2016). Further, Kettle & Trainor, (2015) stress the necessity for new innovative approaches to create partnerships between boundary organisations, specifically to deal with the challenges of climate and water related issues. Local studies and participation between sectors, actors and regions from the developing country context in water and climate activities should be increased (Scheffran & Battaglini, 2011) to further adjust national adaptation and implementation policies (Smit & Pilifosova, 2003). Only a deeper understanding of the bottom-up and top-down processes can facilitate a sustainable and socially equitable flow of information (Azhoni et al., 2018). Yet the validation and integration of the knowledge generated within a boundary organization also needs to be studied (Raymond et al., 2010).

Even with the knowledge validated and integrated, barriers emerge that can shape the adaptation processes in the context of water and climate change. The reasons behind these barriers is a further line of required research (Azhoni et al., 2018). Furthermore, the relationship between ecosystems and the human system (i.e. the socio-ecological system) needs to be studied (Howe et al., 2014). Calhoun et al., (2016) show that understanding this relationship entails the consideration of the social, cultural, historical and the policy aspects as well.

Vugteveen et al., (2015) call for the development of indicators that identify these processes for integrated management strategies in social-ecological systems. Clearly, environmental managers need to move away from thinking of ecosystem assessments as decision-making tools and treat them rather as an opportunity to understand and analyse relationships within the socio-ecological systems (Lele et al., 2013). In the same vein, there have been calls for indicator sets at coastal areas to be more consistent, comprehensive and complete and to thus form part of the overall SDG

assessments (Griggs et al., 2014). Despite the calls for the addition of social indicators in coastal management frameworks, popular indicator frameworks such as the CHW, that is well utilised within developing country contexts, presents shortcomings in the identification, integration and validation of human systems within the framework. Even if the proponents of the framework have already detected the need to add the human system to their framework, to date, the incorporation of this type of data has not been included in any methodological development or practical implementation of the CHW framework.

The information generated by the coastal management frameworks must ensure that all stakeholders that have an influence or interest in the management of the coastal area are provided with an understanding of what the data is communicating. A step beyond that, the visualisation of coastal management data also requires further research to focus on the effective ways to communicate climate change and environmental degradation to all stakeholders. A notable example is the visualisation of data for coastal management in Africa which to date, has largely been overlooked (Abebe et al., 2021). The literature further lacks an analysis on the implications and innovations (Bennett et al., 2022) for the visualisation of coastal data in relation to advancing the development-related agendas (Benson et al., 2021).

Exasperating the situation, the ongoing pandemic has shifted the involvement of stakeholders in data visualization, making it critical to better understand how local participation can aid decision-making processes amid the digital divide (Hassani et al., 2021). Research regarding these issues in Africa will look to bridge the research gap on the continent in terms of climate change and water-related topics (Wehn et al., 2021).

1.5 Thesis aim, objectives, research questions and outline

The impacts of the Anthropocene continue to exasperate the effects of climate change in coastal regions across the globe. Employing the scientific literature presented above, the current investigation pursues a socio-ecological systems management approach that is desirable to foster sustainable change. The impending climate impact on local coastal communities, particularly in developing countries, motivates this thesis, through the aim **to enhance coastal management by improving the integration of knowledge into socio-ecological systems management approaches pertaining to local coastal communities.**

To achieve this aim, the thesis takes a closer look at the renewed interest in integrating bottom-up and top-down knowledge. This "hybrid" knowledge can provide co-developed solutions and holistic management approaches. Introduced in the section above, LEK is now seen as vital to assist in adapting to the changing climate and managing the human activities in coastal areas. Yet there is no clarity regarding the specific barriers to identify and engage with local stakeholders and to integrate this new "hybrid knowledge" nor is there evidence of its use. The first objective of the thesis is thus **to identify the barriers and possible solutions for the integration of bottom-up knowledge and needs in decision-making processes around local environmental (water and climate) issues.**

The generation of this "hybrid knowledge" is a key component in the identification of the coastal challenges. It garners a deeper understanding of the risks and hazards at local coastal communities which in turn allows for social actions to be adapted to the environmental conditions. A variety of coastal management frameworks have been developed to aid in the identification, capture and dissemination of the coastal hazards to contribute to local coastal adaptation. However, the well-known Coastal Hazard Wheel (CHW), lacks the integration of social indicators. The lack of these indicators jeopardises the adaptation management plans, as local coastal community needs, and their local environmental knowledge, is not considered as part of the hazard adaptations. This oversight led to the second thesis objective of **defining a set of practical environmental system indicators from the theoretical to the empirical that indicates the overall health of the environmental system**.

Even if these indicators were to be included within coastal management frameworks, the tools and techniques used to communicate this to the various coastal community stakeholders required further research. The visualisation of data to the various stakeholder groups in a format that is most adapted to the way they want to receive the data can potentially provide a clearer pathway to manage human behaviours in relation to the changing coastal systems. Scientists, in particular, are known to wrestle with communicating the results of their research to different target audiences. The third objective of this thesis is an attempt to overcome this barrier, as it **assesses the stakeholder related challenges in relation to the data visualisation opportunities in the context of climate change in coastal areas.**

For an organised inquiry into my overall interest on how bottom-up knowledge on water and climate needs can be identified, captured and visualised, there are several research questions relate to these objectives. The following research questions are responded to through the remaining chapters of this thesis.

- What are the barriers to effective bottom-up knowledge and needs information gathering? (**Chapter 2**)
- What evidence is there to show that effective bottom-up knowledge interaction and integration has taken place? (**Chapter 3)**
- What is the perceived indicator needs of local coastal stakeholders from a developing country setting? (**Chapter 3)**
- What is the type of visualisation tools or techniques preferred by each stakeholder group to view these types of indicators? (**Chapter 4)**
- In what direction has the global pandemic influenced the communication tools and techniques for environmental information at local coastal level? (**Chapter 4)**

Figure 1 shows the interconnection between these objectives and the process followed in answering the research questions. In addition to the responses to each of the research questions, the overall achievement of the objectives is summarised in a final chapter that also focusses on a proposal for a novel knowledge integration process, which proposes to overcome the gaps highlighted in the literature.

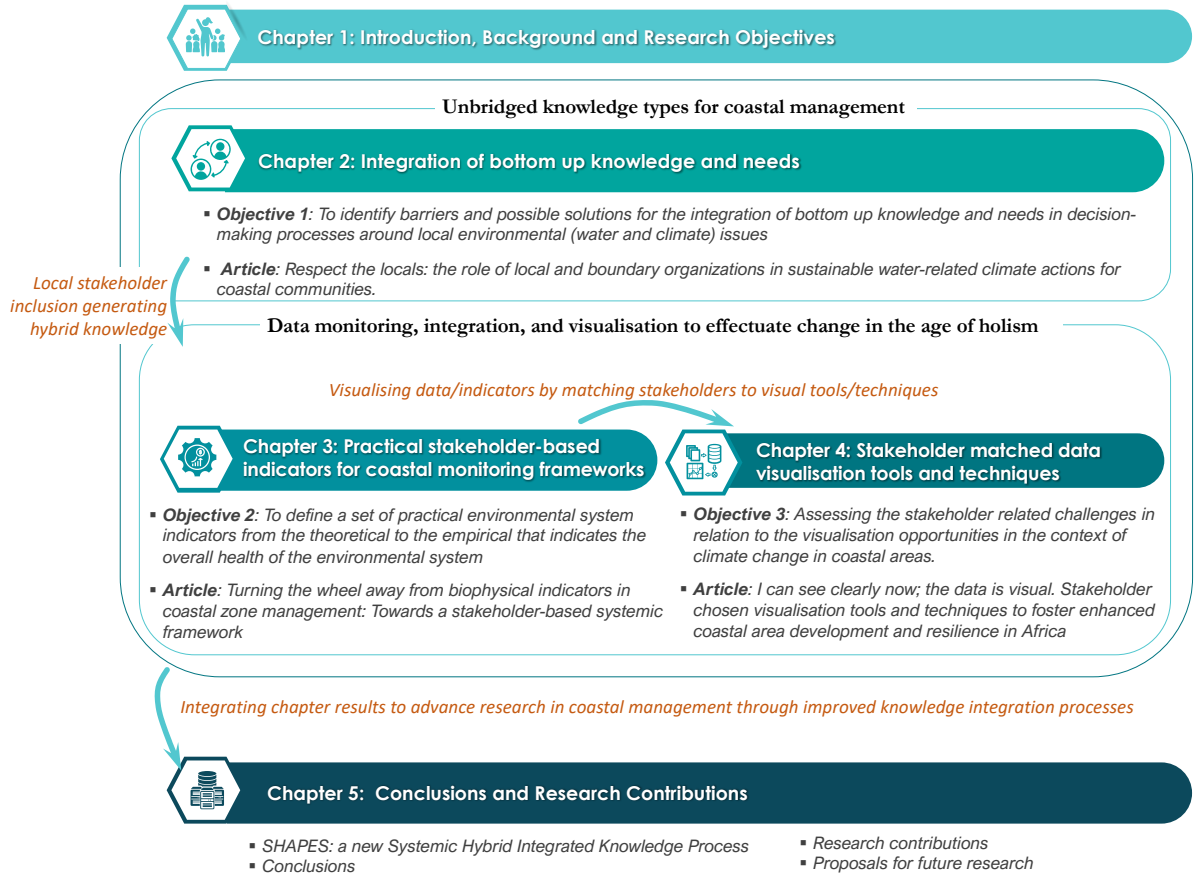

Figure 1: Thesis outline

Chapter 1 provides the motivation that drove this investigation followed by a general introduction and background to the subject matter. The thesis aim, objectives and outline are all included within

this chapter. After setting the scene, **chapter 2** sets out to respond to objective 1 of the thesis by identifying the barriers and potential solutions of integrating bottom-up knowledge for two local coastal communities in Ghana and Mexico. **Chapter 3** integrates bottom-up knowledge into a stakeholder-based systemic framework moving from biophysical indicators to the inclusion of social indicators. The study area for **chapter 3** was undertaken in Ghana and included a large variety of stakeholder groups. To communicate the outcomes from aspects related to **chapters 2** and **3**, visualisation tools and techniques, that are targeted to specific coastal area stakeholders, can enhance the knowledge assimilation, **chapter 4** thus delves into these aspects providing a clear matching between stakeholder and visualisation tools and techniques. **Chapter 5** closes the thesis by providing the conclusions and summarising the research contributions, specifically related to a proposal for a coastal knowledge integration process (SHAPES). Further research proposals are also included in this final chapter.

1.6 Methodological Approach

This investigation combined an array of different qualitative and quantitate research methods, listed in **Table 1**, that were deemed as appropriate to respond to each of the research questions across the stages of data gathering, data preparation, data analysis and data visualisation. Each chapter details the specific methodological choices in accordance with the respective research objective.

Table 1: Overview of the methods used that include the research phase, the activity and to which thesis chapter they relate.

Research Phase	Activity	Thesis chapter		
		2	3	4
Data Gathering	Literature Research			
	Literature Review	X	X	X
	Inclusion criteria	X	X	X
	Empirical research			
	Focus Group	X	X	
	Workshop	X		
	Survey			X
Data Preparation	Automated Content Analysis		X	
	Extracted analytical dimensions	X		X
	Extracted variables		X	
	Code Book	X		
Data Analysis	Excel spreadsheets	X	X	X
	Descriptive statistics			X
	Grounded Theory	X		
	Kendall's tau-b correlation coefficient			X
	Graph theory	X		
	Automated Content Analysis		X	
Data visualisation	Graphs		X	X
	Code Maps		X	
	Radial diagrams		X	
	Nightingale Rose Charts, Coxcomb Chart or Polar Area Diagrams			X
	Concept maps		X	
	Graph theory visualisation	X		
	Sankey diagram			X

Overall, the literature research provided the background knowledge and the guiding questions to drive the empirical data gathering, which included interviews (focus groups), a workshop and a

survey questionnaire. The subsequent data analyses sought to provide evidence when articulating the response to each research question, and data visualisation aimed at offering clarity in the presentation of ideas.

1.6.1 Literature research

A systematic literature review at the start of each chapter provides a solid foundation for research development (Snyder, 2019). The guidelines proposed by Kitchenham (2004) to identify, collect and assess the peer reviewed literature (**chapters 2** and **4**) were enlisted alongside software tools for qualitative content analysis to draw out the central themes from the literature (**chapter 3**). Inclusion criteria (**chapters 2**, **3** and **4**) were chosen to select the articles for the in-depth review, which reduces the research bias and strengthens the reliability of the systematic literature reviews (Moher et al., 2009). This process resulted in the analytical dimensions (**chapter 2**) and variables (**chapter 4**) used during the interview or survey process.

1.6.2 Empirical research

Both qualitative and quantitative research methods were employed. The qualitative research methods of focus groups (**chapter 2** and **3**), a workshop (**chapter 2**) and a survey (**chapter 4**) were implemented. The focus groups and workshop were instigated through field work performed in Accra, Ghana (**chapter 2** and **3**) and La Paz, Mexico (**chapter 2**) meanwhile the survey was launched across the African continent (**chapter 4**). Coastal areas from the Global South formed the focus of this research as the evidence shows that coastal areas in developing and transition countries are going to be most at risk to the changing climate (Day et al., 2021) and Africa in particular is going to bear the brunt of climate change impacts (Niang et al., 2014). Furthermore, the opportunity to have access to enlist responses from multi-actor stakeholders that have an interest or influence in coastal area management in Mexico, Ghana and Africa was afforded through the participation in two European funded projects (WaterClima LAC and AfriAlliance respectfully).

The implementation of these quantitative and qualitative research methods was shaped primarily by budget and time constraints. I would have preferred to undertake fieldwork across many coastal regions in Ghana and Baja California, Mexico to gain a wider perspective from a larger target audience. However, the quantitative and participatory methods conducted for this research has gained insights from a broad group of stakeholders (specifically the quadruple helix stakeholders – academia; industry; civil society and public authorities) with wide coastal area knowledge, making this research unique within the selected topic.

1.6.3 Data Analysis

Involving multiple stakeholders across sectors and scales connecting a vast environmental context (climate change and water issues) and eliciting responses through different empirical research methods, required the data to be analysed using various techniques. The data from the focus groups was recorded, transcribed and coded into common concepts (**chapter 2**) and indicator categories (**chapter 3**). Grounded Theory was used (**chapter 2**) to develop inductively derived outcomes (Strauss and Corbin, 1990).

Software programs were commissioned to facilitate the analysis of the data generated. To assist in analysing the literature, Automated Content Analysis (ACA) was undertaken using Leximancer (McCallen et al., 2019) (**chapter 3**). The analysis of the primary data was undertaken using Gephi (employing graph theory) (Hay Mele et al., 2019) to calculate and visualise the importance of each topic and their relationship between one another (**chapter 2**), MAXQDA (Saillard, 2011) aided in the analysis of the coded focus group transcripts for the different types of indicators and indicator categories (**chapter 3**) and IBM® SPSS® Statistics (v. 28.0.0.0) was used for the statistical analysis to identify the significant statistical associations between the variables of the different topics (Gogtay & Thatte, 2017) (**chapter 4**). The data was displayed using a variety of visualisation tools and techniques including graphs (**chapters 2**, **3** and **4**); concept maps and graph theory visualisation (**chapter 2**); code maps and radial diagrams (**chapter 3**); infographs, Nightingale Rose Charts, also known as Coxcomb Chart or Polar Area Diagrams and Sankey diagram (Grainger et al., 2016b) (**chapter 4**).

CHAPTER 2

Integration of bottom up knowledge and needs

2

Respect the locals: the role of local and boundary organizations in sustainable water-related climate actions for coastal communities[1]

2.1 Introduction

We are in the midst of a climate crisis. As we write this, India, Pakistan and Madagascar are suffering the consequences of deadly flooding made more powerful by the changing climate (Rajeev & Mishra, 2022; Vaughan, 2022). All regions in the world and their inhabitants, transcendent of social class or culture are vulnerable to these impacts (G. Hansen & Cramer, 2015). Floods, hurricanes, wildfires, heat waves, and droughts are just some of the environmental impacts that devastate local communities and their livelihoods (Van Susteren & Al-Delaimy, 2020). Besides effects on the environment and ecosystems, impacts of climate change encompass the physical and emotional wellbeing of the impacted local communities (Markandya & Chiabai, 2009) and impose severe stresses in community livelihood (Adger, 1999a).

Adaption solutions to the environmental changes have to thus be tailored to local communities since this is where climate change impacts will be primarily be experienced (Leiter, 2016b). The integration of local knowledge to respond to these changes and to tailor the adaptation solutions to the local conditions is essential (Makondo & Thomas, 2018). Indeed, through the lens of their cultural setting, local communities can interpret and construct climate change trends using local indicators and adaptation strategies (Adger et al., 2013).

However, there is a recognised gap for decision making between bottom up and top down approaches in environmental and water management (Girard et al., 2015). The flow of information taking into consideration both the bottom-up and top-down perspectives requires greater understanding of the processes to ensure they are sustainable and socially equitable (Azhoni et al., 2018a).

The reasons why barriers emerge with regards to knowledge flows that can shape adaptation processes in the context of water and climate change are also urgently required (Azhoni et al., 2018a). Further, there is a lack of empirical research between sectors, actors and regions from the developing country context in water and climate activities to draw out the contextual perspectives on adaptation (Scheffran & Battaglini, 2011).

[1] *A version of this chapter was submitted to Sustainability Science for publication. Parts of the results in this chapter were presented during the AfriAlliance MOOC for Module 5: Social innovation processes in practice – a case study of the AfriAlliance Action Groups in June 2020 and attended by more than 700 participants.*

Buizer et al., (2016) claim that many of the abovementioned gaps could be bridged through boundary organisations. Accordingly, fostering innovative approaches to create partnerships between boundary organisations would help to deal with the challenges of climate and water related issues (Kettle & Trainor, 2015b). Although potentially beneficial to bridge the bottom-up and top-down knowledge space, there remains a gap in the research of the work of boundary organisations with respect to knowledge validation (Posner & Cvitanovic, 2019) and in relation to water and climate actions in developing countries (Clark, Tomich, et al., 2016b).

Bridging these research gaps, this paper aims to identify and integrate bottom-up knowledge and needs affecting water resources at coastal areas into higher-level decision-making processes. This is driven by three specific research objectives. The first is to identify how bottom-up knowledge on water and climate needs can be identified and captured. The second is to discover what the barriers are to effective bottom-up knowledge and needs information gathering. Finally, the third objectives is to investigate the evidence that can ensure that effective bottom-up knowledge interaction and integration has taken place.

Following this introduction, we provide details of the research framework. To this end, we reviewed scientific literature on practical implementations to identify and integrate bottom-up knowledge into policies and about the use of boundary organisations in a bottom-up processes. After laying out the research methods, we present our results and discuss our insights in relation to environmental management in coastal areas.

The unique contribution of this paper provides the empirical evidence, from multiple local stakeholders, to identify the barriers of knowledge flow through bottom-up processes in coastal communities. Furthermore, we expand on the research field of boundary organisations by providing insights into the effectiveness of the integration of local level knowledge through stakeholder chosen criteria.

2.1.1 Background

The challenge of bottom-up local knowledge flows

Documenting local knowledge or local ecological knowledge (LEK) has gained considerable interest in social environmental research to better integrate local level needs and perspectives into development agendas (Alessa et al. 2016; Saito 2017). Indeed, there has been a substantial move away from exclusive and paternalistic "top-down" professional and scientific "expert" knowledge to a growing acceptance of "bottom-up" approaches including locally derived data (D. J. Smith & Rodríguez-Labajos, 2021).

In this paper we refer to local knowledge or bottom-up knowledge as the informal or expert knowledge at specific locales that reflect expertise and understanding of local phenomena (Kettle et al. 2014; Raymond et al. 2010). The bottom-up approach typically encourages participation of, and engages with, local people including marginalised groups such as women, youth, and people with disabilities integrating their local knowledge, diverse perspectives, skills, needs and experiences into environmental management approaches (Harris, 2014; J. L. Smith, 2008).

The efforts to integrate bottom-up approaches are increasingly recognised as valuable to climate adaptation measures (Raymond et al., 2010; Grêt-Regamey et al., 2013; Armitage et al., 2011; Mastrandrea et al., 2010). This approach to gathering knowledge and needs generates several advantages. It enhances risk-based management approaches and adaptation by providing insights into the adaptation processes and facilitating the co-production of knowledge (Kettle et al. 2014). Indeed, through this approach changes can be effectuated within national and/or regional policies that in turn can positively impact on the local level (Brook and McLachlan 2008; Davis and Wagner 2003; Ford et al. 2016; Huntington 2000). It promotes higher quality decision-making, greater conflict reduction, successful implementation and accountability (Tseng and Penning-Rowsell 2012).

Furthermore, coastal managers, armed with solutions that are grounded in the idiosyncrasies of the local communities can provide future coastal adaptation scenarios that can play a major role in local and global development agendas (Ford et al., 2016a; Markphol et al., 2021). However, significant opportunities still remain for the identification, validation and integration of bottom-up knowledge and insights into these agendas (Pereira et al., 2021). Specifically in Africa, Jiménez-Aceituno et al., (2020) note that only by merging the bottom-up and top-down approaches the monitoring of the success of the efforts to achieve the SDG goals of Agenda 2030 can be realized.

The significant emerging role of boundary organisations

Boundary Organisations are formal organisations that gather together the different perspectives of all interested parties to facilitate the flow of information and collaboration between stakeholders (Franks, 2016; Parker & Crona, 2012a). The assumption behind the concept of Boundary Organisations is that solutions are rarely developed from one side alone (either top-down or bottom-up) (Lorenzoni et al., 2007).

Boundary Organisations in terms of co-learning or "social learning" have ensured that communities' concerns and voices are heard to adapt to the stressors affecting people, and to establish co-learning groups (Cundill et al., 2014). The social learning process is therefore not only focussed on climate change, but also on the contextualised vulnerabilities that are identified as important. Effective organisational mechanisms that facilitate communication, translation and mediation across various stakeholder groups enhance the salience and credibility of the information produced (Cash et al., 2003b).

For instance, Ford et al., (2016), highlights the case of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), which has been able to strengthen the quality of local knowledge intervention through the creation of a task force to enable local peoples participation in the platform deliverables. In a study of ecology research, Safford et al., (2017) call those that interact between knowledge producers and knowledge users "boundary spanners", underlining that they are critical to ensure scientific salience, credibility, and legitimacy. Accordingly, boundary organisations are able to support local networks, facilitate the co-production of knowledge, and reduce conflicts and tensions within complex interactions and continue the knowledge integration processes into the future (Berkes, 2015).

There are several characteristics that define a boundary organisation. They speak multiple "languages" (e.g., policy, public, and scientific); they participate and co-produce knowledge, and they are accountable to more than one entity to which they are linked (Meyer, Ryan, 2014). Although highly relevant, boundary organisations often work under financial duress and hence disappear or re-appear in accordance to political and funding cycles (Safford et al., 2017). "Boundary Objects" are the tools or processes that allow Boundary Organisations to undertake their activities. These tools and processes usually take the form of workshops, reports, forecasts, models, maps or events (Clark, Tomich, et al., 2016b; Guido et al., 2016).

However, caution must be exercised when engaging with boundary organisations, although they can provide the access to capture local level knowledge they may hold on to vital information, defending their role and fearing that once this information flows upwards their organisation will not have a further role or be disbanded (Kettle et al., 2014). The knowledge generated from the boundary objects also requires further research into the means of integration and validation (Raymond et al., 2010).

2.2 Materials and Methods

This section outlines the methods used to conduct this research, starting with the conceptual structure (Figure 2), the data collection methods and the analytical procedures that were followed. The research questions guided the data gathering phase where the literature research provided the guiding questions that were used during the participatory approach to capture the knowledge from the local coastal communities in the two case studies. The subsequent data analysis provided the evidence and clarity to answer the research questions.

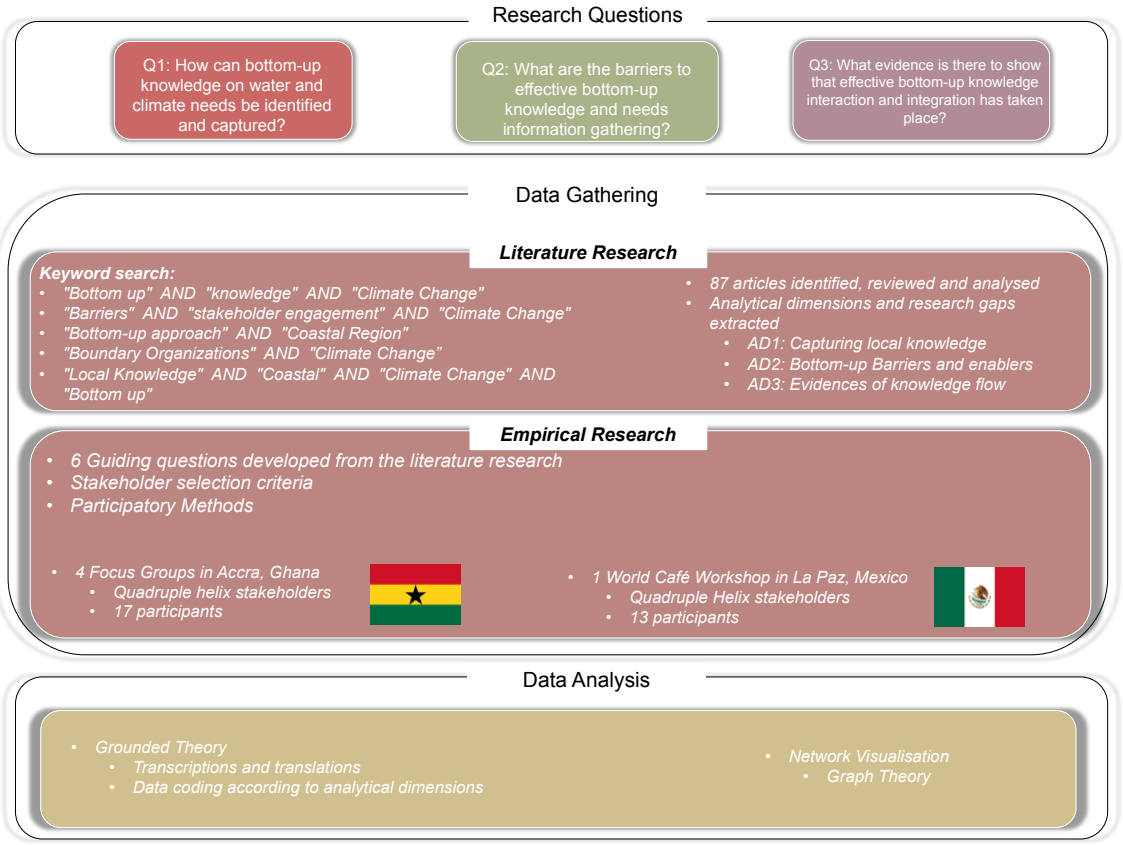

Figure 2: The analytical research framework

2.3 Data gathering

2.3.1 Literature Research

Guided by the research questions, a systematic evaluation of the peer-reviewed literature was initiated through using the following keyword string searches: (i) "bottom up" AND "knowledge" AND "climate change"; (ii) "barriers" AND "stakeholder engagement" AND "climate change"; (iii) "Bottom-up approach" AND "coastal region"; (iv) "Boundary Organizations" AND "climate change"; (v) "local knowledge" AND "coastal" AND "climate change" AND "bottom up. The searches were implemented in the scientific databases of Scopus and Google Scholar. This resulted in 87 articles that were chosen as relevant to this research. Inclusion criteria reduces the research bias and strengthens the reliability of the systematic literature reviews (Moher et al., 2009). Thus, we focused the full reviews of the articles that were ten years or less and explicitly dealt with a combination of the following topics: (i) bottom-up knowledge; (ii) boundary organisation (iii) Boundary Objects; (iv) developing country. A total of 16 articles filled these criteria and were subjected to a full review.

Related to the research questions and following the assessment of the peer-reviewed articles the subsequent analytical dimensions were extracted: i) capturing local knowledge; 2) bottom-up barriers and enablers and 3) evidence of knowledge flow. The guiding questions that were included

in the local participatory processes were developed within the analytical dimensions and anticipate responding to the research questions (see Table 1).

Table 2. Analytical dimensions, research questions and the guiding questions to local coastal community stakeholders.

Research questions	**Analytical Dimensions (AD), research gaps and descriptions to be investigated**	**Guiding Questions to Stakeholders**
How can bottom-up knowledge on water and climate needs be identified and captured?	**AD 1: Capturing local knowledge** • There is a need to reach the local level and to obtain the needs and knowledge that can be fed into local, regional, national or international development and policy agendas (Raymond et al., 2010) • A greater understanding is required of the role of boundary organisations in relation to water and climate actions in developing countries (Clark et al., 2016) • There is a lack of empirical research from a wide range of stakeholder groups in a developing country context to understand water and climate impacts (Scheffran & Battaglini, 2011)	1. Considering the key knowledge partners for your organisation, in your opinion, how best do you interact with them? 2. In the context of climate change challenges, reaching the local level is crucial. In your opinion, what is the best way of identifying local water and climate related needs?
What are the barriers to effective bottom-up knowledge and needs information gathering?	**AD 2: Bottom-up knowledge exchange barriers** • The flow of information has obstacles to overcome to ensure that the bottom-up needs are incorporated (Howarth & Monasterolo, 2016) • Research is required into the reasons why barriers emerge in bottom-up knowledge flows (Azhoni et al., 2018)	3. Why, in your opinion, is knowledge not being effectively shared? 4. What are the barriers that can prevent stakeholders from engaging in certain activities?
What evidence is there to show that effective bottom-up knowledge interaction and integration has taken place?	**AD 3: Evidence of knowledge flow** • Capacity in networking and interaction are important as is the way to spread information and to exchange knowledge (Butler et al., 2015) • Further research is required into the means of integration and validation of locally generated knowledge (Raymond et al., 2010)	5. How best do you interact with your partners? 6. What would you say is the best proof/best examples to show that you have effectively engaged with your partners?

2.3.2 Empirical Research

Our two cases studies were located in Mexico (La Paz) and Ghana (Accra) (see **Table 3**), where the authors had the opportunity to work with boundary organizations through two European funded projects. The case study in La Paz, Mexico formed part of the project WaterClima–LAC (*Watershed and Coastal Management in the context of Climate Change in Latin America and the Caribbean*) funded by EuropeAid. The project had the objective to contribute to the alleviation of poverty and social inequalities by improving the dialogue and cooperation on watershed and coastal management through technical, social and financial mechanisms. To this end, several actions were undertaken, including the summary and evaluation of the current situation in the case studies, developing social and economic models at coastal zones; networking; dissemination; training and capacity building.

The second case study formed part of the European funded project within the Horizon Europe funding program. The AfriAlliance project (*The Africa-EU Innovation Alliance for Water and Climate*) had the aim to better prepare Africa for future climate change challenges by having

African and European stakeholders work together in the areas of water innovation, research, policy, and capacity development.

Two study areas that were used for the investigation are coastal cities affected by climate change and both have a significant number of inhabitants. The interesting aspect of the two cities (La Paz, Mexico and Accra, Ghana) is that they are on different continents with their own idiosyncrasies and cultures but they both face the common challenge that cities in coastal areas face regarding rising sea levels, increased frequency and violence of storms and a significant impact on water resources i.e. the salination of groundwater resources.

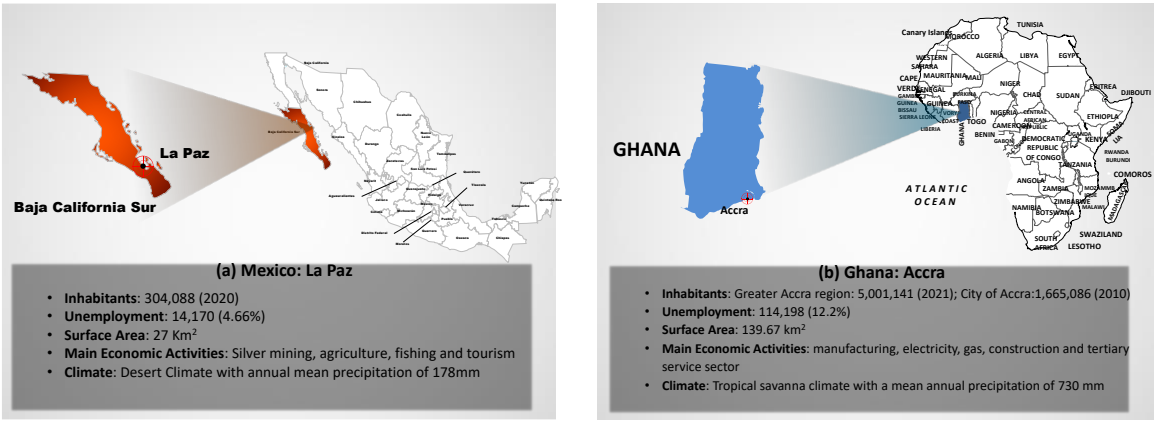

Figure 3: Case study sites and basic data of the study areas: (a) Mexico: La Paz, (b) Ghana: Accra. The data included in the figures is further detailed in the text.

The Ghana case study is as an emblematic example of the possible responses to the increased variability in climate on a seasonal scale in Africa that, coupled with extreme weather events, has led to widespread socio-economic disruption (Hulme et al. 2001). The coastal areas of West Africa represent 31% of the region's population and accounts for 56% of the region's GDP (World Bank, 2016). An estimated sea level rise of 1m by 2050 could inundate 1,120 km^2 of land putting an estimated 113 million people at risk in West Africa (UN, 2015). Accra, according to the latest available census information of 2021, has a regional population of 5,001,141 and a city population of 1,665,086 with the number of unemployed at 114,198 (12.2%) (Ghana Statistical Service, 2021). Accra covers a surface area of 139.67 km^2 with a tropical savanna climate and a mean annual precipitation of 730 mm/year. The main economic activities include manufacturing, electricity, gas, construction and the tertiary service sector (Ghana Statistical Service, 2021)

The city of La Paz in Baja California Sur, Mexico, due to its coastal location and severe water scarcity, also finds itself vulnerable to the impacts of climate change. Increased pumping from water wells has resulted in overexploitation and hence aquifer salinization significantly impacting the groundwater supplies for potable water consumption (McEvoy, 2015). This situation is further compounded by the rapid population growth that has led to poorly managed solid waste generation, as well as an increase in vehicles, deforestation and poor urban planning that has caused several pollution problems and increased greenhouse gas emissions (GGE) (Ivanova et al., 2015). According to the latest government census the number of inhabitants living in La Paz are 304,088 (2020), with the number of unemployed people at 14,170 (4.46%) (DataMexico, 2020). La Paz

covers a surface area of 27 km^2 with a climate described as desert with annual mean precipitation of 178mm/year (DataMexico, 2020).

In both case studies, local organisations were involved to bring together a wide range of local level stakeholders. In La Paz, Mexico we enlisted the assistance of the organisation "Como Vamos La Paz" a Civil Society organisation working as a citizen observatory "proving advocacy in areas of public life in the city and state through strategic communication, citizen participation, dialogue with public actors and the generation of networks and alliances with citizen, social and governmental actors" https://www.comovamoslapaz.org.

In Accra, Ghana we worked with "The Development Institute (D.I)" a Ghanaian sustainable development NGO. It has the aim to "create an enabling environment for empowering Civil Society Organizations and communities to facilitate the linkage between micro and macro levels of society for sustainable development" https://www.thedevin.org.

Through the assistance of these two local organisations in each case study we were able to include a wide range of local level key knowledge holders from research organisations; the public sector and civil society organisations (including woman's groups, youth groups, farmer associations and traditional leaders). The stakeholders were identified based the stakeholders position, their level of influence (power) they hold and the level of interest they have in the specific context (M. S. Reed et al., 2009). Specifically for the two case studies the stakeholders were chosen in accordance with the following criteria:
For La Paz, Mexico:

- Working on aspects related to water and climate issues in La Paz.
- Local authorities with decision making powers over water and climate aspects.
- Local stakeholders with concern over the water management and climate issues in La Paz.
- Local stakeholders looking to entrench the process of integrated water resource management in the city.
- Stakeholders that held an interest in being involved in the activities of the WaterClima LAC project.

For Accra, Ghana:

- Local stakeholders working together in the areas of water innovation, research, policy, and capacity development to increase the preparedness of Africa for future Climate Change vulnerabilities.
- Local stakeholders with a concern and connection to coastal communities in Accra.
- Stakeholders that are interested in connecting and interacting to create/ foster the use of demand-driven solutions for establishing effective water or climate change cooperation within Ghana.
- Expressing interest in getting engaged with the AfriAlliance activities.

The authors adapted to the project objectives in each study case. During the African Water Associations (AfWA) Scientific and Technical Council meeting held in Accra, Ghana in July 2017, within the framework of the H2020 project AfriAlliance (AfriAlliance, 2016). The boundary organisation D.I provided support in recruiting the participants as organisers of the respective events. The table below provides an overview of the stakeholder groups that attended the different

events. The second event took place in La Paz, Mexico on the 30th of January 2018 as part of an event entitled "towards an Integrated Water Resource Management in La Paz" within the context of the project WaterClima LAC (WaterClimaLAC, 2018) and supported by "Como vamos La Paz".

Table 3. Participant Groups in the two study areas

Case study	Stakeholder group	Region represented by the stakeholder	Date	Number of participants
Accra, Ghana (Focus groups)	Local/regional authorities and research organisations	Southern Africa; Western Africa; Africa	20th July 2017	5 (3 male, 2 female)
	Youth groups and Women's groups	Ho, Volta Region National	19th July 2017	6 (2 male, 4 female)
	Indigenous people groups (traditional leaders)	Tamale, Northern region of Ghana (Savanna vegetation) Volta region (middle zone, deciduous forest)	20 July 2017	3 (2 male, 1 female)
	Farmers associations and Civil society (CSO's, consumer's/users' associations, and NGOs.)	Volta Region	19 July 2017	3 (1 male, 2 female)
La Paz, Mexico (World Café)	Local/regional authorities	La Paz, Mexico	30th January 2018	5 (5 male, 0 female)
	Research	La Paz, Mexico	30th January 2018	4 (2 male, 2 female)
	Civil society (CSO's, consumer's/users' associations, and NGOs.)	La Paz, Mexico	30th January 2018	4 (0 male, 4 female)

Qualitative research methods of focus groups (Butler et al., 2015) and workshop based on the World Café methodology (Löhr et al., 2020) were used following successful implementation of the same for integrating top-down and bottom-up knowledge generation in environmental research. These methods allow for an in-depth exploration of the issues of knowledge generation at the boundary face (Cvitanovic et al., 2018). The implementation of these qualitative research methods was shaped primarily by budget and time constraints. The researchers would have preferred to undertake fieldwork in all the coastal regions across Ghana and Baja California, Mexico. However, the participatory methods conducted gained insights from a broad group of stakeholders with wide coastal area knowledge, making this research unique within the selected topic, and has allowed for an international comparative analysis.

2.4 Data Analysis

The researchers have adopted the principles of the Grounded Theory approach to aid in analysing the empirical data that involved multiple stakeholders across sectors and scales connecting a vast environmental context (climate change and water issues). The stakeholders were also grouped according to local/regional authorities and research organisations and CSOs (Civil Society Organisation). The CSOs from Ghana included: youth groups and women's groups; indigenous people groups (traditional leaders); farmer associations and other non-governmental organisations (NGO's), meanwhile in Mexico these included citizen observatories, consumer/user associations and other NGOs. The authors have drawn on the practical experience of Pinsky et al., (2019) and Raymond et al., (2010) of using Grounded Theory from multiple stakeholders to analyse experiences from water and climate actors.

Grounded Theory provides a logical set of procedures to develop inductively derived outcomes (Strauss and Corbin, 1990). The data gathered from the two participatory events in Mexico and Ghana was transcribed, coded and grouped into common concepts. This approach enabled the

researchers to seek out and conceptualise the insights to increase the understanding of stakeholders' behaviour towards knowledge capture and exchange in water and climate related issues. Accordingly, the analysis considered the following aspects: focus group and workshop (World Café) transcriptions, data coding according to the variables identified in the theoretical framework and included in **Table 1**, the aggregation of the data through a constant comparison and an analytical memoing and the construction of the final theories.

To present the data analysis, graph theory was used to visualise the importance of each topic and their relationship between one another. The authors have taken a lead from experiences of using graph theory to highlight critical areas for conservation under climate change (Dilts et al., 2016) and knowledge management (Ríos-Zapata et al., 2017) to analyse and visualise the data. Graph theory is based on diagrams that involve circles (nodes) and lines (edges) which are pictorially presented displaying the mathematical relationship between the nodes and edges (West, 2001). The size of the node presented in the results represents the number of times the concept was mentioned by the stakeholders while the distance between each node represents how closely related each concept is to one another. We have used the graph theory metric of Eigenvector centrality to provide the mathematical relationship between the different nodes (in our case, the concepts mentioned by the stakeholders). The colours of each node depict if the concept was only mentioned in Ghana (green), only in Mexico (purple) or in both cases (red).

2.5 Results

The results from the local stakeholder consultations for the two case studies are articulated around the three analytical dimensions of: (i) AD1: Capturing local knowledge; (ii) AD2: Bottom-up barriers and enablers and (iii) AD 3: Evidence of knowledge flow. Table 4 provides an overview of the responses from the different stakeholder groups from each case study and the topics they indicated as essential within each aspect. A tick in the matrix indicates the stakeholder group that mentioned the topic marked.

Table 4: Matrix of the concepts mentioned and the stakeholder groups that mentioned the concept.

Analytical Dimension	Concepts mentioned	Stakeholder Groups				Percentage Frequency distribution
		Ghana, Accra		Mexico, La Paz		
		Local/regional authorities and Research	CSOs (Youth and Women's groups; traditional leader; Farmers associations	Local/regional authorities and Research	Civil society (CSOs)	
AD 1: Capturing local knowledge	Consult (hold workshops etc.) directly with individual local organisations (e.g., farmer associations, traditional leaders, local river basin organisation, NGOs/CSOs)	✓	✓	✓	✓	40%
	Engage with Boundary / Bridge Organisations such as platforms, advisory groups, associations, committees that incorporate local actors	✓	✓	✓	✓	27%
	Get to know all the key stakeholders that are related to the subject		✓	✓	✓	13%
	Approach grass root organizations (such as river basin organisations)	✓	✓	✓		13%
	Open Knowledge (Knowledge that is open source and freely available)		✓	✓		7%
AD 2: Bottom-up knowledge exchange barriers	Loss of power, influence and/or trust		✓	✓	✓	31%
	Lack of interest from key stakeholders		✓	✓	✓	23%
	There is a lack of partnerships with key local partners		✓	✓	✓	15%
	Information technologies not used in information capture	✓	✓	✓		15%
	Language and cultural barriers		✓	✓		8%
	Lack of economic resources and motivation		✓	✓		8%
AD 3: Evidence of knowledge flow	The implementation of participatory methods and ensuring that local issues are brought forward and then repeated	✓	✓	✓	✓	24%
	Creating partnerships / platforms between key stakeholders so that actions continue over the long term (Boundary organisations)		✓	✓	✓	19%
	Interest, motivation and active engagement from community members (example letter drop-offs)	✓	✓	✓	✓	19%
	Documenting observational changes (particularly at farm scale)	✓	✓	✓		14%
	Implementing monitoring and evaluation processes	✓	✓	✓		10%
	Local media reporting on the issues at hand	✓	✓	✓	✓	10%
	Showing that education schemes exist at community level and documenting the implemented experiences		✓	✓		5%

2.5.1 Analytical Dimension 1: Capturing local knowledge

The consultation revealed several ways to capture local water and climate needs through a bottom-up process (Fig. 3).

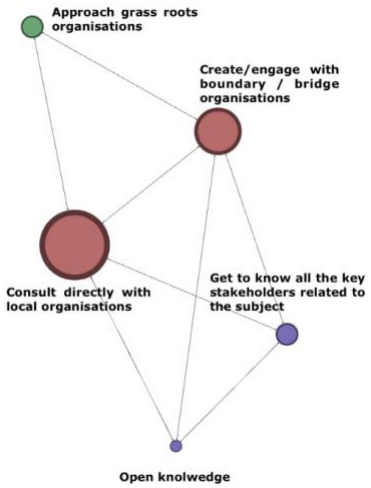

Figure 4: How can local knowledge and needs be captured? *

* The red nodes represent both cases (Ghana and Mexico); the green nodes represent the Ghana case while the purple nodes represent the Mexico case

The combined stakeholder groups consulted from Ghana and Mexico have shown the importance of engaging with organised groups when capturing local knowledge in the context of water and climate needs (Table 4 and Figure 4). With the highest frequency of mentions (denoted by the size of the sphere) from both case studies (red node) the stakeholders have indicated the importance of consulting directly with local organisations. Indeed, the Eigenvector centrality metric (measuring a node's influence based on the number of links it has to other nodes in the network) of 1.0 for "consulting directly with local organisations" indicates the greater influence this topic has over the other topics mentioned with regards to capturing local knowledge and needs.

2.5.1.1 Consulting directly with local organisations

With respect to consulting directly with local organisations, the Ghanian Global Water Partnership (GWP) representative stressed the importance of the use of the river basin offices in each region where direct engagement with the communities can take place and information gathering is sought. Under this perspective, the River Basin Boards formed by the local communities are effective entry points to gather local knowledge and needs. In fact, the Integrated Water Resource Management (IWRM) strategy in Ghana is being implemented through these boards. The Ghanian Water Research Commission (WRC) representative indicated a further pathway to capturing local knowledge was through letters or walk-ins to local community WRC offices across the regions, where local communities can raise their concerns or needs on water and climate. In turn, the WRC will help to distribute the knowledge of these local level problems.

Similarly, the representative of the Ghanian Irrigation Development Authority (GIDA) stressed the importance of interacting with farmer associations, especially with relation to demonstration projects and field days so that all farmers can raise issues and problems in situ, and this information

can be brought back to the head office. The traditional leaders consulted in Ghana stated that they work closely with local NGOs who are aware of the local needs of their tribes. In their words, "foreign cultures do not fully understand the governance schemes of our traditional systems". Therefore, they suggest that by working directly with the traditional leaders or with the local NGOs ensures that local water and climate needs from their tribes are captured.

The local authorities and the civil society organisations consulted in La Paz, Mexico, stressed that before engaging directly with any local organisation, key stakeholders should first be identified. In their view this should be done through forums with local coordinators, committees or local councils that have a continued presence in the area of interest.

2.5.1.2 Engaging with Boundary Organisations

With regards to engaging with Boundary / Bridge Organisations such as multi-actor platforms, advisory groups, associations, committees etc, the local authorities consulted in Ghana suggested a structured approach. For instance, the WASH officer and programme manager for the Ghanaian ministry, who proposes policies for water, monitoring and coordination across Ghana stated: "The national learning alliance platform at local level would be a good entry point". To sustain this platform, the governmental agencies and the Ghana water companies need to gather local knowledge to be able to implement local needs. Therefore, they see local knowledge gathering as a natural process within these multi-stakeholder platforms. The women and youth group representatives in Accra, Ghana, felt that working with networks or clusters that formed part of larger networks, are the best vehicles to capture bottom-up water and climate change knowledge.

In the absence of these boundary organisations, the NGO and farmer groups from Ghana prefer the empowerment of local governments so they can constitute a platform to disseminate available knowledge. A suggestion by the NGO Oilwatch was to create multi-stakeholder knowledge fairs at local level that become continuous learning platforms from/for different sectors. Such knowledge fairs would also inspire locals to gain confidence in their own expertise and give them a voice.

Similarly, the local authorities consulted in Mexico highlighted the value of open source knowledge. This entails making all the local studies, research, consultations and analysis of aspects related to water and climate issues, available through a repository open to all that would need this information. In this way, local level knowledge and needs would be known widely.

Table 5 indicates the benefits and drawbacks of the two main options of consulting local individual organisations and engaging with boundary organisations as detailed by the Ghanian and Mexican stakeholders.

Table 5: Forms of capturing local knowledge in the context of water and climate needs through a bottom-up approach

Concept	Description	Example of the type of organisation	Benefits	Drawbacks

Individual Organisations	An individual organisation representing a specific stakeholder group	– Water Research Commission – River Basin Offices – Local NGOs – Farmer Associations – Traditional Leaders – Woman's Groups – Youth Groups	– No dilution of local knowledge and needs – Greater understanding of cultures, governance schemes and traditional systems. – Direct knowledge gathering, no misrepresentations	– Organisations that include only one type of stakeholder group. – To find out the local knowledge of an area you would need to approach many different organisations who may have opposing views / needs.
Boundary / Bridge Organisation	Multi-stakeholder platforms that incorporate top-down and bottom-up knowledge holders.	– Watershed council – National Learning Alliances – Clusters or networks – River Basin Organisations	– Multi Actor Stakeholders involved – Local knowledge gathering can be seen as a natural process in a boundary / bridge organisation – They bridge the gap between knowledge owners and knowledge users / application – Multiple perspectives of water and climate issues	– Depending on the stakeholder power dynamics involved, there is a potential for top-down processes to dominate bottom-up knowledge and needs – Dilution of local level needs as the knowledge gets transferred up to higher levels.

Establishing the entry points to knowledge capture has been detailed for the two cases of Ghana and Mexico, however establishing an entry point is one aspect, capturing the knowledge and integrating it into communication processes is quite another. In section 4.2 the barriers to effective bottom-up knowledge and needs information gathering is further explored from the two cases.

2.5.2 AD2: Bottom-up knowledge exchange barriers

The analysis of the stakeholder consultations has uncovered several barriers that operate against the effective exchange of bottom-up knowledge gathering. The barriers expressed by the consulted stakeholders from Ghana and Mexico include: the loss of power, influence and trust as the knowledge flows from the local level upwards; the lack of partnerships with key local partners; the lack of interest from key stakeholders; the lack of transparency in terms of knowledge flows and economic barriers to information flow. Further, important aspects mentioned included language and cultural barriers between traditional and national languages, and information technology tools that have not been fully realised, blocking information flow, which is most acutely felt in the rural areas (Fig. 4).

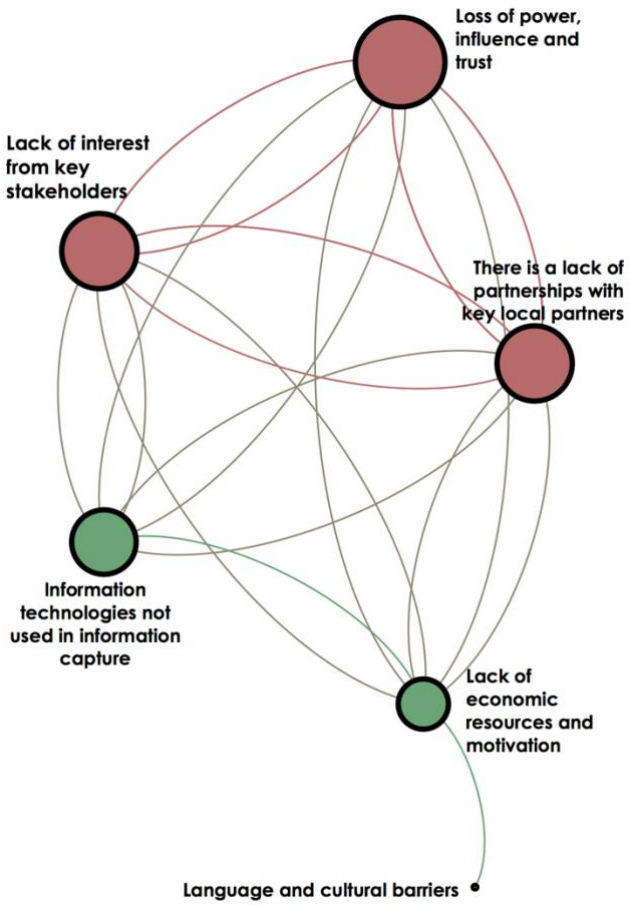

Figure 5: The main barriers as expressed by the consulted stakeholder groups from Ghana and Mexico to effective bottom-up knowledge and needs information gathering

* The red nodes represent both cases (Ghana and Mexico); the green nodes represent the Ghana case

The loss of power, influence and trust was the aspect most mentioned by both stakeholders in Ghana and Mexico. The Eigenvector Centrality measure of 1.0 for this theme indicates the influence of this theme over all the themes mentioned. With an Eigenvector centrality measure of 0.944 for the lack of interest from key stakeholders also indicates the importance of this aspect over the other themes mentioned.

2.5.2.1 The loss of power, influence and trust

The consulted traditional leaders in Ghana felt that their needs have not been integrated sufficiently into policy as one traditional leader noted "the government needs to take us seriously, because at the moment it feels like we are bothering policy makers instead of getting them to act to bring about policy changes". The consulted women and youth group representatives from Ghana feel that networks lose power and influence when the information gets sent upwards, and that their local specific problems may be disregarded in forming part of a more generalised national discussion.

The CSOs consulted in La Paz, Mexico, also highlighted their lack of power and influence in terms of transferring bottom up needs. They mentioned that a water and climate action plan exists at

national level, however, not at a local level (in La Paz) where the water and climate impacts are going to be most felt. Furthermore, the feeling of a lack of transparency and mutual trust, often due to recurrent changes in local and regional governments was also highlighted in La Paz. For example, the consulted stakeholders warned against engaging with the local watershed council in La Paz to obtain local knowledge as it is heavily influenced by the governing party and therefore any local knowledge would be tainted by the current political party mandates. A further example highlights this lack of trust where the director of the "*consejo de cuencas*" in La Paz, explained that a local governor recently ordered for all the water meters that were implemented by the previous governor to be removed. The interpretation was that the new governor wanted to make a statement against the use of water meters, disregarding the long-term projects for efficient water management. The CSOs in La Paz also talked about the lack of transparency in the local government regarding water and climate issues. Likewise, the woman and youth groups in Ghana unveiled problems of transparency linked to a perceived misuse of resources.

2.5.2.2 The lack of partnerships

The lack of partnerships with key local partners was another significant aspect mentioned in both cases (see **Figure 5**). The traditional leaders in Ghana highlighted the low level of networking actions and/or activities such as creating partnerships with key partners as a significant barrier to bottom-up knowledge capture. They further mentioned that the focus group held for this investigation was a first chance they have had to exchange knowledge on water and climate related issues with other key partners.

The CSOs in La Paz highlighted a similar issue. In their case, with their local (municipal) councils changing every three years, they have noted a lack of effective partnerships between governmental organisations and civil society. They note that this has created a barrier to bottom-up information flow.

2.5.2.3 The lack of interest from key partners

Even if partnerships have been forged, often they do not work well, as illustrated in the case of the "*consejo de cuenca*" in La Paz, Mexico. This 'bridge organisation' should have brought different types of actors together, but according to the consulted stakeholders, it did not work well as there was no interest in local water and climate needs as it was mediated by political party interests. One of the CSOs in the workshop stated that they had no idea what the *Consejo de Cuenca* does and what actions they take.

Both the local authorities and the CSOs in La Paz acknowledged a general lack of public interest in water and climate information despite this being a highly water-stressed area with ominous climate impact predictions. They also admit poor information flows towards the public. This general lack of awareness on water and climate issues is seen as a significant barrier for them to try and ensure that local knowledge is captured and information flows upwards towards policy and decision makers.

2.5.2.4 Further barriers to local knowledge capture

A further key barrier to capturing local level knowledge, highlighted by the participants in both Mexico and Ghana, was related to the lack of economic resources (see **Figure 5**). The consulted traditional leaders from Ghana indicated that many activities would need to be funded out of their "own pocket" and with their "own motivation". The traditional leaders also highlighted that there is currently no systematic proactive way of approaching their community and furthermore there is no planning involved to undertake participatory events. Intervention and financing, they state, is only brought when there is an urgent issue or emergency (i.e. a flooding event in the community).

Furthermore, the potential of information technologies has not been fully realised according to the consulted traditional leaders in Ghana (green node **Figure 5**). The consulted institutions from Ghana showed similar concerns. A specific claim was the differences in access between rural and urban actors; the attainment of information technology in urban areas is greater than that of the rural areas, and this can fragment knowledge between urban and rural actors. Although not a widely mentioned topic (as shown in **figure 4**), the consulted farmer and NGO groups from Ghana stressed the importance of language and cultural differences. In their view this creates barriers to effective bottom-up knowledge and needs information gathering. A case in point is the lack of language applicability, for instance translating relevant water and climate documents into local languages or that value systems in the different communities are not considered, which hinders knowledge sharing.

Table 6 provides a summary of the key barriers mentioned by the stakeholders and the reasons behind these barriers. Overcoming the barriers to capturing local knowledge, the evidence that the knowledge has indeed been integrated or exchanged is equally important. In **section 4.3**. we identify from the two cases in Ghana and Mexico how evidence of effective bottom-up knowledge capture has taken place.

Table 6: Summary of the barriers to effective bottom-up knowledge and needs information gathering and the potential reason behind **each** barrier.

Key barriers to effective bottom-up knowledge and needs gathering	Potential reason that the barrier exists as provided by the consulted stakeholders.
A lack of partnerships with key local partners	– Lack of opportunities to form partnerships or a lack of time to forge meaningful relationships. – Inability to identify key local partners or bridge organisations.
Lack of interest from key stakeholders	– Poor information flows to the wider public. – A lack of integrating the local level needs.
Loss of power, influence and trust	– Newly elected politicians want to make a statement regardless of local needs. – Political mandates overshadow interests in local needs. – Misuse of resources. – Local needs and requirements diluted when information flows upwards.
Lack of economic resources	– There is no planning in participatory events and therefore all actions are adhoc without provision for economic resources which affects the motivation to attend
Information Technology not used in information capture	– Full potential of ICT technologies in rural areas not yet realised.
Language and cultural barriers	– Lack of language applicability in translating crucial information into local languages. – Local cultures and value systems not taken into account when sharing knowledge

2.5.3 AD 3: Evidence of knowledge flow

Table 6 offers an overview of the key mechanisms required to evidence effective engagement processes highlighted from both case studies. Interestingly, in this area of investigation the stakeholders from both case studies concurred on four main areas to evidence effective information integration. The Eigenvector centrality metric of 1.0 for the implementation of participatory methods indicates its main influence over the rest of the themes. The interest, motivation and active engagement from community members has an Eigenvector centrality metric of 0.92 signifying its importance in relation to the other mentioned evidence. Creating partnerships/platforms between key stakeholders (Eigenvector centrality of 0.75) and local media reporting on the issues at hand Eigenvector centrality of 0.59) were also topics of importance, but less so than the first two (**Figure 6**).

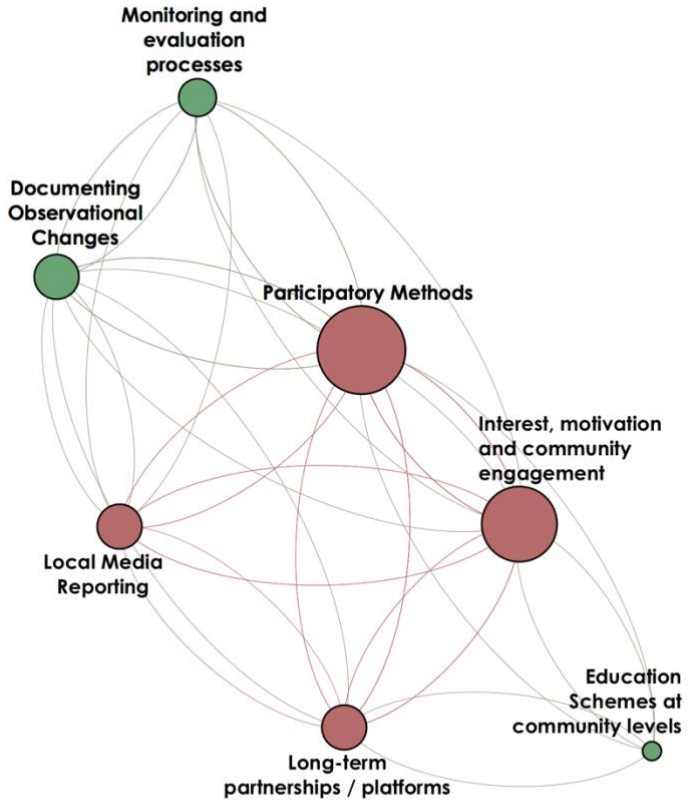

Figure 6: The evidence of effective bottom-up knowledge and needs information interaction and integration as expressed by the consulted stakeholder groups from Ghana and Mexico.

* The red nodes represent both cases (Ghana and Mexico); the green nodes represent the Ghana case

2.5.3.1 Participatory Methods

Indicated by the red node in **Figure 6**, the consulted stakeholder groups from Mexico and Ghana emphasised the importance of implementing participatory methods where local issues can be brought forward and subsequently repeated to know how knowledge capture was useful.

The traditional leaders consulted from Ghana felt strongly that education schemes should take place at local level and that documenting this can evidence that knowledge exchange has been effective. They mentioned various ways that this could be implemented: religious meetings, markets, community durbars, under tree meetings and in schools. The CSOs consulted in Mexico also felt that regular capacity and communication campaigns with regards to water and climate issues would allow for greater evidence of effective knowledge exchange.

The traditional leaders, farmer associations and NGOs from Ghana agreed that with the implementation of participatory methods, such as face-to-face discussions through workshops, meetings and conferences provides evidence of effective knowledge sharing. The Ghanaian local authority representing GIDA, emphasised the importance of face-to-face interactions with farmers as an aspect that is important to educate farmers and conduct assessments on water, analyse water quality, analyse crop yield and to verify if they have taken up information. In this regard, the local authority obtains quantifiable data, which is not only very helpful to them but also allows them to verify if knowledge exchange has been effective.

2.5.3.2 Interest, motivation and community engagement

The consulted local institutions from Mexico suggested that forums for information exchange on water and climate should be implemented at local level as this would drive community engagement and provide space to see how knowledge was taken up.

The traditional leaders in Ghana stated that the community were more motivated to participate and with greater interaction when an issue affects them directly. For example, if the water is polluted, communities will be easily engaged and interact to see how they can keep on using a safe supply of water. An interested, motivated and engaged community can provide evidence that effective knowledge exchange has taken place.

2.5.3.3 Documenting observational changes

The GWP representative from Ghana emphasized that a second round of face-to-face engagement processes, observing any changes, helps to know if the first participatory engagement processes have been effective. A further effective mechanism mentioned was to visit the areas of intervention to check if the implemented solutions are in line with the captured bottom-up knowledge. Farmer associations from Ghana shared this view, with a more hands on approach that included the use of technologies such as mobile phone applications. They have noted that these technologies emerge as an important way to share relevant information regarding changes in climate, weather, crop data and prices. When there is a change in the community or on the farm, it can be shared through a mobile phone application, to other farmers, relevant groups and communities. Using the data shared to create statistics on agricultural practices can improve understanding and improve information sharing and knowledge gathering. Using this technology, the farmer association participants stated that it provides proof of effective engagement as changes are observed and recorded at the local level.

Education schemes at community level and documenting the implemented experiences was also highlighted as an effective way to show that knowledge integration has been effective in both case studies. In a similar fashion documenting observational changes at farm level was also seen as an important way to evidence effective knowledge integration.

2.5.3.4 Long term partnerships/ platforms

The creation of partnerships, associations or networks involving all relevant local stakeholders was seen as an important aspect which was highlighted by all consulted stakeholder groups in terms of evidencing effective bottom-up knowledge and needs information capturing and actioning. The stakeholders highlighted the need to create partnerships and platforms so that all actors are represented and that the generated knowledge at local level is used. The consulted woman and youth groups from Ghana found that effective bottom-up engagement was generated through creating knowledge sharing platforms and documenting best practices and lessons learnt from these platforms. They also felt that the inclusion of traditional leaders within group exchanges were essential and that a "Climate Change Hub for Ghana" could be an essential starting point of including all stakeholders.

This concept was also tabled by the consulted local authorities in Mexico that stated that forums should be created and implemented to effectuate efficient and prolonged information exchange. This goes hand in hand with the previously expressed concern of the length of the governmental mandates in Mexico. Acknowledging that water and climate action plans should be greater than one governmental mandate, interviewees suggested that a water and climate plan should span for at least ten years, and be followed from one political mandate to the next. The consulted CSOs from Mexico held a similar view in that they stated that evidence is shown of effective bottom-up knowledge integration if there is continued interaction and collaboration between all the key stakeholders.

The consulted traditional leaders in Ghana stated that communities were more confident to interact with partnerships or platforms working in the area, especially ones that involve NGOs. There is greater trust with these organisations as there is legal proof of their registration and their activity in the government and that communities know that they are there to help, and without a hidden agenda.

2.5.3.5 Monitoring and Evaluation Processes

Monitoring and evaluation processes (M&E) were brought forward by the farmer associations in Ghana who stated that a M&E process for local farmers allowed for the evaluation of the effectiveness of previous engagements. The local authorities in Accra, also highlighted the importance of monitoring to show effective engagement for bottom-up knowledge gathering. They mentioned that water policy and monitoring help to find out if people are following the guidelines. Yet they stressed that there is a gap in a systematic feedback loop from the local level of these policies to measure their effectiveness. At the same time, they did mention some online feedback mechanisms. For instance, the WRC uses their website for sharing documents and reports and guidelines on the activities, although they do not have a feedback loop to know if this is effective. A walk-in library that people can use for research purposes and letter drop offs from the general

public are widely used for certain water and climate issues in Ghana, which gives them an indication that certain engagement activities have worked.

2.5.3.6 Local media reporting

The role of the local media is also seen as a vital point to know if local knowledge interaction and integration has taken place. The local authorities consulted from Ghana felt that if the local media was communicating on local water and climate issues it provided evidence that their knowledge interaction and integration had taken place.

Table 7 below provides a summary of the knowledge engagement processes and the corresponding evidence of effective bottom-up knowledge and needs information interaction and integration as expressed by the consulted stakeholder groups from Ghana and Mexico

Table 7: Multi-actor chosen criteria for effective bottom-up knowledge and needs information interaction and integration

Multi-actor chosen criteria that evidences effective knowledge interaction	Evidence of effective engagement
The continued implementation of **participatory methods**	Following a first set of participatory methods a follow-up processes should be implemented to evidence that previous knowledge has been integrated.
Creating partnerships / **platforms** between multiple stakeholders (**Boundary organisations**)	If a boundary or bridge organisation is created or enhanced to share and integrate knowledge this can provide the evidence that effective interaction has taken place.
Showing that education schemes exist at community level and **documenting the implemented experiences**	Through bringing in local education schemes and documenting the evidence of these schemes gives good evidence that knowledge integration is taking place.
Documenting observational changes (particularly at farm scale)	Observational changes or Information Technology integration evidencing changes at local level (especially related to farm level changes) indicates knowledge integration.
Implementing **monitoring and evaluation processes**	The implementation of Monitoring and Evaluation processes not only provides a feedback loop but can also provide evidence of knowledge exchange.
Sharing information on aspects that directly affect the community. Generating interest, motivation and active engagement from community members (example letter drop-offs)	If there is knowledge shared on aspects that directly affect the community, their interest motivation and engagement in these aspects gives evidence of effective engagement.
Local media reporting on the issues at hand	If there are reports from the local media following aspects that have been tabled by the local community, this can provide good evidence that knowledge has been taken up.

2.6 Discussion

The global coastal regions are in a position of double jeopardy, they are some of the most populated regions on earth (Toimil et al., 2020) which are going to be the most affected by climate change (Lu et al., 2018). Two coastal regions that are significantly at risk to the changing climate is West Africa (Amuzu et al., 2018) and Baja California (Martínez-Austria & Jano-Pérez, 2021). How effectively the communities adapt to these changes and how they can protect their livelihoods depends on their ability to include their needs and concerns within future coastal environmental policies and plans. Environmental managers (which include local authorities) on the other hand, require local level knowledge to incorporate lessons learnt from coastal communities currently facing these environmental stressors (Ayeb-Karlsson et al., 2016).

This paper has provided empirical evidence through a local level multi-actor participatory approach to identify and capture local level knowledge. Simultaneously, the paper has provided stakeholder identified barriers to the knowledge flow from bottom-up processes in coastal communities.

Furthermore, we respond to Raymond et al., (2010) call for local knowledge validation through providing local coastal area multi-actor chosen criteria that evidences effective knowledge interaction through bottom-up processes. This paper also covers the identified research gap of providing new insights on transdisciplinary approaches to knowledge production to formulating policies that include local and indigenous knowledge (Celliers et al., 2021).

The case studies from Ghana and Mexico provide differing idiosyncratic social, cultural, environmental, economic and governance perspectives. Settings that have the potential to be so different also have the potential to provide very contrasting perspectives to the questions posed to the local level stakeholders. However, our study has found that, at least in these two cases, even though their settings are different, they share the same barriers and vision to capture, integrate and validate bottom-up local level water and climate knowledge.

Identifying and capturing local knowledge is the essence of the first step in identifying the needs in a bottom-up process. By knowledge capture we mean the process by which knowledge is converted from the tacit to the explicit form (Pritchard, 2018). In responding to our first research question, we provide two main pathways to identifying and capturing bottom-up knowledge on water and climate needs. The stakeholders have indicated the importance of consulting directly with local organisations and engaging with Boundary / Bridge Organisations such as multi-actor platforms, advisory groups, associations, committees etc. Both pathways can be beneficial to capturing local level knowledge. In this paper we have provided the benefits and drawbacks of each option when looking to capture local level knowledge.

Although the stakeholders did not explicitly mention “boundary or bridge organisations” we know from the definition of a boundary organisation from Parker & Crona, (2012) that they are formal organisations existing at the interface of knowledge exchange and collaboration between all relevant stakeholders. Furthermore, we know that boundary organisations cannot be singular persons (Safford et al., 2017). The key difference therefore between consulting with groups or with “bridge or boundary organisations” is that the “bridge or boundary” organisation, incorporates all local stakeholders meanwhile consultation with local organisations consists in addressing each stakeholder group (e.g. farmer association or traditional leaders) on an individual basis that involves an organisation of one stakeholder type.

Seeing the value in bottom-up knowledge capture, the consulted traditional leaders in Ghana stressed that education in the participation of bottom-up approaches is key to ensure that the next generation are better skilled as a community to provide their input of their local needs.

This paper also provides a clear view of the barriers with regards to local knowledge flows and thus responding to Azhoni et al., (2018) call for further research in this direction. One of the main barriers expressed by the consulted stakeholders included the loss of power, influence and trust as the knowledge flows from the local level upwards. This concurs with what is frequently referred to as power inequalities in participatory processes (Reed 2008; Tseng and Penning-Rowsell 2012). The barrier to creating partnerships with key local partners as mentioned by the consulted stakeholders in turn decreases the potential for improved knowledge outcomes (Kirchhoff et al., 2015). This issue is further highlighted by Reed et al., (2016) who state that one of the challenges they found in integrated landscape and climate management lies in how to integrate community

issues and to maintain the motivation of the local people towards participatory monitoring processes, specifically once project financing has ended.

The lack of interest from key partners was a further noteworthy barrier mentioned. This barrier concurs with the research on how local engagement and social capacity of the stakeholders, such as access to information, motivation, and participation in networks and organisations is of importance in knowledge capture (Kuhlicke et al., 2011). Indeed, when the traditional leaders in Ghana stated that the community were more motivated to participate in issues that directly affected them it concurs with Buizer et al., (2016) who points out that a fundamental shift in engagement in their study on connecting climate predictions to local actions occurred when researchers no longer discussed forecasts but started to focus on environmental resource aspects that local people cared about.

Knowing that knowledge has been taken up and integrated or actioned allows us to know that the bottom-up knowledge capture processes have been effective. In responding to our final research question in knowing how we can evidence this fact, the stakeholders indicated, amongst other aspects, the need to implement participatory methods. These participatory events allow gathering local knowledge, validating knowledge already collected, and interaction between important actors on climate change issues. According to Parker and Crona (2012), these activities can be known as *Boundary Objects* which allow stakeholders of different communities to interact and coordinate their activities.

The creation of multi-actor partnerships/ platforms (essentially boundary organisations) was also advocated by the stakeholders to be a vehicle to show evidence of knowledge uptake. The concept of a multi-stakeholder platform for engagement and knowledge update and validation is not a new concept as it is extensively mentioned in the literature as a solution to effective engagement (Edelenbos et al. 2017; Fraser et al. 2006; Oteros-Rozas et al. 2015; Tseng and Penning-Rowsell 2012; Wehn et al. 2017). Our empirical research, however, concurs with these theoretical findings. However, with environmental challenges it is vital to have a competent Boundary Organisation that can offset the weak bargaining position of the less advantaged with concerns that weaker Boundary Organisations in combination with scientific work, can be used by national governments and business interests to control development activities of rural land users (Lee et al., 2014). This was very much a concern of the stakeholders from Mexico regarding the role of the “consejo de cuenca” in La Paz.

The implementation of monitoring and evaluation processes as further knowledge validation methods proposed by the consulted stakeholders can take various forms. For instance, the use of mobile phone applications by farmers in Ghana can show that knowledge has been received and integrated in how they use the applications. Indeed, through using this form and communication, it removes the institutional barriers and complicated communication networks to show directly how new knowledge is being implemented (Karpouzoglou et al., 2015). Further, our research provides Butler et al., (2015) information that monitoring and evaluation processes for the implementation of climate adaption strategies, especially in coastal areas, are currently being implemented.

2.7 Conclusions

Water management issues and climate change impacts are global phenomena. However, they affect most starkly the local level, especially the coastal regions. Consulting a range of stakeholders representing various organisations from coastal areas in Ghana and Mexico has given us a unique opportunity to engage at the local level. We consulted on how knowledge can be gathered, the barriers to knowledge flow and the evidence that knowledge integration has taken place. We confirmed that the identification of bottom-up knowledge and needs is a vital process to decision-making, environmental planning and coastal adaptation to ensure that local needs are taken into local, regional and national policy and global development agendas. Without which it seems that top down political agendas can be forced on local coastal areas.

To showcase the empirical advantage and bottom-up process of engaging with boundary organisations, our research methods identified and engaged with local organisations to gather local level knowledge. Our research therefore provides coastal area managers with practical stakeholder experience and examples of local coastal water and climate knowledge capture, integration, validation and barriers to knowledge flow. We believe this research will allow for better identification and integration of knowledge from local coastal stakeholders and provides coastal managers with salient information to implement effective policy recommendations and coastal community adaptation and planning.

While promising and finding space in the so-called citizen science approach, it seems that - according to the consulted stakeholders- ICT technologies still have a long way to go until they can effectively be integrated into a bottom-up and top-down knowledge exchange process. The overwhelming result from the empirical research is that face-to-face interaction and participatory processes are currently the better methods to identify, capture, exchange and validate local knowledge and needs. We have shown that the stakeholder groups in both cases of Mexico and Ghana concurred that platforms, networks and clusters were the effective mechanisms to bring stakeholders together and to share knowledge and to allow space for local needs to be expressed. These types of organizations all lie within the concept of a boundary organization that bridges the gap between local knowledge and high level decision makers. Engaging directly with individual stakeholder groups (for eg. Farmer associations, NGOs, traditional leaders etc.) is also seen as a highly effective method to capture local knowledge and needs.

Although numerous concepts for knowledge identification, barriers to knowledge flow and evidencing knowledge integration were mentioned, a common theme throughout for the stakeholders from Ghana and Mexico was the creation, enhancement or use of “boundary organisations”. In our case studies, these organisations have been set up in some areas already, such as the National Learning Alliance in Ghana or the Consejo de Cuenca in Mexico. However, our results have shown (especially in the Mexico case) that unless they are perceived as fully independent there is a risk that a bottom-up process of knowledge transfer is converted into a political vehicle that essentially forms part of a top-down process.

If a boundary organization does not exist, they can be created to fill this void of knowledge exchange between multiple actors. These types of organisations are also widely mentioned as a method to allow for continued interaction between stakeholders and therefore allows for the

barriers of knowledge integration to be overcome. Furthermore, the creation or enhancement of boundary organizations is mentioned as a means to show that effective knowledge interaction has taken place. Moreover, participatory activities (for example workshops) within these boundary organisations (known as "boundary objects") are effective mechanisms to show that knowledge interaction has taken place.

As coastal areas move towards finding solutions to the current and future impacts of water related climate change impacts, our research has shown that it is vital that there is interest from key stakeholders. Key partnerships should be implemented in these areas to effectively overcome the knowledge and needs barriers from local level and that the influence of the knowledge gathered in these organisations is not lost as it moves up.

Boundary organisations / multi-stakeholder partnerships that bridge the gap from local level to policy making level hold a potentially important key in this process. However, unless these partnerships undertake action and focus on the concerns of the local communities (for example, participatory processes, implementing local education schemes or monitoring and evaluation processes) interest in the issues facing local communities in coastal areas will not be garnered. Through our empirical research we advocate for the creation or enhancement of multi-stakeholder organisations (boundary organisations) within coastal communities. We see these organisations as vital vehicles to combat the climate change issues facing local coastal communities and in such our empirical research concurs with many theoretical studies on this subject.

We conclude this paper with a call for further research to focus on how boundary organsations should be established, organised and what their roles should be within the water and climate challenges that the local coastal areas are facing specifically in developing countries.

CHAPTER 3

Practical Stakeholder-based Indicators for Coastal Monitoring Frameworks

3

Turning the wheel away from biophysical indicators in coastal zone management: towards a stakeholder-based systemic framework[2]

3.1 Introduction

More than half of the world's population live up to 200 km inland from the coastline, a number that is set to double by 2025 (Inácio et al., 2018; Micallef et al., 2018). This stands to reason as coastal zones contain the most productive habitats around the globe (Eriksen & Silva, 2009) adding to the attraction for human settlement taking advantage of livelihood opportunities in these areas (Barragán & de Andrés, 2015).

However, the latest report from the Intergovernmental Panel on Climate Change (IPCC) suggests that the global mean sea level rise is accelerating (Oppenheimer et al., 2019). Moreover, non-climatic anthropogenic drivers –including rapid urbanisation in coastal areas and growth of megacities are adding to the pressure on coastal communities. Specifically with regards to exposure and vulnerability to the accelerated sea-level rise and extreme weather events (Stronkhorst et al., 2018).

Coastal areas are consequently progressively affected by climate change (Appelquist & Balstrøm, 2015; Appelquist & Halsnæs, 2015; Kronen et al., 2010; Zhu et al., 2010). The disruptive impacts are particularly challenging for developing countries where planning in coastal development is often lacking (Wong et al., 2014). Further compounding this issue, coastal migration has largely taken place in flood and cyclone-prone areas exacerbating the impacts from climate change (de Sherbinin et al., 2011).

Natural and human systems in coastal areas are extensively entwined as paired socio-ecological systems, yet they are often measured separately (Stojanovic et al., 2016). Typically, the natural systems of coastal areas include ecosystems and detailed biophysical attributes (Wong et al., 2014). Meanwhile, the human systems encompass the built environment, economic activities (e.g., tourism, aquaculture, fisheries) and the formal and informal institutions that organize human activities (e.g., policies, laws, customs, norms, and culture).

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[2] *A version of this chapter was published in Ecological Indicators in 2021. Smith, David J., and Beatriz Rodríguez-Labajos. "Turning the wheel away from biophysical indicators in coastal zone management: Towards a stakeholder-based systemic framework." Ecological Indicators 125 (2021): 107527.*
The results of this work was also discussed in a video meeting with Dr. Lars Rosendahl Appelquist, the founder and head of the CHW and the Head of Programme, for Marine Environment and senior expert for the United Nations Environment Program (UNEP).

These human systems are critical as they drive many of the impacts (both environmental and social) and changes seen at the local level in coastal areas. The drivers of these human systems involve a combination of social, economic, and institutional factors including taxes and subsidies, aesthetics and recreational attractiveness of the coast, as well as increased mobility (Bagstad et al., 2007; Palmer et al., 2011).

Identifying both the natural and human-related changes in coastal areas is essential in order to effectively manage them. Developing countries have a greater challenge in this regard, since data, capacity, expertise and economic resources are limited; further, coastal populations in these countries are generally growing more rapidly and haphazardly (Appelquist & Balstrøm, 2014).

In order to make sense of these changes, indicators with the ability to gather and present data in a relatively straightforward manner are required. Only then, can complex systems or phenomena be appreciated in a way that is reasonably simple to understand by coastal zone managers (Choobchian et al., 2015a). Indicators are useful for sharing the results of technical analyses or for monitoring the characteristics of these natural and human systems. They also enable comparisons across sustainability criteria or indeed across regions, as it so happens within the fisheries sector for example (Le Gallic, 2002).

Over the years, a plethora of indicators have been developed to give insight, monitor and manage coastal areas. However, the majority of coastal area indicators relate to the biophysical systems, with the human systems (for e.g. socio-economic, economic, governance, culture, norms etc.) requiring a more integrated or holistic focus (Becken et al., 2014; Biedenweg et al., 2017; King et al., 2014). Evaluating indicators in isolation provides a portion of the whole picture. Thus a systemic framework is required to help guide environmental decision making (Werner et al., 2014). (T. T. X. Nguyen et al., 2016) stress the importance of combining social and biophysical systems in an integrated framework, especially in relation to policy-driven assessments towards adaptation measures in coastal areas.

Numerous frameworks, models, and approaches try to make sense of these abundance of indicators to better manage and understand the changes taking place at coastal areas. Table 8 features a non-exhaustive list of approaches divided into four categories according to their focus ((i). social, (ii) interface between social and biophysical, (iii) biophysical, (iv) systemic). This list evidences the lack of an approach that encompasses all aspects of the indicator assessments at coastal areas. Indeed, what is clear from the literature is that there is a general lack of successful implementation of the different approaches (Suinyuy et al., 2016). There also seems to be a poor integration of the human system aspects of economic, political and governance facets within the majority of the indicator approaches.

Table 8: Indicator frameworks, models and approaches in coastal areas

Focus	**Framework/model/approach**	**Reference**
Social	Community Wellbeing index (CWBi)	(M. M. Buot & Cardenas, 2016)
	Multi-dimensional Poverty Index (MPI)	(Alkire & Santos, 2010)
	Community Based Management	(Baines, 1982)
Interface between Social and Biophysical	Drivers-Pressures-Ecosystem Services-Response (DPSER) model	(Kelble et al., 2013)

	Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism (MUSIASEM)	(Giampietro et al., 2009)
	Socio Ecological Systems at Coastal Areas	(Murphy, 2015)
Biophysical	Ecosystem health (in relation to coastal areas) (CEH)	(Costanza & Greer, 1995)
	Coastal Vulnerability Index	(Thieler & Hammar-Klose, 1999)
	Coastal Hazard Wheel	(Appelquist & Halsnæs, 2015)
	RISC-KIT Coastal Hazard Assessment module	(Van Dongeren et al., 2018)
	Coastal erosion risk assessment	(Narra et al., 2017)
	Smartline	(Lins-de-Barros & Muehe, 2013); (Sharples et al., 2009)
Systemic	Integrated approach to community-based coastal resources management	(Magpayo, 1995)
	Community Capitals Framework	(Flora & Flora, 2008)
	Integrated Coastal Zone Management	(Sorensen, 1993)
	Community Based Coastal Resource Management	(Maliao et al., 2009)

The Coastal Hazard Wheel (CHW) featured in Table 8 (Appelquist & Balstrøm, 2015) is a recently developed indicator-based framework that has raised significant interest at the practical level for its ease of implementation. As a rapid assessment tool to coastal hazards, it requires low or no primary data collection (Appelquist & Halsnæs, 2015). Examples of its implementation exist for India (Appelquist & Balstrøm, 2015), Timor Lest, and Malta (Micallef et al., 2018)). As evidence of its institutional significance, different intergovernmental organisations have adopted the CHW, including the United Nations Industrial Development Organisation (UNIDO), the United Nations Environment Programme (UNEP) (Appelquist Rosendahl et al., 2016) and the Climate Technology Centre and Network (CTCN) (CTCN, 2017).

Developed as a method to address coastal management issues, the CHW has a specific focus on the biophysical elements, with outcomes of the assessments indicating where further engineering interventions are required (. The method therefore assists regional planners and decision-makers in obtaining an overview of the hazard profile of the coastline and in identifying hazard hotspots (Appelquist & Balstrøm, 2015).

The lack in the consideration of the human systems within the overall assessment is a major shortcoming of the CHW framework. Indeed, its proponents already detected the need to add the human system to their framework: “supplementing the physical CHW assessment with socioeconomic data may in many cases be relevant for improving the information base for coastal planners and managers. This would provide CHW users with a combined picture of physical hazards and societal activities which could be relevant for supporting long-term planning decisions.”(Appelquist & Halsnæs, 2015:PP 9). However, to date, the incorporation of this type of data has not been included in any methodological development or practical implementation of the CHW framework.

Wider research also calls for the incorporation of human systems into these types of frameworks and assessments. (Howe et al., 2014a) identify research needs in the interplay between socio-economic factors, human well-being and ecosystems. (Calhoun et al., 2016) suggest that understanding the social-ecological system requires the consideration of the social, cultural,

historical, and legal/policy aspects as well. (Vugteveen et al., 2015) call for the development of indicators that identify the processes of social, economic and ecological subsystems for integrated management strategies in social-ecological systems.

Clearly, ecosystem analysts need to move away from thinking of ecosystem assessments as decision-making tools and treat them rather as an opportunity to understand and analyse the nature-society (i.e. natural and human system) relationships (Lele et al., 2013b). In the same vein, there have been calls for indicator sets at coastal areas to be more consistent, comprehensive and complete and to thus form part of the overall SDGs assessments (Griggs et al., 2014b).

Therefore, we can observe that there is a clear call to bring dedicated human system indicators into the current coastal area assessments to enhance management decisions and approaches, as well as to better understand the natural and human system relationships. This article therefore focusses on three main objectives aiming at pursuing this call:

1) To analyse the existing set of indicator themes and categories in coastal areas.
2) To contrast this set of indicators with the perceived needs of local coastal stakeholders from a developing country
3) To propose a set of indicator categories to be included as part of a systemic coastal zone management framework that takes it further than just the natural systems.

This paper thus provides the methods to which this investigation was undertaken followed by a section on the results, the discussion and the final conclusions that were drawn up and the suggestions for further research in this field.

3.2 Methods

A research framework (
Figure 7) was devised to facilitate the systematic collection of data and its subsequent analysis. The framework was guided by the three main objectives of this paper. The secondary data (scientific literature) and primary data (focus groups) collection was undertaken before their subsequent analysis using supporting software.

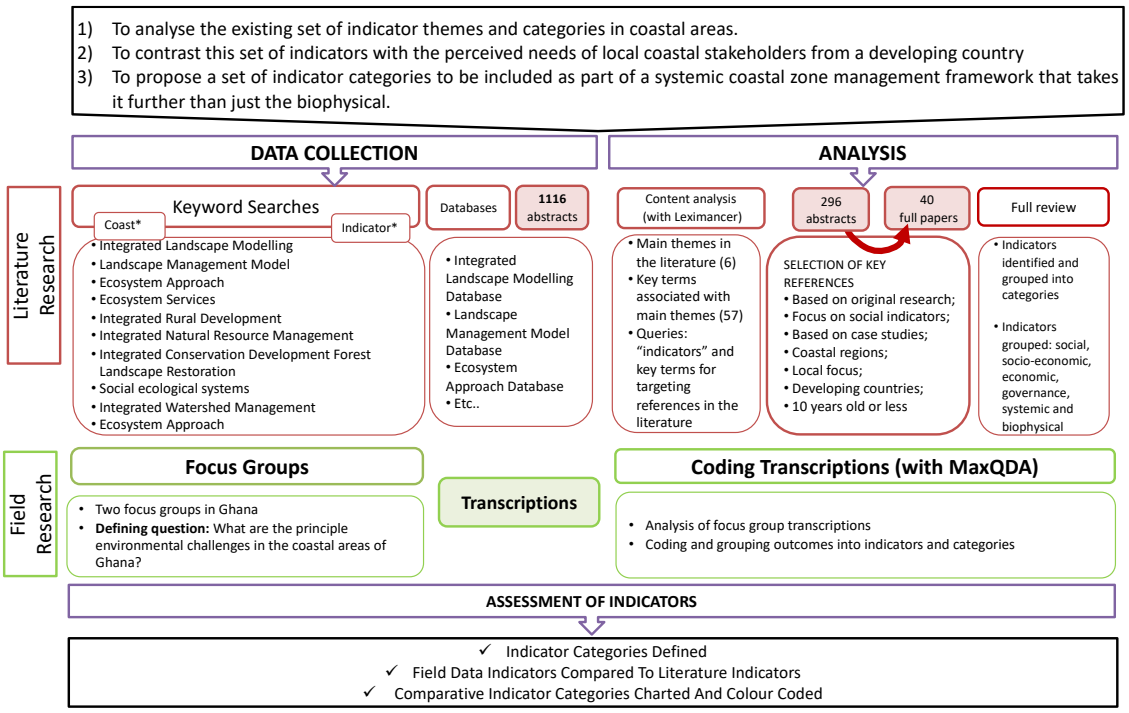


Figure 7: The Research Framework

3.2.1 Eliciting indicators from the scientific literature

A systematic evaluation of the peer-reviewed literature started with the first set of keywords: coast* AND environm* AND system* AND indicator* in the scientific databases Scopus, Google Scholar and Web of Science (February 2019). The first search strings were followed by a host of others, which eventually totalled a combination of 38 different keyword strings. This resulted in 1116 articles that were identified as relevant to this research. The sheer number of relevant articles is indeed symptomatic of the current challenge facing ecological research in that extensive literature exists on the subject, which is currently referred to as "big literature" (Nunez-Mir et al., 2016).

A further significant challenge in the analysis of the identified and selected literature is that the vast majority of articles involve qualitative outcomes in the form of narrative reviews (Koricheva et al., 2013). To overcome both these challenges we used *Automated Content Analysis* (ACA), i.e., algorithms that enable 'concept mapping', to ascertain the thematic composition of our body of literature. Themes in literature emerge from the frequency at which words and concepts appear and the relationships among them (Nunez-Mir et al., 2016).

The software program chosen to perform the analysis was Leximancer (Leximancer, 2019), which has been abundantly applied to ecological research (Cretchley et al., 2010; Grech et al., 2002; Knott et al., 2019; McCallen et al., 2019; Nunez-Mir et al., 2016; Penn-Edwards, 2010; Sullivan et al., 2018; Wavrek et al., 2017). Apart from the ability to perform ACA, Leximancer also provides a measure of the associations between concepts, which is an important aspect when looking to compare indicators in the literature. This step unveiled key themes, terms associated with those themes, and their connection to the word "indicator(s)". After removing 21 words without

substantial relevance (e.g., “different”; “results”; “paper”), we identified 36 relevant words from the ACA literature analysis.

Next, we selected the articles that included the term “indicators” as the main theme, together with other theme words that emerged from the ACA. The process yielded 296 articles whose abstracts were then reviewed against the following inclusion criteria:

- Based on original research, and not reviews or meta-analysis;
- Explicitly identifying indicators, with specific focus on social indicators;
- Based on empirical studies (case studies);
- Focused on coastal regions;
- Local focus (not national, regional or global);
- Case studies undertaken in developing countries
- The articles should be 10 years old or less

The particular focus on the social indicators is due to the perceived gap in the literature in measuring social indicators at coastal areas in comparison to measuring biophysical indicators. This research is concerned in covering the gap on 'social' indicators, without neglecting its relationship to all the other indicators. However, we realise that with the specific focus on the social indicators in the literature the biophysical issues, for example, may be under-represented, but the concern here is on the systemic indicators for coastal zone management (and the perceived under-representation of social indicators within these systemic indicators) and not with the state of the ecosystem.

This revealed a total of 40 articles that attained these requirements and were thus subjected to a full review. The indicator categories, sub-categories and individual indicators were then pulled out of each of these articles and included into a large Excel database.

For practical terms, we grouped the indicators under the following topics: “Biophysical”, “Economic”, “Socio-economic”, “Social”, “Built Environment”, “Systemic” and “Governance”. The grouping in this manner was based on approaches undertaken by other researchers, for example, (Abdullaev et al., 2009).

3.2.2 Eliciting indicators from stakeholders

Two focus groups were held in Accra, Ghana, in March of 2019. Ghana is a suitable location for our enquiry as it fits perfectly within the empirical criteria we used to select the articles, i.e. Ghana is a coastal area in a developing country that is heavily affected by climate change impacts. Additionally, the first author has extensive work experience and a network of contacts in the country that facilitated bringing together local relevant stakeholders into a focus group setting.

The focus group was chosen as a research technique as it employs “a guided, interactional discussion as a means of generating rich details of complex experiences and the reasoning behind [an individual's] actions, beliefs, perceptions and attitudes” (Powell & Single, 1996). The interest for this research was in gathering the perceptions and knowledge from local stakeholders and ensuring that viewpoints could be exchanged between the *quadruple helix* stakeholders that ensures

a wide range of opinions (Yun & Liu, 2019). This meant involving industry, academia, government and civil society from the coastal region in Ghana.

We conducted two focus groups ensuring a manageable number of informed stakeholders in each session (8 and 5 participants respectively). To ensure the representativeness of the informed stakeholder groupings the following the criteria were used: (i) The stakeholders had to be from Ghana; (ii) The stakeholders had to belong to one of the following stakeholder groups: NGOs; Farmer Org.; Youth Groups; Women Groups; Gov. Inst.; Traditional Authorities and (iii) The stakeholders had to have a relation to coastal zones. Working together with a local umbrella organization we recruited the informed stakeholders.

The stakeholders were tasked with providing their opinions on indicators related to systemic (natural and human systems) for environmental management in coastal areas in Ghana. The protocol for the Focus Groups outlined the main objectives and a set of guiding questions to help focus the discussions around the following objectives:

1. To define a set of criteria in order to choose practical natural and human system indicator (sub)categories that show the overall health of the environmental system.
2. To determine the needs and perspectives of indicators at local coastal areas in Ghana.

To analyse the data from the focus groups the recorded conversations were transcribed verbatim and then coded using the software program MAXQDA (MAXQDA, 2020). MAXQDA provides functions especially adapted for qualitative data analysis of focus group data (Saillard, 2011). Furthermore MAXQDA provides intuitive access to the focus group transcripts as well as to statements and contributions made by individual participants (Kuckartz & Rädiker, 2019). A code book was developed and imported into MAXQDA, which facilitated the coding of the transcripts grouping them according to the different types of indicators and indicator categories. These codes were further grouped into social, socio-economic, economic, biophysical, systemic, governance and built environment. Grouping in this manner allowed for a comparison to be undertaken with the results from the literature analysis.

3.2.3 Assessment of Indicators

The process described above yielded two sets of indicators for local coastal management, one set from the case studies in the scientific literature and the other from the stakeholders' perspective that are currently facing the challenges of holistic coastal zone management in their local area. In order to assess and analyse these two sets, the indicators were grouped into categories, sub-categories and lists of individual indicators using a spreadsheet (Excel). Their comparison unveiled indicator categories absent in the existing literature.

3.3 Results

1) Literature insights of indicator themes and categories

The content analysis, using Leximancer, of 1116 article abstracts from the original dataset (

Figure 8) revealed a number of interesting outcomes. It shows that studies regarding coastal systemic management focusing on the term ‘indicator’ connects to six main themes. The most frequently mentioned theme was ‘ecosystem’ (4269 mentions or ‘hits’). Clearly, this shows that the literature related to systemic coastal zone management indicators accentuates the notion of ecosystem services, as well as ecosystem-based management approaches, assessments and frameworks with particular emphasis on marine and fisheries aspects.

The following most common theme was ‘development’ (3699 hits) which has a strong link to the systems theme which in turn links to the management of ecosystems theme. The development theme further relates to human, environmental, natural, ecological, social and economic themes, signaling a clear focus and connection in the literature for both human and natural systems in relation to coastal area development. Interestingly enough, the development sphere relates to the ‘changes’ sphere (3049 hits) through the terms ‘local’ and ‘impacts’, pointing to local coastal areas as a place of environmental and social change. Looking further into the ‘changes’ sphere, the terms ‘climate’, ‘community’ and ‘water quality’ point to relevant aspects in local coastal areas.

‘Changes’ also relate to the ‘fishing’ sphere (1197 hits) through the term ‘results’. Therefore, a high number of case studies analyzing change focus on fishing and show results using indicators. Interestingly, in the ‘fishing’ sphere the terms ‘time’ and ‘production’ are connected to ‘indicators’ showing us the importance that the literature places on indicators that reflect time spent fishing and the subsequent effects on fish production.

The terms in the ‘forest’ sphere (262 hits), ‘forest’ and ‘land’, are both connected with the terms ‘areas’ (in the ‘change sphere’) and ‘indicators’ (in the ecosystem sphere). This positions forest lands in coastal areas as places of ecosystemic change that the indicators seem to be monitoring. Meanwhile the ‘urban’ sphere (168 hits) is the least frequent in the literature, connecting with the term ‘regional’ (in the ‘development’ sphere).

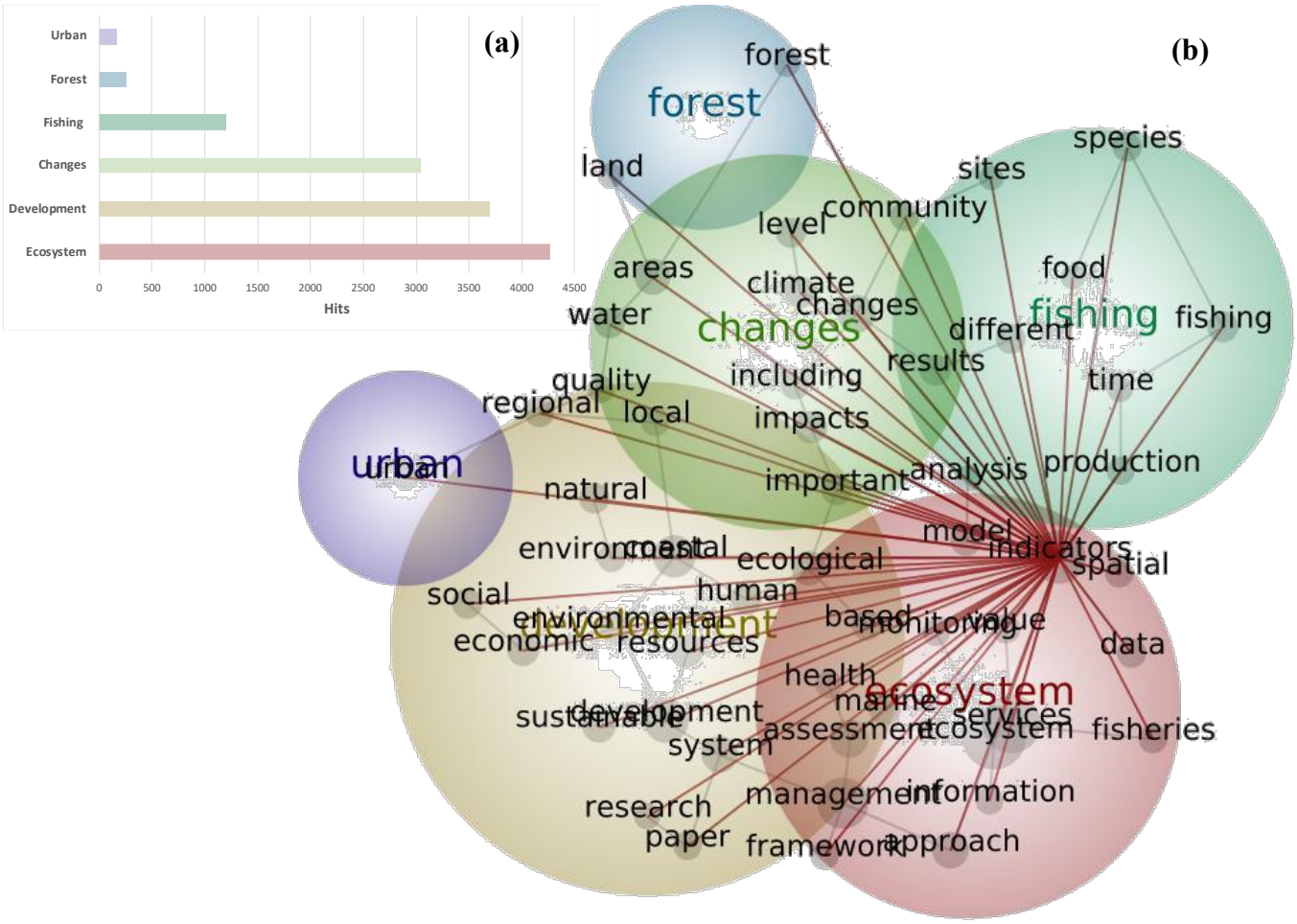


Figure 8: Graphic representation of main themes in the coastal management literature: (a) number of hits per theme; (b) relationship of the term 'indicator' with other terms. Source: Own elaboration using Leximancer

Figure 8 offers an insight into the topics that academic research has focused its interest on over the last ten years with regards to coastal systemic management and indicators. With the aim of advancing towards a systemic approach, using indicators for environmental management in coastal areas, we selected the terms (as described in the methodology) according to the well-established indicator categories of: Social; Economic; Governance; Biophysical and Systemic (Li et al., 2018) (Table 9). Admittedly, this categorization forces choices in some overlapping categories. However, this step was fundamental for advancing to the next step: to provide a convergent focus for the full article review on articles that are related to the subject matter.

Table 9 confirms, through the array of topics, that current research screened through content analysis concentrates on the biophysical aspects of coastal area management. Still, many terms fall under the systemic category, where a number of holistic management frameworks and indicators are used to support environmental decision-making processes at local level (Loomis & Paterson,

2014; Werner et al., 2014). The governance category did not reveal any other associated term and the economic category only revealed the associated term of 'economic'.

Table 9: Indicator category and its associated terms as a base for the classification framework

Indicator category	Associated words from Leximancer analysis
Social	community; social; human;
Economic	economic
Governance	-
Biophysical	ecological; environment / environmental; fishing/fisheries, marine; water; species; land; urban; soil; natural; forest; biophysical
Systemic	framework; spatial; model; sustainable; system; changes; ecosystem services; management; time; approach; regional; coastal; resources

Using the selection criteria described in the methodology yielded 40 articles that were subjected to a full review. Indicators were extracted from each of these articles (with the particular focus on social indicators) and classified according to the indicator categories presented in Table 2. Evident from the first full article review was that a further category of 'built environment' was required, and thus it was added to the classification framework. The grouping of indicators into the category of "built environment" at coastal areas was based on the approaches from (M. Buot & Dulce, 2019a; Tefe, 2012; Van Eijck et al., 2014). The category "built environment" considers the human-made environment, however at the coastal zones this indicator set does not take into account the urban context as this would be subject to an entirely different set of indicators.

An extensive list of individual indicators was extracted for each main indicator category. Analogous indicators – the indicators that had similar features to each other and thus comparable – were grouped together. A frequency count of the times that analogous indicators were mentioned in an indicator category is visually represented in Figure 9A.

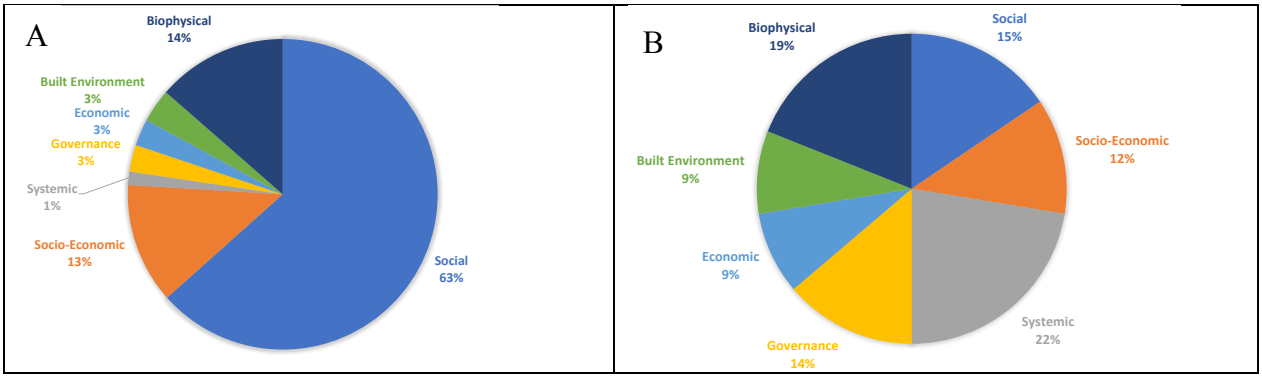


Figure 9: Frequency of indicators mentioned in the literature (A) and those mentioned in the field data (B).

This revealed that **Social** was the indicator category with the highest frequency of related indicators (63% of all the listed indicators). Examples of social categories can be found in (Choobchian et al., 2015b; Dacks et al., 2018b; Marín-Monroy & Ojeda-Ruiz de la Peña, 2016; Mollah, 2016) that trace aspects such as togetherness; livelihoods; access to basic services; security; health and education levels. They all highlight the importance the analysed literature has placed on community indicators.

The **Biophysical** category (14% of all the listed indicators) delivers a host of indicators from the analysed literature. They range from the specific (e.g., *reduction of emissions of industrial sulphur dioxide* (Meng & Chi, 2018) to the more general for instance the *Biodiveristy index* (Rakhmanissazly et al., 2018) and the *Coastal Hazard Wheel* (Appelquist & Balstrøm, 2015)) highlighting the vastness of this area of investigation and the need to specify locally relevant indicators.

The **Socio-Economic** category followed in frequency, with 13% of all the listed indicators. (Adger, 1999b; M. Buot & Dulce, 2019a; Tian et al., 2018) are examples of how socio-economic indicators can be used, i.e., in relation to coastal livelihoods and coastal economies; food provision; income stability and housing. Meanwhile, a host of authors (Clements, 2009; Dannevig & Aall, 2015; Dogliotti et al., 2014; King et al., 2014; Thaler & Levin-Keitel, 2016) show the importance of the indicator *'level of food autonomy'*, highlighting the relevance of self-subsistence at community level in coastal areas in developing countries.

The **Built Environment** (3% of all the listed indicators) from the analysed literature shows indicators related to aspects such as road infrastructure; water and light infrastructure; state of agricultural infrastructure (M. Buot & Dulce, 2019b; Camill et al., 2012; Ghisellini et al., 2016; McCarter et al., 2018). These indicators highlight the relevance of essential structures to livelihoods at local level.

The **Economic** indicator category (3% of all the listed indicators) focusses on the fishing and tourism sector, as could be expected at coastal regions. This entails indicators of fisheries household income (Miswar et al., 2018); fisheries contribution; market price of fish; income from fishing; share of catches per person (Choobchian et al., 2015b; Kronen et al., 2010) and tourism and recreation income (Choobchian et al., 2015b; Tian et al., 2018). Indicators in relationship to household economies also appear in the analysed literature: some examples include three or more income sources; savings ratio; ownership asset and household income as some examples from (Choobchian et al., 2015b; Dacks et al., 2018b; Kronen et al., 2010).

Examples of indicators within the **Governance** category (3% of all the listed indicators) focus on institutional aspects: institutional stability (Mollah, 2016); environmental services of institutional ecosystems (Zaldívar-Jiménez et al., 2010); total sustainability of institutional criteria (Choobchian et al., 2015b); fishing tools policy (Choobchian et al., 2015b); land management policies (Roy et al., 2018) and protective areas including coastal protection and species protection (Tian et al., 2018). This highlights the relevance the literature has placed on an integrated or holistic look at policies, but also the importance placed on the need for institutions to be stable and sustainable in developing countries.

Finally, the **Systemic** category of indicators (1% of all the listed indicators) from the analysed literature was the least featured. Examples include: cooperative's roles; total sustainability of coastal management criteria, as well as indicators related to frameworks (e.g., Energy Systems Theory (EST) and Emergy Analysis (EA)) (Berrios et al., 2017). Also within the systemic category we found indicators of central tendency and dispersion measurement (Bandoc et al., 2014), ecosystem approach (Engler, 2015) and Community Based Management (Borges et al., 2017; Boyd

& Charles, 2006; Courtney & White, 2000; Lawson et al., 2010a; Pomeroy et al., 1997; K. Sherman, 2014). These indicators provide a relation to theories, approaches, analysis or management models which highlight the complexity of implementation in practical terms.

The analysed literature thus reveals a variety of entry points to better portray the processes involved in the management of coastal regions, with a focus away from developed countries according to the OCED definition (United Nations, 2005). We acknowledge the diversity of the so-called "developing countries" that could be divided into several sub-categories, from least developed, transition to emergent economies. We have further addressed this point in the discussion.

2) Indicators from the bottom up

The perspective from the local level stakeholders provides an insight into the potential indicators that are relevant to monitor and control the natural and human systems at local coastal areas. The coding of the transcripts from the focus groups thus disclosed a greater need for governance, systemic and economic indicators at local level in Ghana than those that have emerged from the literature review. The coded categories are represented in Figure 9B. Biophysical (26% of all the coded indicators) and Governance (25% of all the coded indicators) were the categories with the most frequently mentioned indicators by the local quadruple helix stakeholders. These were followed by the categories Systemic (16%), Socio-Economic (7%), Built Environment (8%), Economic (9%) and Social (9%).

Diving deeper into the sub-codes mentioned within each category, the analysis disclosed 35 sub-categories of indicators. Within the category 'Built Environment' *Climate Affected Structures* was the most frequently mentioned item by the focus group participants (6,19% of all the listed sub categories). A participant from the Fisheries Commission gave insight into the reason for this: "*along the coast it* [climate change] *affects a lot of infrastructure houses and things in my community. A lot of houses have been destroyed*."

Within the Biophysical category 'changing rainfall pattern' was most frequently mentioned with 5.15% of the total mentioned items. "*About the rain, we also have periodic drought, for example, in the first rain the farmer thinks 'ok let me start preparing for farming' and then all of a sudden the rain breaks so there are alternative issues of drought and flooding*", comments a local private company participant.

Community Associations (5.15% of the total mentioned items) were most frequently mentioned within the category Governance. A participant from the Fisheries Commission provides insight into the reason for this talking about equipment for fishing: "*two or three of them* [fishermen] *should come together* [cooperatives] *and have a stronger vessel to work with*".

Within the Economic category the most frequently mentioned sub-category was 'climate affected incomes'. A participant from a farmer association explains why: "*I have 5 acres of land. I'm not getting the same harvest as before as a result of the climate and the weather. Last year there was no crops and the mango it doesn't bear fruit; this has affected my income*"

Education (4.12% of the total mentioned items) was the most frequently mentioned sub-category within the Socio-Economic category. The same participant from the farmer association gives insight into this: "*Until the government changes the policy that at a certain age children should be made to go to school and shouldn't be seen loitering around the villages - because school is better, its free - but until that policy is made, we will have trouble with the children in the villages as the elders and leaders cannot enforce them to go to school*".

Within the Systemic category both with 4.12% of the total mentioned categories are the sub-categories of 'holistic fisheries management' and 'Information Exchange'. On the topic of holistic fisheries management a participant from a company supporting farmer associations explains: "…*so we asked the oyster fishermen what they wanted to do, and they said that they wanted to have greater income. So, of course, what we did is we put that into a holistic management context with measures to show where it fits. So we don't want to harvest more, we want to add value to the little harvest they have. For example, if I am harvesting three but I am getting the same income level that I was getting* [when I was harvesting two]*, there is no motivation to go in to harvest more. We help them to understand this*". The need for a sub-category of Information Exchange becomes apparent in the words of a participant from the Peasant Famers Association of Ghana: "…*for example, if the farmers have issues with chemical fertilizers, this is an issue that they can speak out on at the district level".*

Under the Social category the sub-category of 'Social Information Exchange' had the highest frequency of mentions with 3.09% of the total sub-category mentions. "*It depends on what you want to communicate. In the oyster community, most of the community do not read or write. Then you need to be careful with the kind of information that you share - you should have some positive communication as opposed to negative communication, instead of showing pictures of "don't do this" show pictures of "do, do this",* stated by a participant from the private company.

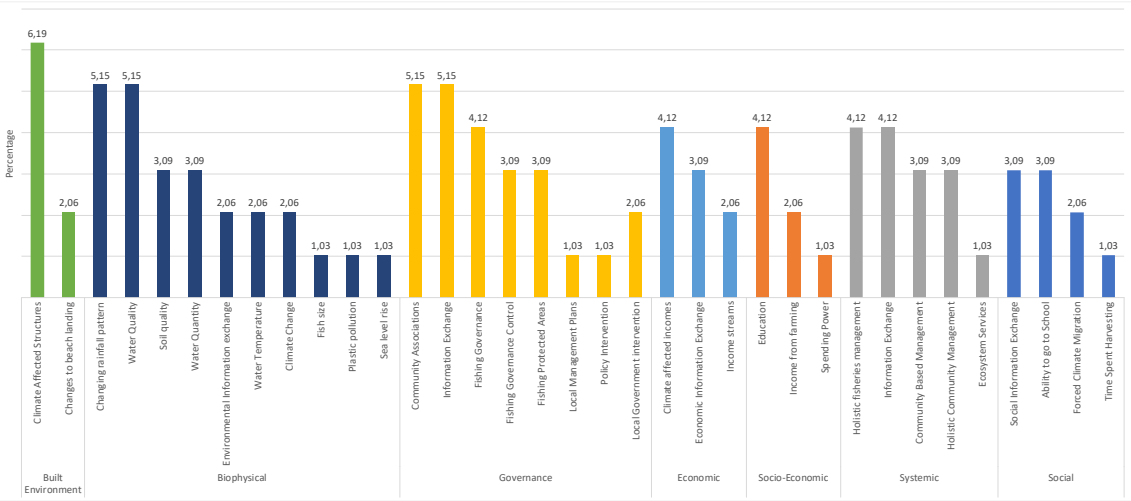


Figure 10: Categories and their sub-categories of indicators from the focus groups, with the percentage of mentions of a sub-category in relation to every other sub-category.

Other than the frequency of times a sub-category is mentioned it is important to observe their interaction, as it can signal groupings of indicators of that are of interest for management or monitoring. Figure 11 shows the sub-categories mentioned together and their the frequency of times mentioned (the number in brackets).

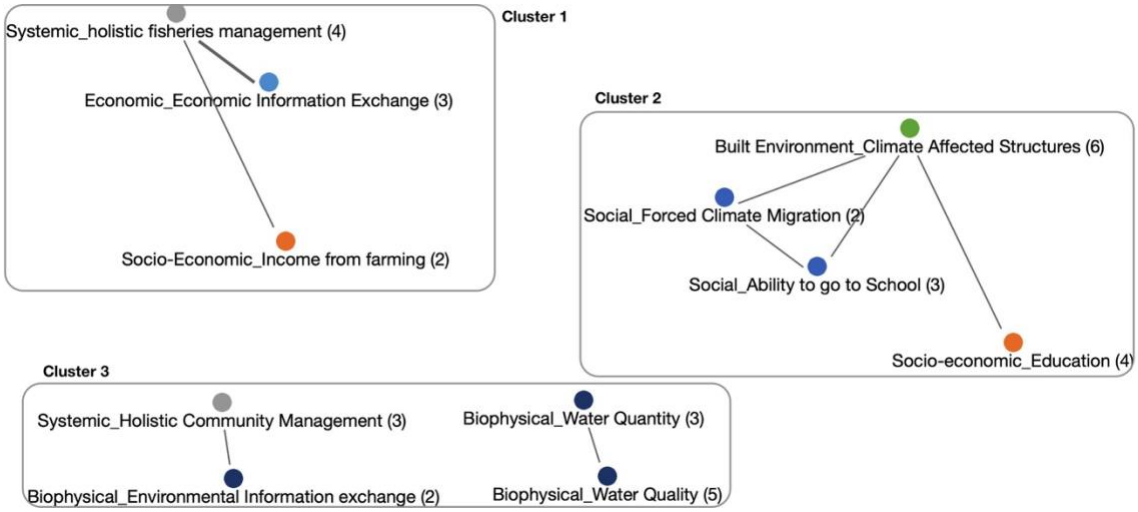


Figure 11: Clustering of the co-occurrence of codes mentioned from both focus group transcriptions. *The code colours match those of the indicator categories in Figure 3.

The code map (Figure 11) is developed through the multidimensional scaling method (Bazeley, 2009) which is used to position the codes on the map given the distances between them. The intersections of the codes are placed in accordance with the number of times two codes have been assigned to a segment together. In this case our interest was to know which codes intersected (co-occurred) in a segment of the transcripts from both focus groups. This allows us to know which indicators could potentially be correlated together allowing for indicators to be handled together, either in terms of joint measure or for selecting one as a signal for a cluster.

The code map can be clustered into three clusters of codes (i.e. indicators) that have intersected in the transcripts. In intersected codes cluster 1, *Systemic Holistic Fisheries* management was central to *Economic Information Exchange* and *Socio-Economic Income* from farming. This is evident from the reflection from a social advocate participant who mentioned: "*one of the other things that is affecting the local fishermen is the lack of technology or the lack of understanding of the devices to detect the weather patterns. For instance, the fishermen are already set to go out fishing but all of a sudden there is a heavy wind from the sea. So that has disrupted their activities for the day […] What is clear is that they do not have access to this information that can help them to plan ahead and thus they have lost out on their economic activities of that day. I believe that if the fishermen are equipped with these modern technologies, communications and devices they will know the effects the weather will have on their activities and this will also help them to plan better.*"

From cluster 2, participants from the focus groups highlighted the relationship between the following indicators: *Climate Affected Structures* (Built Environment), *Forced Climate Migrations* (Social), *Ability to go to School* (Social) and *Education* (Socio-economic), indicating that the one affects the other. The intersection of these codes is evident from the reflection from an education

youth group participant that mentioned: "*I would like to touch on education and coastal communities as climate change has already affected the infrastructure by destroying some local schools. Students have then not been able to go to school in their community and they have to travel quite a distance to another community to go to the school there*".

Within cluster 3, unsurprisingly, water quantity co-occurred with water quality. A representative from a local development consultancy stated "*along the coast there is some fresh patch of water on top of the salt water. But with climate change, now that level of freshwater is being infiltrated by the salt. This creates a combination of things. […] Normally if it rains then the aquifer is recharged, but with the lack of rain, we now have more of the brine water coming up, so it affects the soil quality*. Furthermore, within this cluster, holistic community management co-occurred with Environmental Information Exchange. A social advocate participant, after listing several types of climate and market-related information and services provided to farmers and communities, he reasoned: "…*what I think ESOKO* [Digital Solutions for Agriculture and Data Collection] *needs to do is to add more environmental information about the coastal area as well as economic information and social information and they would need to provide this information in the local dialects in order to solve the high social needs of those places…*"

3) Contrasting the Literature and Field Indicator Categories

The two components of Figure 9 described individually in the sections above can be now compared side by side. We note that the social category (Figure 9A) has the greatest representation meanwhile the systemic category was the least represented from the analysed literature. Meanwhile, the analysis of the data from the focus group participants (field data) reveals an even spread between the indicator categories, with systemic proving to be the category the participants showed slightly more importance towards. Here we note the relevance of bottom-up vs a top-down approaches where a significantly higher importance was placed on the social category from the field data than the top-down literature analysis (a frequency of 63% and 15% respectively).

The difference between the perspectives of academic research and local stakeholders creates a valuable opportunity to assess the state and prospects of indicators for systemic coastal area management. In this respect, Figure 12 offers a visual representation of the subcategories of coastal zone indicators by combining insights from the literature and from the field data. This visual representation aims at reinforcing the range of indicators included in coastal indicator frameworks, in order for the natural and human systems to be taken into account together.

We created a classification system that sorts the indicators into five situations according to their saliency in both the literature and in the field. A colour code qualifies each situation. With 20 or more mentions of a certain sub-category in the literature and if that sub-category was mentioned (presence) in the focus groups, the sub-category was coloured green; if its salience in the literature was less frequent, between 1 to 19 mentions, and was still mentioned (presence) in the focus groups, the subcategory was then coloured light green. If, however it appears in the literature but was absent in the field, it was coloured light yellow (when it is abundantly mentioned in the literature, with at least 20 mentions) or orange (when it is less mentioned in the literature, with 19 mentions or less). If there was no mention of the sub-category from the literature but there was a mention of it (presence) in the field data, it was coloured red.

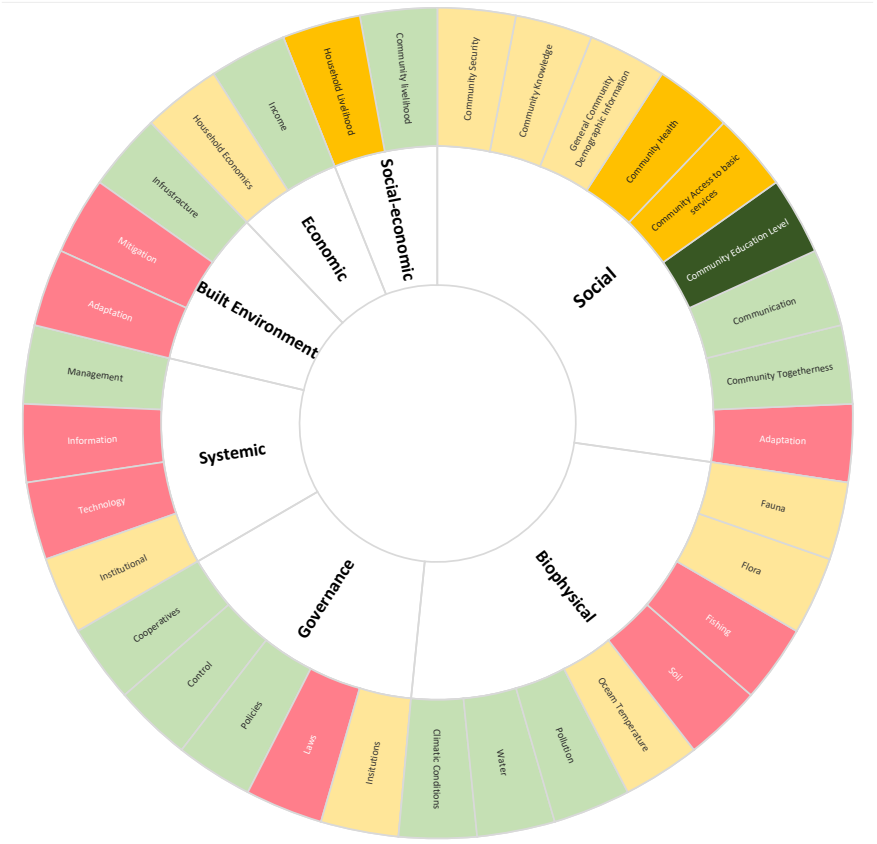


Figure 12: Homogenised literature and field sub-category coastal zone indicators

Figure Key

		Field data	
		Presence	Absence
Literature data (No. times mentioned)	≥20		
	1-19		
	0		

Therefore, Figure 12 helps us to distinguish three different scenarios in terms of the indicators for systemic coastal area management. The **first scenario** is a co-occurrence of the literature analysis with the identified needs from local coastal stakeholders. There is a total of 14 analogous indicator subcategories that were mentioned in both the literature and the focus groups, across all the indicator categories (see examples in Table 10). These could be the first candidates towards an expansion of the current existing frameworks vis-à-vis becoming more encompassing of the aspects beyond just the biophysical or social elements currently focussed on in the literature.

Table 10: Combined mentions in the literature and field data of the indicator sub-categories with examples of locally (Ghana) defined indicators.

Category	**Sub-Category**	**Indicator example (from the Ghana focus groups)**
Social	Community Togetherness	*Number of associations that are present in the community*
	Communication	*Number of information exchange events (meetings, presentations etc) held in the community.*
	Community Education	*Number of children that have the ability to go to school.*
Socio-economic	Community livelihood	*What is the trend in the economic spending power*
Systemic	Management	*Is there a community-based management plan in place?*
Governance	Cooperatives	*Do cooperatives exist at local level (fishing, canoe sharing etc.?)*
	Control	*Are closed fishing seasons implemented?*
	Policies	*Do policies exist against beach sand mining?*
Economic	Income	*Number of community members that are changing their principle income stream*
Built Environment	Infrastructure	*Number of infrastructures destroyed by climatic events over the last 10 years and the number rebuilt since.*
Biophysical	Climatic Conditions	*Rainfall patterns over the last 10 years.*
	Water	*Changes in the lagoon salinity levels.*
	Pollution	*Tons of plastic present in the lagoon in 1 year*
	Fishing	*Change in fish sizes and in fish catch*

The **second** scenario is where we have the sub-categories mentioned in the literature but not mentioned at the local Ghanaian level. In this case, there are 12 sub-categories that have emerged from the literature that at local level, in Ghana, were not considered by the stakeholders. This outcome is crucial as it shows us that a first approximation to the local stakeholders needs to be undertaken to know what is important to be considered in each local coastal community. In other words, armed with a full set of sub-categories, a researcher can approach a local community to discover from the sub-categories which have relevance for them to measure and monitor in terms of their local coastal management of the natural and human system needs. The differences in the types of sub-categories mentioned in the literature also reveals the encompassing nature of the literature case study data. A number of categories from the literature expose the types of indicators that could potentially be more commonly used in least developed, transition and emergent countries than in Ghana. For instance, coastal infrastructures indicators may not emerge from the local stakeholders in Ghana as infrastructure is not seen as an issue that may be a more significant issue in other developing countries. Table 11 provides the sub-categories mentioned from the literature that did not have any mentions from the field data, with some examples.

Table 11: Sub-categories from the literature not mentioned in the field data.

Category	Sub-Category	Indicator example
Social	General Community Demographic Information	- *percentage of population below 6 years of age* - *percentage of dependent population* *(Mollah, 2016)*
	Community Access to basic services	- *percentage of community access to health services (Nemes, 2005)* - *percentage of community that has access to water* (Alamarah Tamimi et al., 2007; Appelquist & Halsnæs, 2015; Biedenweg et al., 2017; Dondeynaz et al., 2012; Ghermandi et al., 2009; Howe et al., 2014b; King et al., 2014; Marín-Monroy & Ojeda-Ruiz de la Peña, 2016; Mussetta et al., 2017; Narra

		et al., 2019; Nemes, 2005; Rosendahl Appelquist, 2013; Shifeng Fang et al., 2014; Strezov et al., 2017; Tian et al., 2018; Vallès & Oxenford, 2015; Vella et al., 2009)
	Community Knowledge	*Utilization of local knowledge on resource management (Biedenweg et al., 2017; Miswar et al., 2018)*
	Community Security	*Number of homes and farms located in areas of floods or landslides (Dondeynaz et al., 2012; Hove et al., 2016)*
	Community Health	*body mass index / Human Development Index* (Biedenweg et al., 2017; Ghisellini et al., 2016; Kwasi et al., 2011; Marín-Monroy & Ojeda-Ruiz de la Peña, 2016; Strezov et al., 2017; Tian et al., 2018; Vallès & Oxenford, 2015)
Socio-Economic	Household Livelihood	*Number of families with Credit support and insurance (M. Buot & Dulce, 2019a; Matzdorf et al., 2014; Rakhmanissazly et al., 2018)*
Systemic	Institutional	*Total sustainability of institutional criteria (Choobchian et al., 2015b)*

The **third** scenario is where the local Ghanaian coastal stakeholders have mentioned sub-categories of indicators that were not uncovered in the 40 articles that were subjected to a full literature review. This case shows us that although a researcher may believe to have uncovered all the potential indicator categories from the literature and the current indictor frameworks, there may still be potential indicators that need to be taken into account from a local perspective – at least from the evidence obtained from the case study in Ghana. In this sense, it reiterates the need to have indicators that encompass a wide range of aspects but that ultimately take the local level needs into account. Table 12 provides the sub-categories that were mentioned from the field data but that did not have any mentions from the literature.

Table 12: Sub-categories from the field data not mentioned in the literature.

Category	Sub-Category	**Indicator example (from the Ghana focus groups)**
Social	Adaptation	*Number of adaptive measures that have been brought in that affect the community (i.e. after a school was destroyed by a storm, the kids stayed at home).*
Systemic	Information	*Full systemic information available to farmers / Farmer access to information regarding the systemic management of the local area / Is information available to be used by farmers? Eg. smartphones, climate data, fishing data etc.*
	Technology	*Do fishermen have access to technologies that can allow them to manage all their fishing aspects in an integrated manner (for e.g. weather devices, radios, communication technology etc.)*
Economic	Income	*Number of community members changing economic activities (i.e. from fishing to farming) / Changes in rain fed crops to irrigated crops*
Built Environment	Adaptation	*Number of recent changes made to the built environment in response to climate change impacts that improve the community livelihood*
	Mitigation	*Number of well-developed landing beaches in the local fishing community that can support larger vessels*
Biophysical	Ocean Temperature	*Changes in sea water temperature*
	Soil	*Changes in Soil salinity*

3.4 Discussion

Climate change impacts are currently referred to as a climate crisis (Brugger & Crimmins, 2015; Hoppe et al., 2013; Navarro, 2018). Some countries across the globe are better prepared than others to cope with the impending climate change impacts. For instance, Bangladesh is purported to be one of the most vulnerable countries to climate change in the world (Minar et al., 2013), however it is better prepared than most developed countries in terms of adaptation and mitigation measures. As in Bangladesh, West Africa - specifically Ghana - is going to be one of the more climate vulnerable developing countries affected by coastal zone impacts (Sylla et al., 2016), this determined our choice of empirical reference. Our analysis provides a fined-grained identification of indicators from the literature and from the field that are relevant for the management of coastal areas of developing countries that are highly vulnerable and/or that are currently affected by climate change (and extreme weather) impacts.

While negative impacts will manifest on the biophysical and built environments, it is society that will bear the brunt of these impacts (Adger, Brown, et al., 2005; Azhoni et al., 2018b; Clements, 2009; Odemerho, 2015; Rasul & Sharma, 2016). Our results mirror the idea that the way in which different shorelines and marine environments are managed, and what they are managed for, should be a reflection of what society wants from those environments (Loomis & Paterson, 2014). Therefore, the measurement and monitoring of climate change effects and coastal management should include not only the natural systems but the human systems as well.

Thus, it is important that the integration between the natural and human systems relies not only on the scientific advancement in this field but the practical implementation thereof. Therefore, screening the literature to identify the academic advancement, has been an important element of this research, however, the contrast with local stakeholder needs is vital to ensure that the entire process of developing a systemic framework is not only guided by the theoretical approaches that would have difficulty to be implemented.

Unsurprisingly 83% of all the indicators identified in the literature and 70% of the indicators identified in the field refer to domains outside the physical environments and thus emphasizes this human dimension.

Accordingly, we contribute to the idea that a holistic set of indicators at coastal regions with a focus on the local level is well-suited to aid decision makers. The choice of the right indicators expands their information base on what society wants and how to protect society from climate change impacts.

A recently implemented CHW framework in West Africa as part of a UNIDO funded and CTCN managed project highlighted some of the shortcomings of the CHW framework (CTCN, 2017). The report highlights that even at its first evaluation phase, the CHW would benefit greatly from having a set of rapid social, economic and systemic assessments, with the possibility to expand the list of potential management options of the CHW to include governance or political implications.

A combination of literature and local stakeholder-based sub-category indicators - obtained from Ghana - has allowed us to define three scenarios for uncovering indicator sub-categories that could

be included as part of the current set of measuring and monitoring indicators for natural and human systems at local coastal areas. The first scenario (a co-occurrence of the literature analysis with the identified needs from local Ghanaian coastal stakeholders) is the one we promote to be incorporated into the current coastal indicator monitoring frameworks (for example by upgrading the CHW – the framework advocated for use in developing country contexts). This could be by including for instance the sub-category "Community Togetherness" by measuring the number of associations that are present in the community.

The other two scenarios (**scenario 2**: sub-categories mentioned in the literature but not mentioned at the local level and **scenario 3**: local Ghanaian coastal stakeholders mentioned sub-categories of indicators that were not mentioned in the literature) offer insights in terms of implementation, rather than on expanding current indicator frameworks. These last two scenarios imply that coastal management indicator frameworks should be adapted to each local situation. They show us that coastal zone indicator frameworks uncovered in the literature need to be adapted to the natural and human systems at local coastal areas.

3.5 Conclusion

This paper has detailed the process of discerning, accessing and analysing a complex set of indicator data that has exposed indicator categories and sub-categories. The paper has furthermore contrasted these results with the perceptions and needs of the local quadruple helix stakeholders from the coastal areas in Ghana. Finally, a set of sub-categories has been proposed to be included within the current monitoring/hazard assessment frameworks that combines the natural and human systems.

Literature analysis is no substitute to local assessments and the subsequent understanding of local conditions. Then again, local assessments are no substitute to a literature analysis. This is no more evident than shown in our results where the literature focusses predominantly on social sub-categories of indicators, meanwhile at the local level there is a greater integration of these natural and human systems. The unique contribution of this paper is the combination of literature and stakeholder-based indicator sub-categories that should be added to the current set of coastal monitoring frameworks - such as the Coastal Hazard Wheel - to ensure that the natural and human systems are considered holistically. In other words, our methodological process of combining both a top-down (literature) and bottom-up (local Ghanaian coastal stakeholders) indicator identification has provided the platform for the inclusion of local expert knowledge based on internationally accepted indicators for coastal zone management. This insight provides a salient call to field analysts and the donors or policy makers that commission the work to take into account the value of local experts and local knowledge when devising the natural and human system indicators for coastal zone management.

Researchers at coastal zones should continually drive to be multidisciplinary, focusing on the interconnectedness and the knock-on effects of one system on another. An observation from one of the participants of the focus groups provides the reasoning for this, where she described how an extreme storm destroyed a local school. This resulted in the children no longer able to go to that school meanwhile, those that could, had to travel to the next village to attend school. All participants seemed to have a similar experience to this one as this observation was backed up with

anecdotes of how those children that could no longer attend school spent their days loitering around the villages, some turning to crime. From these statements, there is no clearer evidence of how the natural system has impacted the human system and the very reason why both systems need to be measured and monitored and included in the current coastal frameworks that are devoid of these combined indicators.

To build in these sub-categories into the frameworks currently available we propound to focus further research on integrating the human and natural system indicators prioritised from a stakeholder base of data that is easily obtainable. Furthermore, there is a strong need to investigate the concept of weighting or indeed non-weighted indicators and subcategories in function of their importance. Finally, we propose that further work needs to take place in the visualisation of the collected indicator information to provide managers with stronger coastal zone management tools.

CHAPTER 4

Stakeholder Matched Data Visualisation Tools and Techniques

4

I can see clearly now; the data is visual. Stakeholder chosen visualisation tools and techniques to foster enhanced coastal area development and resilience in Africa[3]

4.1 Introduction

Population growth coupled with economic development and growing urbanization place coastal areas at increasing risk to the changing climate (Narra et al., 2019; Wong et al., 2014). Human activities are the primary drivers impacting on the coastal ecosystems (IPCC, 2022), which further exacerbate the vulnerability of coastal areas through accelerated environmental degradation and natural resource depletion (Lagacherie et al., 2018). Intensified stress on the ecosystems also places more people at risk to rising sea levels and climate change impacts (Adger, Hughes, et al., 2005). These trends are very concerning in Africa, where population is expected to grow to around 1.3 billion people by 2050, making it the fastest growing continent in terms of future population (Jambeck et al., 2018). An additional 49 million people in Africa are expected to live in coastal areas by 2060 (Neumann et al., 2015).

Social change is essential to protect the environment and to reduce these risks at coastal areas (Dacks et al., 2018b). Changes in human behaviours in relation to the environment are possible and can be managed (Aswani, 2011), but they require knowledge integration and exchange. Emerging data science technologies are expanding the possibilities to enhance evidence-based policies in support of global development agendas where coastal risk adaptation is a case in point (Eriksen et al., 2021). However, environmental knowledge generated by scientists (or co-generated in top-down and bottom-up processes) does not always influence, nor even reach, non-scientific audiences (Fisher et al., 2020).

Although there has been good advancement in achieving the SDGs set by the Agenda 2030, the goals in relation to Africa and specifically the coastal areas require considerable progression (Keulertz et al., 2020). Digitial transformation coupled with data visualtions may hold an important key to bridge bottom-up needs with top-down global goals. Indeed, as data and visual science communication advances, new opportunities for the transmission of ideas and information go beyond written communication (Finkler & León-Anguiano, 2019). Data visualisation helps non-scientific audiences to make informed decisions with regards to environmental management

[3] *A version of this chapter was submitted to Environment, Development and Sustainability. The results were presented at the 3rd Global Smart Water Summit | 5th - 6th May 2022 | Barcelona, Spain*

(Grainger et al., 2016). Bringing local stakeholders together with data is critical to close the gap between scientific knowledge generation and societal goals, and to understand which communication tool and channel works best for local stakeholders (digital or not) and which visualisation method can bring greater engagement (Grainger et al., 2016). In terms of coastal management, this aligns with recent results for the incorporation of all concerned stakeholders in the identification and selection of indicators for coastal zone management (D. J. Smith & Rodríguez-Labajos, 2021).

Compounding the issue of information flow, the recent global pandemic caused by COVID-19 has modified the ways we interact and communicate (Rich & Pather, 2020). The lack of access to digital infrastructure, combined with socio-economic conditions at household level and specifically in coastal areas have intensified the inequality of knowledge assimilation (Singh et al., 2021). Indeed the pandemic has shone a spotlight on the *digital divide* (Aissaoui, 2021), the gap between those who benefit from ICT-ready technologies and the information they provide against those who do not (Mariën et al., 2016). Felsenstein and Lichter (2014) anticipated a widening of the digital divide in the coastal areas when contrasting the empowering capacity of increasingly sophisticated and informative coastal zone data and the unequal conditions to access such data by stakeholders involved in coastal zone management.

The expanding field of data visualisation requires further research to focus on effective ways to communicate climate change and environmental degradation with lay audiences, specifically in coastal areas (Grainger et al., 2016) and in Africa which is currently understudied (Abebe et al., 2021). The literature further lacks an analysis on the implications and innovations (Bennett et al., 2022) for the visualisation of coastal data in relation to advancing the development-related agendas (Benson et al., 2021).

Further, it is critical to better understand how the pandemic has shifted the involvement of stakeholders in data visualization and how local participation can aid decision-making processes amid the digital divide (Hassani et al., 2021). Research regarding these issues in Africa will look to bridge the research gap on the continent for climate change and water-related topics (Wehn et al., 2021).

This paper addresses these knowledge gaps through **two interconnected objectives**, both with focus on the coastal areas of Africa. The first one is to expand the understanding of the current visualisation approaches that can convey environmental management information. This requires the identification of the visualisation tools or techniques preferred by each stakeholder group or their type of expertise and the obstacles for its use. The second objective is to discover in what direction the global pandemic has influenced the communication tools and techniques for environmental information at local level. This leads to a greater understanding of any barriers or enablers that the pandemic has induced, and how it has potentially changed data visualisation for environmental management.

After this introduction, we provide a background of the current state of the art in this field with an overview of the challenges of the current visualisation techniques in engaging stakeholders. The paper then moves into providing a description of the methods used. Finally, we present the research results and discuss our insights into data visualisation techniques in coastal areas across Africa.

This paper provides a unique contribution to expand the understanding of the use of environmental data visualisation tools and techniques in coastal areas of Africa. It further provides a matching of these to each coastal community stakeholder group and their area of expertise. The barriers and enablers to provide communication to local coastal communities further advances the current research in this area. It thus provides coastal zone managers with authoritative information to support their choice of tools or techniques for environmental data visualization and communication to foster behavioural changes in relation to climate mitigation strategies. Further advances in this research can have implications in bridging critical gaps between the final users and data managers with recommendations grounded in local coastal community needs and recommendations.

4.2 Background

4.2.1 Visualisation tools and techniques in environmental management

Socio-ecological transitions cannot occur without significant changes in human behaviour and perceptions (Voinov et al., 2016). Regardless of which vision of development is adopted, information and knowledge sharing will be part of these changes (Cummings et al., 2019), hence, the benefit of data visualization, which in itself is a vibrant field of research (Rink et al., 2014). The visualisation of data is the process of making something seeable (Grainger et al., 2016a), an "exemplification" (S. Glaser et al., 2008b) and a representation and presentation of data to facilitate understanding (Kirk, 2016). Thus, visual communication lessens language and disciplinary barriers, while helping to convey essential information (Vogiatzakis et al., 2006).

The necessary understanding of the human impacts on the environment and future climate requires effective tools and techniques to communicate data (Sheppard, 2012). A way to classify the wide array of visualisation tools and techniques to explain environmental data is through their targeted audience and the intended use (**Table 13**). A description of each of these visualisation types, provided in Table 13, for the most frequently targeted audience is provided with a brief description of the intended use of that visualisation type. A reference to the literature for each of these is also provided. As environmental communication has developed well beyond environmental monitoring, conservation groups and regulation setting, communication has started appealing to a broad set of local and global stakeholders (Schmidt et al., 2019). New communication frameworks (for e.g. Participatory Environmental Communication) have appeared in the literature as specifically, African stakeholders become more involved in the communication processes (Harris, 2018).

Table 13: Visualisation types, intended use and targeted audience.

Most frequently targeted audience	Visualisation type	Intended use	Reference
Public authorities, Scientific & Business	Statistical graphics (e.g., scatter plots, histograms, box plots)	Quantitative information communication	(Tufte, 2001)
	Maps (Including GIS)	Ability to analyse and display qualitative metrics and to distribute them geographically.	(Lumley et al., 2022)
	InfoVis	User interaction with fluid data	(Fekete, 2004)

NGOs and CSOs	Information graphics (infographs)	Combining graphics, text and numbers in an easy to follow and visually appealing way	(Kosara & Mackinlay, 2013)
	Journalistic	Easing journalistic information communication	(Grainger et al., 2016)
	Scenario-based techniques	Communicating environmental problems (flooding; land-use, etc.) at multiple scales	(Grainger et al., 2016)
	Web-based	Improved understanding through greater interaction	(Sundar, 2004)
General Public	Narrative-based approach & storytelling	Communicating environmental stories over time, combining narratives with interactive graphics	(Grainger et al., 2016); (Segel & Heer, 2010)
	Artistic	Mapping data to an image helps to create novel art and interest in a subject	(Manovich, 2011)
	Silent comics	Improved comprehension and awareness of local communities for environmental protection	(Stenchly et al., 2019)

4.2.2 The challenges of the visualisation tools and techniques in engaging stakeholders.

The visualisation types presented in **Table 1** enable stakeholders to engage in the decision making process and subsequent management in decisions that affect them and their communities (Lawson et al., 2010; Voinov et al., 2016). Yet the rich availability of visual approaches is not always understood by governmental actors and environmental experts, including environmental scientists (A. Hansen, 2011).

Clearly, computer-supported, visual representation of data has great potential to shed light on environmental issues (Sadiku et al., 2016), especially after the rise of social media and web applications changed the scale of stakeholder participations and interactions (Voinov et al., 2016). However, the widespread use of new ICTs is not always the best option. For instance, Stenchly et al. (2019) show the limitation of ICT tools in rural farming areas in developing countries. Incomplete mobile phone coverages, slow internet connections, and people who have only recently confronted internet-ready devices were seen as common limitations. Unsurprisingly, more "traditional" visualization tools appear to communicate scientific knowledge better to local communities than mobile phone technologies in this case.

The literature has long advised environmental researchers to become participants in the communication process and thus to act as the interface between science and society (Willems and Regeer, 2009). In practice, top-down communication approaches with limited local engagement in the decision-making process still prevail in engagement and communication actions specifically in rural coastal areas of developing countries (Ruiz-Mallén, 2016). As a case in point, Ewuzie et al., (2021) provide a detailed example of the issues of engagement and collaboration in communication and the decision-making process for the water sector in Nigeria. Perceptions between the multitude of coastal area stakeholders are underexplored yet they are fundamental to understand the effectiveness of the knowledge exchange processes (Yiwo et al., 2022). Boundary organisations – formal organisations existing at the interface of knowledge exchange and collaboration between

all relevant stakeholders (Parker & Crona, 2012a)– may assist in this regard by enhancing the knowledge exchange processes (Clark, Van Kerkhoff, et al., 2016).

Communicating scientific environmental data to general audiences is an area requiring further work. A first point to tackle is the role of visualizations in environmental communication (Schmidt et al., 2019) and the perspective of environmental data visualisation options for the non-scientific audiences (Grainger et al., 2016). Segel and Heer (2010), for instance, pointed out the need of gaining insights from both authors and readers in exploring data stories. However, the lack of field studies and user-centred evaluations of environmental data visualisation inhibit the enhancement of scientific knowledge communication from the perspective of non-scientific audiences (Harold et al., 2016; Lorenz et al., 2015). This is particularly apparent in coastal areas and specifically in Africa where human behaviours need to be managed to mitigate the maladaptive behaviour that works against the environmental services at coastal areas (Oyero et al., 2018). Furthermore, intersectoral communication and data visualisation is advocated for in order to enhance the resilience of socio-ecological systems in developing countries (Wen et al., 2015).

Adding to the challenges of communication, the advent of the global pandemic has changed certain behaviours across all sections of society. The most salient change has been the obligation to stay at home to prevent the spread of the virus. This change has compelled a shift to online interactions, e-learning and home working, enhancing the need for computer supported interactions (Baber, 2021). However, not all individuals could participate equally in this process. In developing and transition countries such as Brazil, Costa Rica and Peru, educated workers, wage employees and women had a greater ability to work from home (Gottlieb et al., 2021).

Moreover, working from home requires having access to digital computer-based technologies a lack of which can result in certain deficits. For instance, a study undertaken on students in Ghana showed a learning loss of 66% in foundational numeracy of students without access to computer based technologies during the pandemic lockdowns (Sabates et al., 2021). Indicating that a lack of home support and resources may result in the widening of the learning gaps.

Throughout the pandemic online based communication strategies were seen as crucial to reduce the virus risk and to tackle misinformation (Anwar et al., 2020). Communicating the benefits of collective action against the spread of the virus and the integration of precautionary work behaviours were purported as some of the enablers to tackling the spread of the virus (Mohd Hanafiah et al., 2021). Communication barriers during the pandemic included messaging inconsistencies, the adverse socio-economic impact and the digital divide (Mohd Hanafiah et al., 2021). Overcoming these barriers can have significant implications on poverty reduction specifically in Africa (Bargain & Aminjonov, 2021). Further research is called for in the types of visualisation tools and techniques for communication and the need for a cautious role of the media in its use of graphics with regards to the pandemic “as visual messages tend to have more impact than text” (Jacob, 2020)

The complexities of the techniques of visually conveying environmental data coupled with the global pandemic has placed a significant spotlight on the digital divide and the subsequent impact on global development (Oldekop et al., 2020).

Overcoming the range of these communication challenges highlighted above can start to provide coastal zone managers and decision makers with the knowledge required to enhance resilience at African coastal areas.

4.3 Methods

4.3.1 Framing and data gathering

To further understand the use of environmental data visualisation in coastal areas of Africa, this paper is driven by two objectives, one focused on stakeholders' preferences and the other on the effect on communication driven by the pandemic. Their connection with the methodological process is summarized in Figure 13.

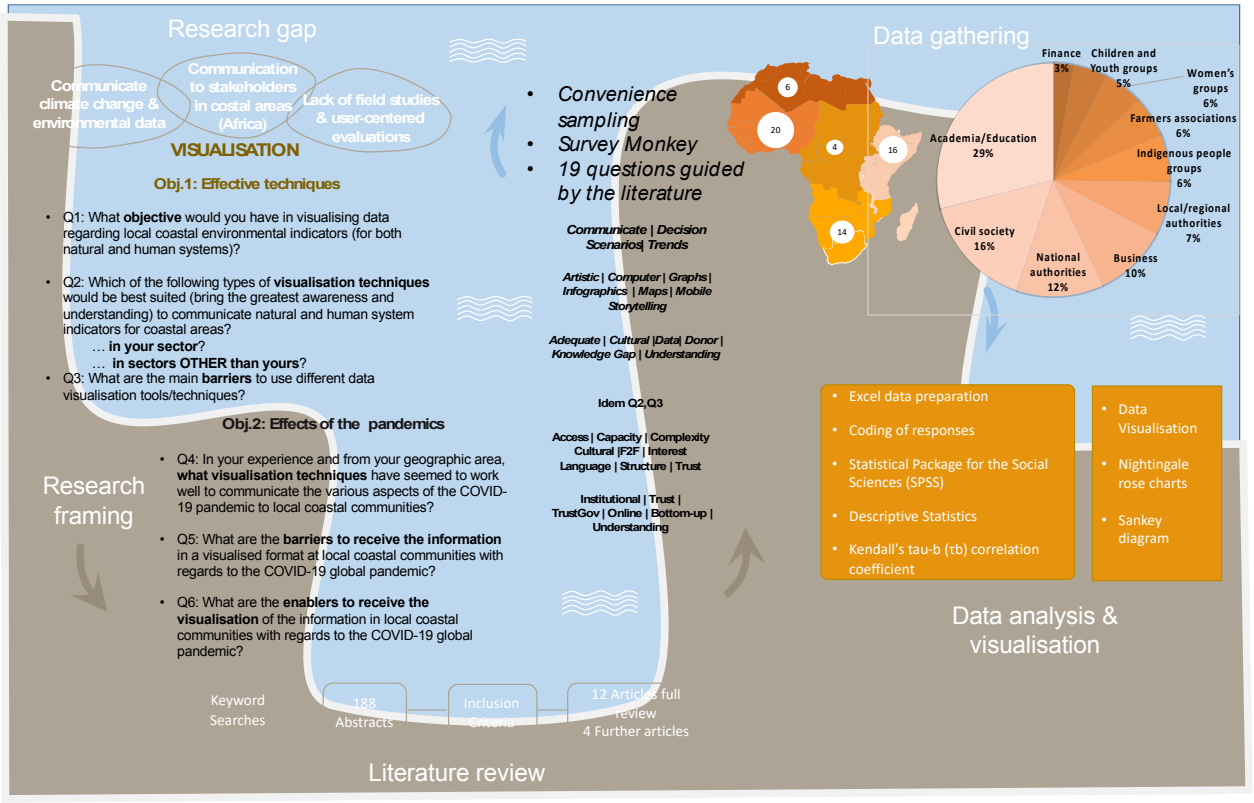


Figure 13: Infographic of the research design

Overall, the research process involved a survey with experts across the African continent. The questionnaire was standardised following an in-depth analysis of the key terms selected from the literature that had a focus on environmental data visualization. We used the guidelines proposed by Kitchenham (2004) in order to identify, collect and assess the peer reviewed literature obtained from two data sources (Scopus, and Google Scholar). The search sequence combined visualization terms (e.g. visuali* tools) with terms regarding scientific knowledge (e.g., knowledge transfer OR scientific communication), environmental data (e.g., environmen* indicator*), and geographic focus (e.g., Africa OR coastal areas). A supplementary search connected visualization with

pandemic related terms (e.g., pandemic OR COVID-19). Without providing a finite number of entries we reviewed the first 5 pages of the Google Scholar search entries. The search yielded 211 articles that, after eliminating 17 duplicates became a final list of 188 unique entries. Find the complete search sequence and returned results in supplementary material 1.

The systematic review of the literature provides a solid foundation for research development (Snyder, 2019). However, specifying inclusion criteria reduces the research bias and strengthens the reliability of the systematic literature reviews (Moher et al., 2009). Thus we focused the full reviews of the empirical articles that were ten years or less and explicitly dealt with a combination of the following topics: (i) "coastal areas"; (ii) "data visualisation"; (iii) "environmental aspects"; (iv) "Africa"; (v) "science communication" and (vi)"local community". A total of 12 articles filled these criteria and were subjected to a full review. Additionally, a separate search for articles related to the "digital divide" "coastal communities" and impacts on communication caused by COVID-19 provided a further 4 relevant articles for full review.

Analysing the articles permitted the identification of variables that shaped the definition of the questions posed to the survey respondents. Examples are the types of visualisation techniques currently in use, the barriers to use different data visualisation approaches, and the potential changes in the face of the global pandemic caused by COVID-19 (see supplementary material 2). Regarding the visualisation approaches, we ensured a diverse representation of visualisation tools and techniques according to usages reported in the literature for different stakeholder types (e.g., academic and business audiences, NGOs and CSO, and the general public), as defined in Table 13. Thus, the 19 questions in the questionnaire included pre-set options guided by the literature analysis. The first 7 questions asked the participants to provide their demographic and background information in terms of their area and years of expertise on the African continent (North, East, West, South or Central), the stakeholder group they represent and their level of education.

Likert scale rating is a well-known data collection method in social sciences and is specifically useful in eliciting responses from coastal area stakeholders (Dyckman et al., 2014; Josephs & Humphries, 2018; Karnauskaitė et al., 2018; Nicolodi et al., 2021). The questions that followed (see Figure 13) on the visualisation tools, techniques and communication during the pandemic was thus implemented using a Likert rating scale of 1 to 9 – forcing the participants to "pick a side" and to think carefully regarding their responses as opposed to choosing just a neutral answers (Taherdoost, 2019). The questionnaire was launched online using the survey platform SurveyMonkey (https://www.surveymonkey.com/r/2YL5T6T).

Convenience sampling, as a well-recognized sampling method in developmental research (Bornstein et al., 2013) was the chosen method to conduct the survey. This meant that participants with the desired expertise were recruited based on their availability. The authors used their own networks and best available means to spread the survey link as far across the African continent as possible while targeting practitioners with experience in the coastal areas of Africa. Invoking responses from participants across the African continent provides a varied view from different cultures, experiences and coastal realities that cannot be elicited from an individual case study.

The survey was launched in the MOOC of the AfriAlliance project (*Africa-EU Innovation Alliance for water and climate*) between June 2nd – July 12th, 2020. The AfriAlliance online portal further

promoted a link to the survey. The social networking site LinkedIn helped to push the survey into professional working groups calling for those with experience in coastal areas in Africa to respond. Finally, a local organization in Ghana was recruited to extend the survey into underrepresented groups. In this regard the authors have attempted to overcome the main disadvantages of convenience sampling in relation to non-focused population groups and the under representation of minority groups.

The survey operated between June of 2020 and June of 2021. As mentioned, our research sought to obtain stakeholder groups from different age categories, professions, and work experiences across the African continent. We achieved this objective to a large extent gathering 54 responses from across regions of the continent, age groups, and professional expertise (Figure 13). Keeping in mind the relatively narrow research scope (those with experience of working on environmental aspects in coastal areas) and sampling effort, we are satisfied with this number of responses, specifically in relation to the high average completion rate of our long questionnaire (73%.).

The majority of the respondents have worked in West Africa (with 20 respondents) and East Africa respectively (16 respondents) (Figure 13). The split between male (57%) and female (43%) participants was fairly even and with the majority of respondents in the age category of 20–30 years old (21 respondents) and 30-40 years old (19 respondents). To aid in the analysis of the data, the stakeholders were clustered into for main groups: Academia, Business, Public Authorities and CSOs, with academia representing (29% of respondents), civil society (16% of respondents), public authorities (12% of respondents) covering more than half of the respondents (Figure 13)

The majority of the participants have experience in Integrated Water Resources Management (IWRM) (31 participants) followed by climate change adaptation and mitigation (23 participants), and with a fairly equal spread between water and climate data monitoring (14 participants), human capacity development (14 participants), other (12 participants) and food security / agriculture (11 participants). The least number of participants had experience in environmental management (8 participants).

4.3.2 Data Analysis

The analysis of the survey information followed two strategies. On the one hand, we identified significant statistical associations between the variables of the different topics addressed. On the other hand, we plotted the frequency of the responses for each topic, and the interactions between some of the topics and displayed the results through Rose charts and a Sankey diagram.

We used the software IBM® SPSS® Statistics (v. 28.0.0.0) for the statistical analysis. A bi-variate analysis measured the strength of association between pairs of selected variables and the direction of that relationship (Gogtay & Thatte, 2017). As our data consisted of ranked answers, the appropriate analysis to use was Kendall's tau-b correlation coefficient which is based on rank correlation coefficients (Bullock & Tubbs, 1990). This type of analysis mostly focused on the types of visualisation tools or techniques and the stakeholders view on the most suitable option for their own stakeholder group as well as other groups.

To present the data of the barriers and enablers to receive the data visualisation we used *Nightingale Rose Charts*, also known as *Coxcomb Chart or Polar Area Diagrams*. These charts were employed as they provide a clear visual representation, much as a bar chart would, but in a format that stresses a clear communication of the data statistics (Gilbert & Stocklmayer, 2013) where the numbers in our case represent all the participants responses and the sum of their average rating (from 1 to 9).

We used the open source Sankey program (Bogar, 2022) to visualise the connection between the stakeholder grouping, the areas of expertise and their preferred type of visualisation. Sankey diagrams emphasize the major flows or movements within a defined system (Chong et al., 2021). In our research we have provided a Sankey diagram that is based on the sum of the average rating (from 1 to 9) for each stakeholder type and expertise area and their preferred visualisation type.

4.4 Results

4.4.1 Expanding the understanding of visualisation approaches through the perceptions on effectiveness: functions, preferred approaches, and barriers for data visualization in coastal zones

Making improved environmental management decisions and creating policies with this information is the **main reason why respondents want to visualize data** (36% of all responses). The ability to show data trends follows in the frequency of responses (26%). According to the responders, this leads to a greater understanding of what is occurring at a particular level (international, national, regional, local). For instance, one participant from East Africa working in academia indicates that data visualization helps

"to determine the extent in which coastal destruction has taken place with respect to the human activities within the coastal environment".

It is then easier to present a range of possible outcomes while developing adaptation scenarios. A participant in academia from West Africa stated that visual information

"*will increase awareness, thus improve the circulation of information and help with managing situations around coastal areas*",

Communication was the least chosen option for visualizing coastal zone environmental information (11% of all responses). As an interesting supplementary function, a public authority from West Africa indicated that visual information

"*will help to gain widespread public acceptance".*

As an important result, **Fig. 2** features the **visualisation approaches** that are **perceived to bring the greatest awareness and understanding** to communicate environmental management at coastal areas in Africa. The visualisation tools or techniques are ranked according to nine suitability levels, from "not at all suitable (1)" to "extremely suitable (9)". The figures in the horizontal bars indicate how many participants have selected each suitability level. Accordingly, infographics, maps and visual storytelling are the most favoured tool or technique to visualize data according to

the participants. Meanwhile, mobile phones and graphs were rated the least suitable of all the visualisation techniques when stakeholders were expressing preferences within their own sector.

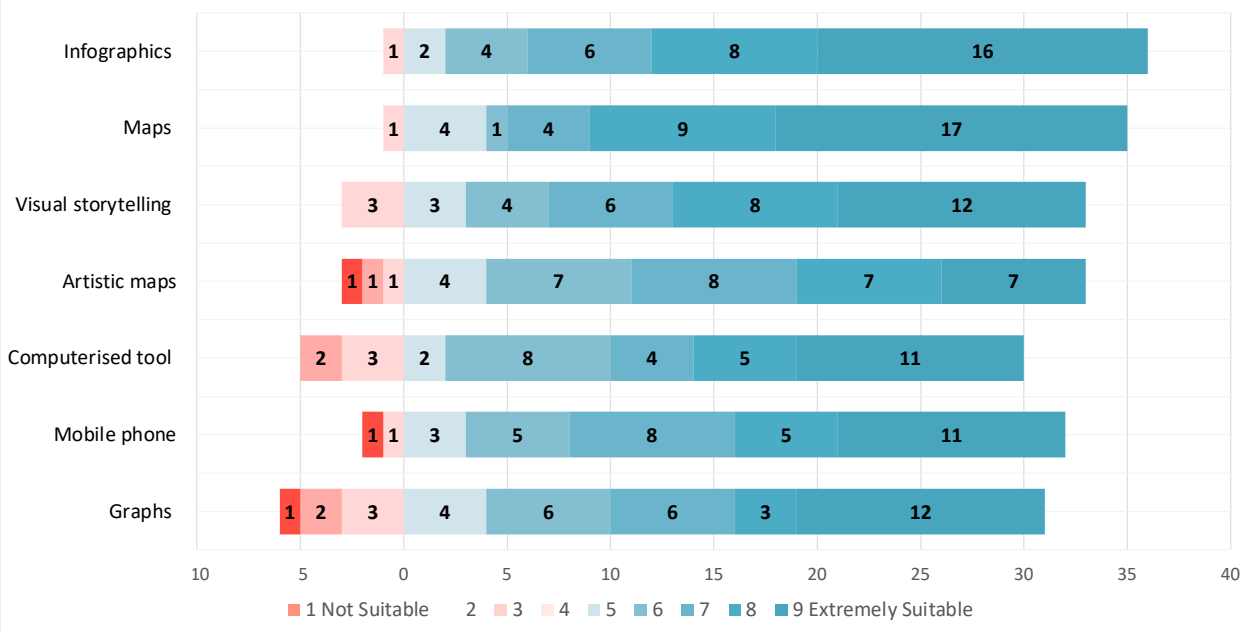


Figure 14: Responses to the question "Which of the following types of visualisation tool or technique would be best to communicate natural and human system indicators for coastal areas in your sector? Note: the figures in each category represent the count of times participants chose a certain rating. (n=39) (1 = Not at all suitable – 9 = Extremely suitable)

Scrutinizing the data reveals ***further insights*** behind the preferences regarding the visualisation of environmental management data for local coastal communities. In terms of gender, male respondents have a slightly higher average preference for using maps (20% of all visualisation options), while female respondents have a slightly higher preference for infographs (23% of all visualisation options). A significant correlation exists between the business stakeholder group and storytelling-type visualizations ($r(41) = 0.397$, $p < 0.05$) (see supplementary material 3). Further, the mean ratings (as chosen by the participants from least suitable 1 to most suitable 9) of the business group are remarkably high for storytelling (n=40, mean rating =8.6/9) and infographs (n=40, mean rating =8.6/9) (see supplementary material 3). The CSOs also had a high average for the use of infograph visualisation techniques (n=40, mean rating=7.88/9). A representative of a woman's group (CSO) from West Africa further detailed the types of visualisation tools and techniques for her sector

"*posters and traditional story telling*"

Likewise,

"posters in public areas work well to communicate visual data" (CSO in Central Africa)

according to a participant from a community development program (CSO) in Central Africa. Meanwhile the public authority participants (n=40, mean rating =7.5/9) and academia (n=40, mean rating = 7.65/9) stakeholder groups had higher mean ratings for map visualizations.

Gaining a better intersectoral perspective on the suitable type of visualisation technique is important for environmental communication. Clarifying how the stakeholders perceive **data visualisation in sectors other than their own** can provide clear communication tools or techniques that has the potential to increase knowledge assimilation for coastal area management. The correlation analysis in **Table 3** showed some significant results that includes the intersectoral views between academia, public authorities (public), CSOs and business stakeholder groups. In each case, the underlying data refers to a rating of the visualisation techniques that the consulted stakeholder groups (origin stakeholders) (rows) perceive to be suitable to communicate natural and human system indicators for coastal areas in different sectors (target stakeholders) (in columns).

Table 14: Kendall's tau_b correlations between the stakeholder groups and the types of visualisation tools and techniques they

Sector		Graphs				Maps				Infographs				Storytelling				Artistic				Computer				Mobile			
		A	P	C	B	A	P	C	B	A	P	C	B	A	P	C	B	A	P	C	B	A	P	C	B	A	P	C	B
Academia	CC		-0,09	0,04	0,21		0,01	0,18	0,17		-0,08	-0,09	0,17		.339*	0,23	.399*		0,23	-0,07	0,15		-.355*	0,21	-0,04		0,03	.390*	0,12
	Sig.		0,59	0,85	0,24		0,93	0,36	0,37		0,64	0,63	0,37		0,04	0,22	0,03		0,14	0,71	0,41		0,04	0,25	0,84		0,84	0,03	0,54
	N		29	23	25		31	23	25		31	25	25		29	25	24		31	25	24		29	24	24		30	25	24
Public	CC	0,26		-0,05	-0,16	0,27		-0,06	0,05	.376*		0,07	0,05	0,07		0,08	-0,08	-.422**		0,04	-0,13	0,15		-0,16	0,19	0,15		-0,11	0,20
	Sig	0,10		0,79	0,39	0,11		0,76	0,80	0,02		0,71	0,80	0,66		0,68	0,67	0,01		0,83	0,48	0,35		0,40	0,31	0,35		0,56	0,28
	N	35		23	25	32		23	25	34		25	25	32		25	24	32		25	24	34		24	24	34		25	24
CSOs	CC	-.314*	0,11		0,07	-0,22	-0,08		-0,02	-0,07	-0,17		-0,02	-0,17	-0,09		-0,10	0,09	0,03		0,10	-0,22	-0,12		-0,31	-0,22	-0,19		-0,24
	Sig	0,04	0,51		0,70	0,19	0,62		0,90	0,65	0,30		0,90	0,28	0,60		0,59	0,57	0,83		0,59	0,17	0,47		0,10	0,17	0,25		0,19
	N	35	29		25	32	31		25	34	31		25	32	29		24	32	31		24	34	29		24	34	30		24
Business	CC	0,22	-0,16	-.409*		-0,07	-0,06	-.431*		0,09	-0,04	-.381*		-0,19	-0,28	0,12		0,00	0,00	0,13		0,27	0,22	-0,27		0,27	0,23	0,02	
	Sig	0,16	0,33	0,03		0,69	0,72	0,02		0,59	0,82	0,03		0,22	0,10	0,53		1,00	1,00	0,48		0,09	0,20	0,15		0,09	0,17	0,92	
	N	35	29	23		32	31	23		34	31	25		32	29	25		32	31	25		34	29	24		34	30	25	

Respondents representing the academia stakeholder group perceive storytelling as an effective way to communicate with the public authority sector and with the business sector ($r(24) = 0.399$, $P < 0.05$). An academic representative from Central Africa clarifies that

"TV/Radio spots and T-shirts"

are potential other types of visualisation approaches that can support their work towards the public authority sector. Academic representatives also believe mobile-based techniques work with CSOs

(r(25) = .390, P < 0.05). In this regard, a participant from academia in West Africa clarifies that visual information

"should be explained in the language of the inhabitants and also simple graphs should be used in explaining concepts".

Academics however believe that the public authorities do not respond well to computer-based visualization techniques (r (29) = -.355, P < 0.05). Interestingly, participants representing public authorities perceived that, while artistic approaches are not the best technique to use with academics (r (32) = -0.422, P < 0.05), infographs work well (r (34) = .376, P < 0.05). Unanticipated by us, participants from the CSO sector expressed that using graphs does not work so well with academic sector (r (35) = -0.314, P < 0.05)).

The business stakeholder group of participants do not see the suitability of using graphs (r (23) = -0.409, P < 0.05); maps (r (23) = *-0.431*, P < 0.05) nor infographs (r (25) =-0.381, P < 0.05) to convey data to the CSO sector. Contrary to this, the CSO sector themselves provided the highest mean rating (7.88/9) for the use of infographs as a suitable technique within their own sector.

Taking into consideration **the participants' area of expertise** revealed an additional significant association. If the stakeholders had experience in climate change adaptation and mitigation, there was a significant negative correlation with the use of graphs (r (41) = -0.313, P < 0.05), which suggests a reluctance from this group to consider graphs as a suitable visual approach to convey environmental management information in coastal zones (see complementary material 3). The best rated visualization approach by professionals with this expertise were maps (n=40, mean rating =7.5/9). Maps were also the best rated approach by those with environmental management experience (n=40, mean rating =8.33/9). Notably, experts in human capacity development rated equally graphs, infographs and storytelling (n=40, mean ratings = 8.00). Unsurprisingly to us, the experts in water and climate data (monitoring, collection, forecasting, and analysis) rated the use of mobile phones the highest as a tool for visual communication (n=40, mean rating =8.00).

We analysed the stakeholders' sector and the area of expertise together displaying the highest average rating for each visualisation type in a "Sankey" diagram, using a threshold rating of 7 or above. The visualisation tools and techniques of infographs (30.01 sum of the ratings) and maps (23.80 sum of the ratings) emerge most prominently. All stakeholders bar public authorities and all areas of expertise bar human capacity development favour highly the use of infographs. The use of maps is also highly rated by stakeholders other than CSOs that together with the business stakeholders rate highly the use of storytelling visualisations. Stakeholders with human capacity development experience and those with IWRM experience are the only two stakeholder groups that do not highly rate the use of maps, preferring infographs and storytelling respectfully.

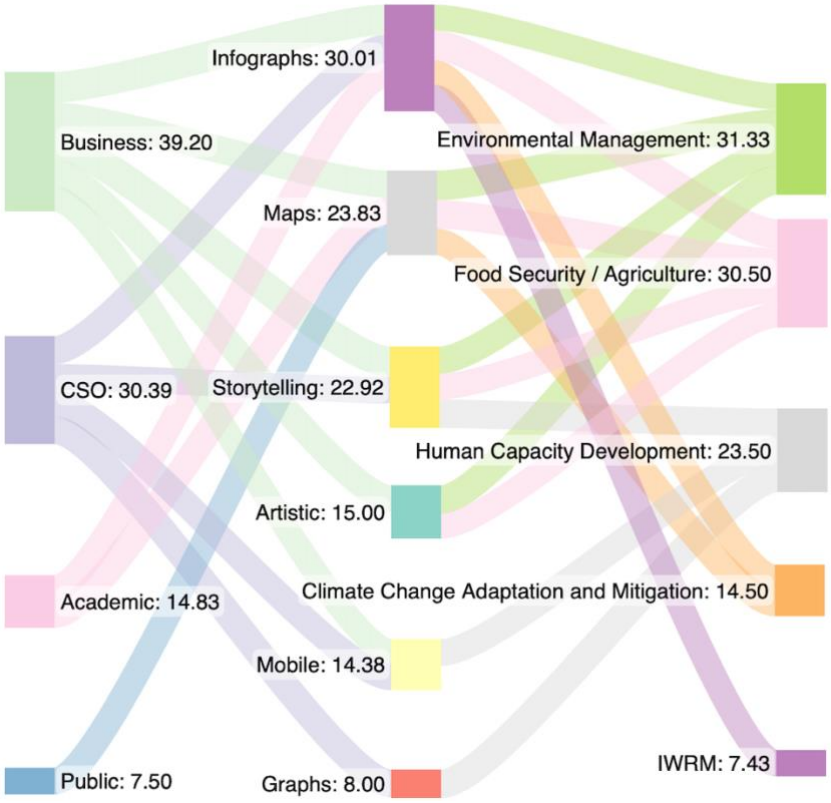


Figure 15: Sankey diagram displaying the flow of the highest average rating from stakeholder and experience type to visualisation tool/technique.

A further summary of the above results is provided through a matrix overview of the type of visualisation approach and the stakeholder grouping and sector of experience (**Table 15**). Infographs, maps and storytelling seem to rank well across the stakeholder groupings and the areas of expertise. In contrast, mobile applications, graphs, and particularly, computer-based approaches are deemed to be less suitable for visualizing environmental and climate data in coastal areas of Africa.

Table 15: Summary matrix of the visualisation tools and techniques for each stakeholder group and sector experience.

	Graphs	Maps	Infographs	Storytelling	Artistic	Computer	Mobile
	Stakeholder Sector						
Academic		X	X				
		O	O				
Public Authority		X					
		O	O				
CSO	X		X	X			X
				O			
Business		X	X	X	X		X
		O	O				
	Stakeholder Area of expertise						

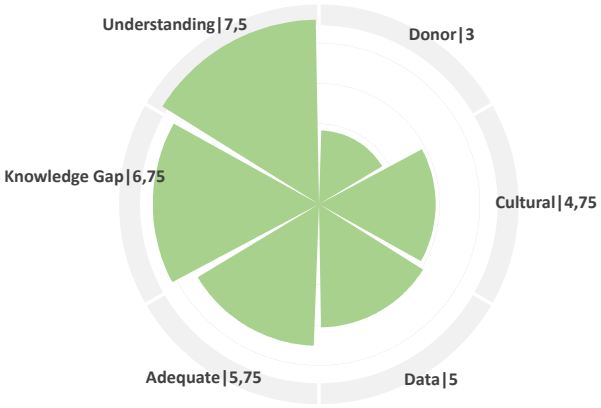
Environmental Management		X	X	X	X		
Food security/agriculture		X	X	X	X		
Human Capacity Development	X		X	X			
CC adaptation and mitigation		X	X				
IWRM			X				

Table 15 indicates that stakeholder sectors do concur on a number of visualisation tools and techniques. For instance, the academic stakeholder group and those wishing to communicate with this group concur that infographs and maps are most suitable. Concurrence in the suitability of the use of maps is indicated for in the public authority stakeholder group. The CSO stakeholders indicate that a wide range of visualisation tools and techniques are suitable for their sector, however, stakeholders outside of their sector only concur in the suitability of storytelling. Although the business sector foresees a wide range of suitable tools and techniques, stakeholders outside of their sector only concur with the suitability of infographs and maps. In considering the area of expertise, most notable is that overwhelmingly infographs is advocated for in all areas of experience.

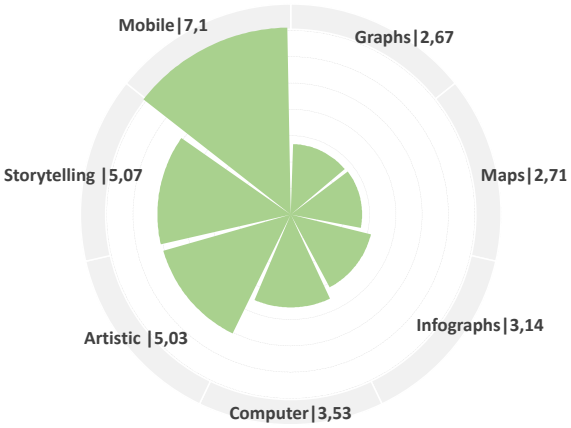
An overall question regarding the suitability of specific visualisation approaches to reach their target audience are the **barriers that could inhibit the effective use of the different data visualization** tools or techniques. Confronted with several options identified in the literature, the participants ranked the barriers according to their experience (**Figure 16a**). Accordingly, the main barrier is the lack of understanding of how to interpret a visualisation tool or technique. Further, they see a knowledge gap that exists for those wanting to communicate the data using different tools and visualization techniques, and scientists that are unable to present the information in an adequate tool or technique for their target audience. The participants chose to a lesser extent the type of data needing to be visualized or the lack of cultural awareness as barriers to use data visualisation techniques. Donor requirements (i.e., to use donor approved visualization tools or techniques) from donor organizations, companies or universities could hinder a practitioner to use other (new) data visualisations tools and techniques was the least chosen barrier. As we further explain below, the pandemic has potentially created additional barriers or indeed enablers for the visual information to reach its intended target.

4.4.2 The impact of the pandemic on coastal data visualisation

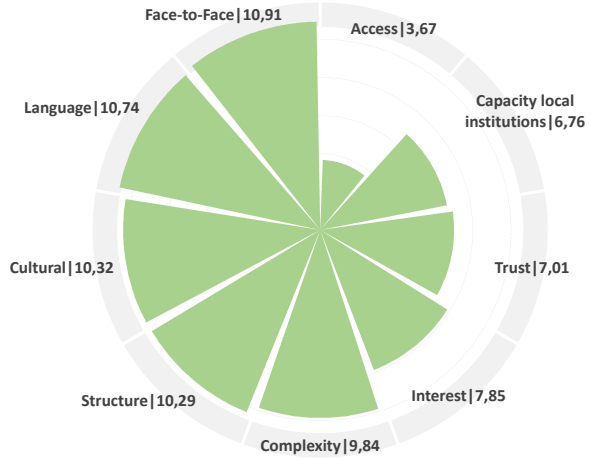
The tools and techniques that seemed to have **worked well to communicate** environmental management information to coastal communities **during the COVID-19 pandemic** (Figure 16**b**) was our next focus of interest. Perhaps unsurprisingly, according to the respondents, mobile phone applications were the overwhelmingly preferred method to communicate to local coastal communities. Interestingly, storytelling and artistic methods (e.g., visual maps) were options that, according to the participants, also worked well during the pandemic. Computerized or web-based, interactive tools and interfaces were not chosen as much by the participants as those mentioned above, neither were infographs, maps nor graphs.



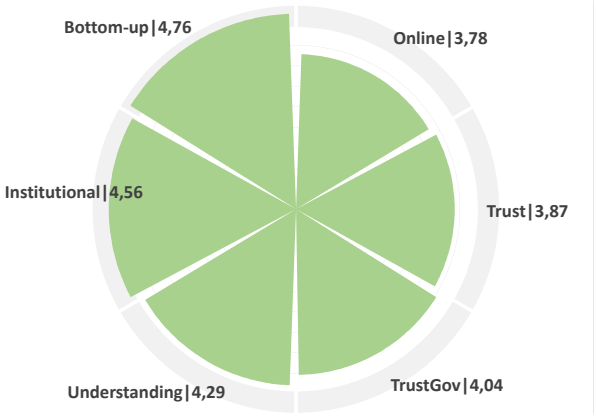
a. What are the main **barriers** to use different data visualisation tools/techniques?



b. What visualisation tools/techniques have seemed to work well to **communicate the various aspects of the COVID-19** pandemic to the local coastal communities in your geographic area?



c. What are the **barriers** to receive the information in a **visualised format** at local coastal communities with regards to the **COVID-19** global pandemic?



d. What are the **enablers** to receive the **visualisation** of the information in local coastal communities with regards to the **COVID-19** global pandemic?

Figure 16: Rose Chart of the combined participants responses to questions on the use of visualisation tools regarding barriers (a), and the COVID-19 pandemic (b-c).

*Note: **a, c**, figures indicate the sum of the average rating provided by each stakeholder group (Likert scale 1 = not considered to be a barrier 9= considered to be a significant barrier). b figures indicate the average rating as indicated by all participants (Likert scale 1 = not at all well, 9 = exceptionally well). d, figures indicate the sum of the average rating provided by each stakeholder group (Likert scale 1 = not considered to be an enabler 9= considered to be a significant enabler). For the description of the labels see supplementary material 4.*

Seeking to unveil the main **barrier to receive information in a visualised format** at local coastal communities **within the framework of the pandemic (**Figure 16c), we provided the participants with specific options. Their combined responses suggests that due to the pandemic, a significant barrier was the inability to interact face-to-face, such as in communities of practices (CoP) or community fora to show visual information. Specifically, a participant from a farmer association

from West Africa mentioned that the most effective means to communicate aspects of the pandemic to local coastal communities was to

"raise awareness through youth groups in their local dialects and their customs to communicate and visualise the messages in accordance with their cultural ways to express the state of emergency and the terrifying conditions."

A similar hurdle stemmed from the use of difficult language, or new concepts or jargon regarding a new disease that the public was unfamiliar with. The participants also perceived barriers in the visual data not adapted to the cultural settings. A prime example of this is the visualization of social distancing guidelines amidst notions of personal space that vary across cultures and social settings. The respondents expressed complex social structures may require different visualisation techniques for different stakeholder groups. In contrast, the participants saw as less of a barrier the potential lack of interest in trying to understand the visualised information, the perceived lack of trust of the visualised information received, and the potential lack of capacity of local institutions to transmit effective visualisation communications.

Surprisingly, the participants did not perceive a barrier with regards to a lack of adequate access to digital tools and technologies. Instead, capacity and resources were seen as more of an issue, as a national authority representative from Southern Africa put it:

"There is a lack of technical and financial capacity to produce appropriate data for maps and posters as well as language barriers to interpret them"

This idea was echoed by a CSO representative from East Africa who commented

"There are insufficient funds to receive information in a visualised format at local coastal communities" [with regards to the COVID-19 pandemic]

Do **enablers** matter **in order to receive the visualisation** of environmental management information at local coastal communities under pandemic conditions? Apparently not. Figure 16**d** shows participants valued, on near equal terms, the enablers that were proposed. However, the most highly rated enablers were strong bottom-up approaches that have allowed for traditional and indigenous needs to be considered when transferring visual information. Strong institutional capacity of local institutions to transmit effective visual communication, and a high understanding and/or interest of the visual data received.

In addition to the enablers provided as part of the survey, other options were offered by the respondents. A national authority participant from Southern African specifically mentioned

"*adequate and trained human resources, donor support, interest by people conveying the message and strong political will"*.

A participant from an indigenous people's group from East Africa highlighted the relevance to ensure a

"*good link between the management and the beneficiaries/residents"*.

Even beyond that, a CSO representative from central Africa focused on the need to use local people in communicating visual information:

"*Local staff must be on* [the] *frontline* [rather] *than expats"*.

In an open question the participants were asked **how they believe data visualisation may change post-pandemic**. The responses to this question suggest that graphs and maps will continue to be significant to visualize environmental information post-COVID in coastal areas. In the participants' view, under certain conditions the communication of coastal management options may increase and be more directed to target audiences using new channels and needs emerging during the pandemic. In this regard, a participant from academia from North Africa stated:

"*If the visual data can be directed in the right way and reach the stakeholders, the people will understand how to overcome the financial and physical impact of climate change post COVID-19*".

The participants also anticipated new tools and approaches emerging from the lessons of the pandemic. Specifically, a CSO participant from West Africa commented that [visualization]

"will help in easy identification of hotspot areas and also help understand the spread of the virus".

A participant from the business sector from East Africa advocates for participatory approaches in these new developments:

"The use of participatory research and a bottom-up approach can enhance the good achievements of a project goals and ensure community ownership".

Finally, a participant from academia from Southern Africa highlighted different channels where the visual information should be shared:

"*Visualisation techniques or results should be communicated in local newspapers, television and radio outlets as well, so that everyone affected is communicated to, especially rural areas and underdeveloped areas"*

4.5 Discussion and conclusions

This research covers a mosaic of regions, cultures, sectors and areas of expertise in the framework of coastal areas across the African continent that are facing significant environmental and human challenges due to climate change (Baarsch et al., 2020; Fischer, 2018). A main insight from this process is the participants' convergence on the use of infographs, maps and storytelling to visually communicate environmental management information at local coastal communities. This idea lead us to challenge the notion, as claimed by certain authors, that the digital divide is a significant

barrier to data visualisation. The consequence of the pandemic on the visualisation of environmental data communication in local coastal areas of Africa is also further considered.

With our work we respond to the calls from Harold et al., (2016) and Lorenz et al., (2015) to provide user-centered evaluations for environmental data visualisations. Notwithstanding advancements in climate communication strategies, there are still significant challenges to communicate data and scientific information and to bring about effective knowledge exchange (Kirchhoff et al., 2013), specifically in light of the current global pandemic.

Further, despite the ongoing efforts from academia, the integration of scientific knowledge into policies continues to have significant challenges (Cvitanovic & Hobday, 2018) specifically in environmental coastal management policies (Frohlich et al., 2022), and in Africa (Iroegbu et al., 2020). Our research has shown that communicating new academic knowledge (data or information) to public authorities (that have the potential to create new environmental policies or legislation) should be prepared using visual geographical maps, and especially, visual storytelling.

Furthermore, academics are long known to wrestle with providing relevant concepts to target audiences, specifically, local stakeholder groups including CSOs, in recognisable ways (Bruine de Bruin & Bostrom, 2013; Dale et al., 2019; Lejano et al., 2021). Our research provides new insights that indicate that academics would do well to share new knowledge that could potentially assist in climate change adaptation in a visual story format that appeal to local coastal communities. Conversely, public authorities are known to grapple with the different ways to provide knowledge and data to the business sector for them to work together with the public authorities to adapt their practices and to improve environmental management (Doh et al., 2019).

The concept of storytelling as a strategy within the business sector is particularly interesting as it is used together with data to forge connections amongst people, places and ideas (Boje & Rana, 2021). The participants of our research have shown that using stories, to tell the tale behind the data, can provide stakeholders with a clear view of changes required in terms of environmental management at coastal communities. The suitability to storytelling-type of visualisations for business stakeholders engaged in coastal management is supported by statistically significant results in our study, albeit the robustness of these results are bound by the reduced sample size. Such suitability is supported by Falchetti et al., (2022) who unequivocally established that storytelling increased a business's likelihood of increased funding. Williams, (2018) also demonstrated that business "stories" help to repurpose businesses towards a paradigm shift for the role of business in society towards achieving the SDGs.

A critical insight in our research is related to the concept of the digital divide. Our research does not concur with Felsenstein and Lichter (2014) who anticipated that the digital divide in coastal areas will not allow the diverse stakeholders to access the data and the visualisations of that data in equal conditions. Of all the barriers that have been mentioned by the participants of this research, access to data and the visualisation of that data was the least prominent, even under the pandemic conditions. Indeed, this could be related to the fact that the majority of the participants filled out the survey online, signalling that access to digital tools for them is a reality. However, overwhelmingly the biggest barriers to data visualisation were related to understanding the

visualized information and the lack of face-to-face interactions, especially under the pandemic conditions.

Our results however, do support the calls from Park et al., (2021) for bottom-up solutions to tackle the COVID-19 pandemic and potential future pandemics. The research participants rated strong bottom-up approaches as the main enabler to receive the visualisation of the information in local coastal communities with regards to the COVID-19 global pandemic. In terms of the future data visualisation post pandemic, we side with Botzen et al., (2021)'s view that climate mitigation communications can be promoted as pandemic mitigation communications. Our research has shown that with the most suitable visualisation tool or technique for the specific stakeholder group or area of experience, the data will reach the right target audience in the right format. In doing so, it will allow people to understand the need for behavioural changes in relation to climate change.

The global pandemic has undoubtedly affected society in ways we will not yet fully comprehend. However, the participants have indicated barriers that have affected data visualisation opportunities during the pandemic in coastal zone areas of Africa. The participants identified opportunities as well. Our research has shown the strong preference for mobile phone applications during the pandemic. However, storytelling and artistic maps were visualisation techniques that were still preferred over computer tools. Therefore, we could surmise that post pandemic, improved applications made for mobile phones that are visual in nature combined with storytelling and artistic maps would allow to communicate the various aspects of environmental management (and conservation) in local coastal communities as advocated for by Andrachuk et al., (2019)

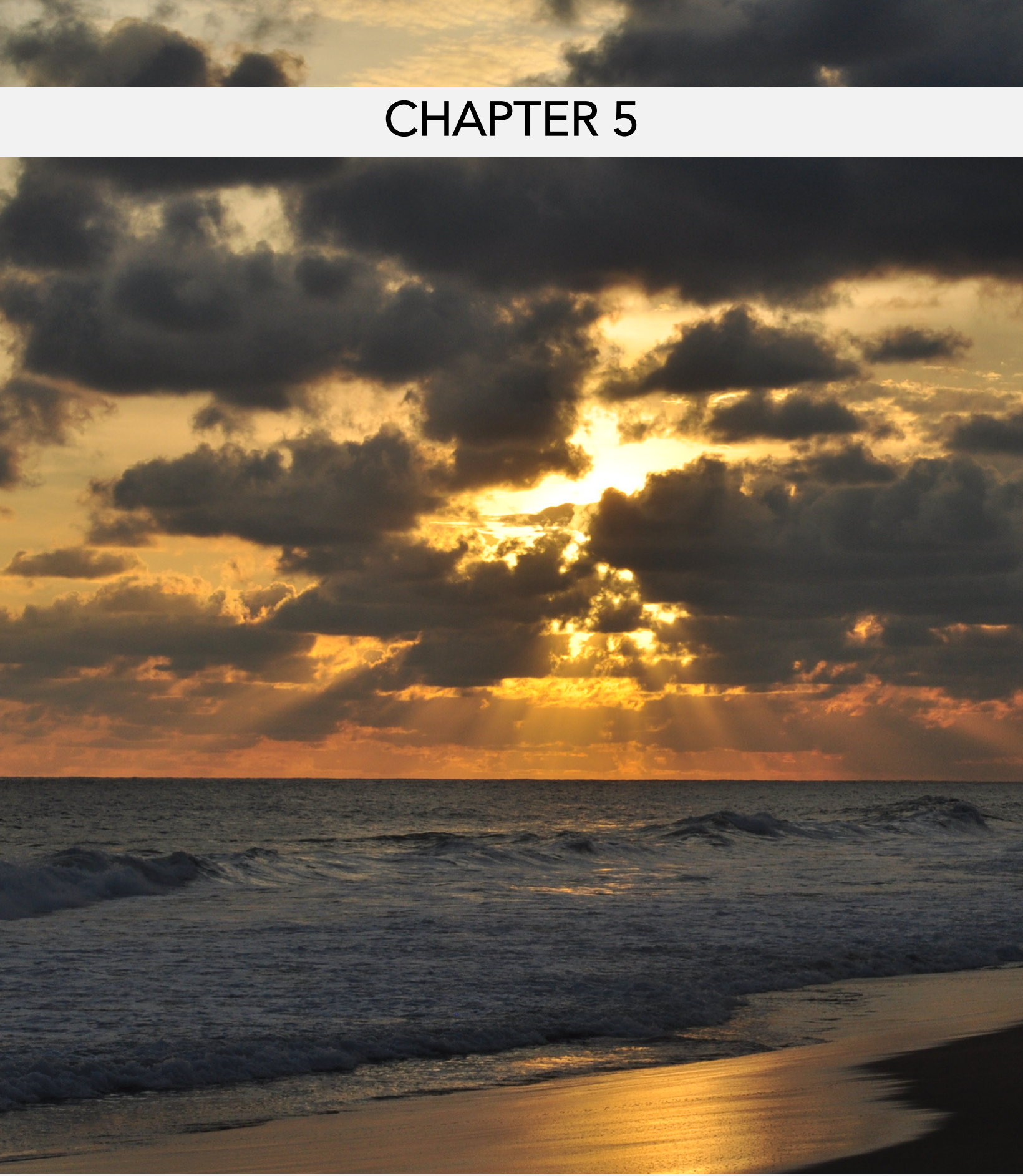
The unique contribution of this paper provides a clear direction of the types of visualisation tools and techniques for each type of coastal community stakeholder group and area of expertise. The barriers and enablers to provide that communication advances current research in this area and provides coastal zone managers with clear directions of how to communicate with their target audience to foster behavioural changes in relation to climate mitigation strategies. Thus, a stakeholder that wants to convey a message for coastal area management, we have demonstrated not what the best tool is, but rather to which target audience a specific communication tool or technique is most suited. Improved data visualisation and communication will advance the development of global coastal areas and assist local coastal communities to achieve the UN Agenda 2030 Sustainable Development Goals (P. de Alencar et al., 2020)

As we are aware of the limitations of the paper in terms of sampling, we also identify further lines of research so that coastal zone managers have an even clearer picture. For instance, we now know the type of visualisation tool or technique that we can use for each target group. Yet, qualitative research is still lacking to understand the reasons behind the stakeholders' visualisation choices. Additional research into the types of messages and data visualisation required for each target audience would also ease coastal zone managers work in providing clearer messages to each target group. Overall, reaching the rural and underdeveloped areas to further assess the potential for (or the irrelevance of) a digital divide in these areas in relation to data visualization is an exciting and necessary line of research.

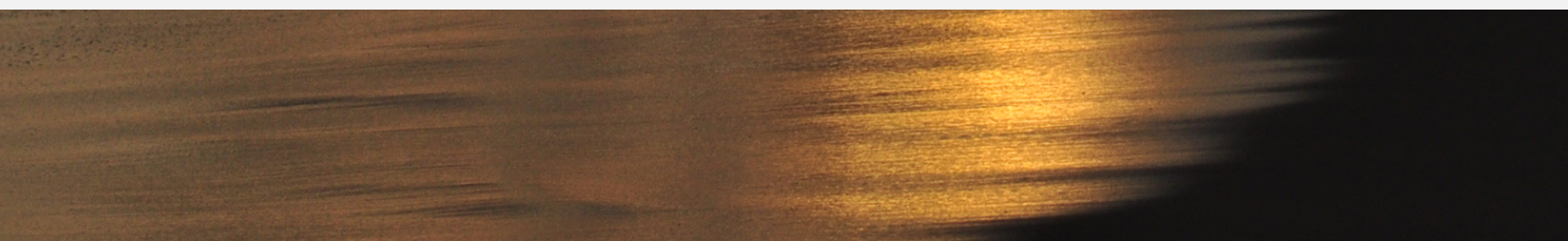
In the words of Kofi Annan (UN Secretary General 1997-2006): *knowledge is power, information is liberating, education is the premise of progress in every society, in every family*. Armed with

environmental data and visualisation tools and techniques for each target group, coastal zone managers in Africa can now enhance their communications to inspire human behaviour change to reduce local environmental and climate risks.

CHAPTER 5



Conclusions and Research Contributions



5

Conclusions and Research Contributions

This thesis has aimed to enhance coastal management by improving knowledge integration in the approaches to socio-ecological systems, specifically in the Global South. To achieve the aim of the thesis, three related objectives were devised, and investigated regarding the practical challenges of bottom-up knowledge integration, the improvement of indicator frameworks, and the challenges of visualization. For each objective, a review of the literature guided the research and provided the background to the development of the analytical and research framework for each objective.

After presenting the results pursuing the objectives in **Chapters 2 to 4**, this chapter concludes by synthesizing the main findings and research contributions of each of the research objectives. Thus, **section 5.1** focuses on the process of knowledge identification across multi-actor coastal stakeholders. Contributions refer to the barriers and enablers to integrate the new hybrid knowledge, the use of local or boundary organisations in knowledge generation, and the processes to validate local knowledge. **Section 5.2** pinpoints the practical social indicators derived from the literature and improved through participatory approaches and summarises how the new social indicators to the CHW framework can enhance its application to coastal management approaches. These insights lead to the conclusions presented in **section 5.3**, on data visualisation in coastal areas with specific relation to visualisation tools and techniques that are matched to different coastal stakeholder groups.

Further to the individual contributions of each research question and chapter, I found it important to formulate a coherent articulation of the research insights in such a way that they held true to my original motivation. While the research insights presented above take into account the conventions of scientific research, the thesis also provides the participants from local coastal communities and coastal area managers practical information on integrating and visualising knowledge. To this end, the final **section 5.4** outlines a knowledge integration process that incorporates insights gained during my investigation. From an academic perspective, this operative framework represents a contribution to theories of knowledge integration processes. In practical terms, the new coastal knowledge integration process proposed here (SHAPES: **S**ystemic **H**ybrid Knowledge Integr**a**tion **P**roc**es**s) is conceived to provide opportunities for coastal managers to enhance local coastal management and for local communities to better adapt to the changing climate.

5.1 Contributions to local knowledge identification, capture, exchange and validation at coastal zones

Consulting a range of stakeholders representing various organisations from coastal areas in West Africa (Ghana) and Mexico (Baja California) provided a unique opportunity to engage local level stakeholders. How effectively can communities, situated in two coastal regions that are significantly at risk (Amuzu et al., 2018; Martínez-Austria & Jano-Pérez, 2021), adapt to this changing climate? Furthermore, how can they protect their livelihoods? To a large extent, the response to these questions depends on the communities' ability to include their needs and concerns within future coastal

environmental plans. If environmental managers (including local authorities) obtain local level knowledge from coastal communities currently facing these environmental stressors, this knowledge can be incorporated within future adaptation and management plans. Similar to our research, this was eloquently evidenced in the study by Ayeb-Karlsson et al., (2016) in the Ganges–Brahmaputra delta in Bangladesh. They showed that by engaging with the local community, future policy and adaptation planning can help the community to adapt to the changing climate and protect their livelihoods.

Consultations took place with the stakeholders on how knowledge can be gathered, the barriers to knowledge flow and the evidence that knowledge integration has taken place. While promising and finding space in the so-called citizen science approach, our results suggest that ICT technologies still have a long way to go until they can effectively be integrated into a bottom-up and top-down knowledge exchange process (**Section 2.7**). In line with the results from the food-energy-water systems case (Karpouzoglou et al., 2017), it has shown that the full potential as well as the understanding of how ICT can better support management decisions (in our case coastal environmental management) is still lacking.

The overwhelming result from the empirical research showed that face-to-face interaction and participatory processes are currently the better methods to identify, capture, exchange and validate local knowledge and needs, which Ricart, (2020) argues is absolutely indispensable when engaging with local stakeholders. The stakeholder groups in both cases of Mexico and Ghana concurred that platforms, networks and clusters were the effective mechanisms to bring stakeholders together, to share knowledge and to allow space for local needs to be expressed.

These types of organizations can lie within the concept of a boundary organization (a term coined by Guston, (2001)) that bridges the gap between local knowledge and high-level decision makers. Engaging directly with individual stakeholder groups (e.g. farmer associations, NGOs, traditional leaders, etc.) is also seen, by the participants of our research, as a highly effective method to capture local knowledge and needs.

The creation, enhancement, or the use of boundary organisations was seen as essential by the participants to identify knowledge, the barriers to knowledge flow and evidencing knowledge integration (**Section 2.1**). In our case studies, boundary organisations seemed to already be in place. *The National Learning Alliance* in Ghana or the *Consejo de Cuenca* in Mexico where two such organisations. However, our research (especially in the Mexico case) shows that unless the boundary organisation is perceived as fully independent, there is a risk that a bottom-up process of knowledge transfer is converted into a political vehicle that essentially forms part of a top-down process. This is contrary to the arguments from, Hoppe et al., (2013) that suggest that if the stakeholders accept the blurring of the boundaries between local level and policy, then the boundary work can be successful.

However, concurring with Guido et al., (2016) on the lack of empirical studies of boundary organisations, our results indicated that a boundary organisation can be established to fill a void in knowledge exchange between multiple actors – providing new insights into the scientific literature on the creation and roles of boundary organisations. These types of organisations are also widely mentioned as a method to allow for continued interaction between stakeholders and therefore allow for the barriers of knowledge integration to be overcome. Furthermore, the creation or enhancement of boundary organizations is mentioned as a means to show that effective knowledge

interaction has taken place. Moreover, participatory activities (for example workshops) within these boundary organisations (known as "boundary objects") are effective mechanisms to show that knowledge interaction is (or has) taking place.

Therefore, as coastal areas move towards finding solutions to the current and future impacts of water related climate change impacts, our research points to the convenience of establishing boundary organisations or multi-stakeholder partnerships that bridge the gap from local level to policy making level. The research, concurring with Posner & Cvitanovic, (2019) on their theoretical review of the role of boundary organisations, indicates that such mechanisms could potentially hold an important key in the process to overcome the knowledge and needs barriers at local coastal areas. However, it is worth mentioning a caveat. Although these organizations can be set up, unless they undertake action and focus on the concerns of the local communities, interest in the issues facing local communities in coastal areas will not be garnered.

5.2 Contributions to top-down and bottom-up integration of natural and human system indicators for coastal zone management

The negative impacts of climate change will manifest on the biophysical and built environments, however, it is society that will bear the brunt of these impacts (Adger, Brown, et al., 2005; Azhoni et al., 2018b; Clements, 2009; Odemerho, 2015; Rasul & Sharma, 2016). The results of the investigation into the natural and human system indicators at coastal zones has aligned well with Loomis & Paterson, (2014) in that coastal area management should be a reflection on what society wants from that environment. The research has further demonstrated the strong connection between the natural and human systems in coastal areas, aligning with Barnard et al., (2021) multidisciplinary case study from Santa Barbara, California indicating that the measurement and monitoring of climate change effects and coastal management should include the natural and human systems. Thus, the integration between the natural and human systems relies not only on the scientific advancement in this field but the practical implementation thereof. This finding can also help to provide local community governance structures that relate directly to the environment. This continues the notion proposed by Turner et al., (2014) in their study on the quantitative governance principles and community perceptions related to the natural systems. In our study, the process of combining both a top-down (literature) and bottom-up (local Ghanaian coastal stakeholders) indicator identification has provided a pioneer mechanism for the inclusion of local expert knowledge based on internationally accepted indicators for coastal zone management.

Three scenarios ensued from the investigation including indicator sub-categories that could be encompassed as part of the current set of measuring and monitoring indicators for socio-ecological systems at local coastal areas. The first scenario (a co-occurrence of the literature analysis with the identified needs from local Ghanaian coastal stakeholders) is the one that should be incorporated into the current coastal indicator monitoring frameworks (for example by upgrading the CHW – the framework advocated for use, by intergovernmental funding agencies, in developing country contexts). As a side note, Dr. Lars Rosendahl Appelquist, the founder and head of the CHW and the Head of Programme, for Marine Environment and the senior expert for the United Nations Environment Program (UNEP) manifested his interest, through a video conversation, to explore how this research can provide an enrichment to the current CHW framework.

The other two scenarios (scenario 2: sub-categories mentioned in the literature but not mentioned at the local level and scenario 3: local Ghanaian coastal stakeholders

mentioned sub-categories of indicators that were not mentioned in the literature) offer insights in terms of implementation, rather than on expanding on the current indicator frameworks. These last two scenarios imply that coastal management indicator frameworks should be adapted to each local situation. In this regard we side with P de Alencar et al., (2020) and their Circles of Coastal Sustainability Framework that advocates for a coastal zone indicator framework that builds on the literature and is adapted to the local coastal socio-ecological systems.

5.3 Contributions to environmental data visualisation tools and techniques in coastal areas of Africa

As described in the chapters above, the African continent is facing significant environmental and human challenges due to climate change (Baarsch et al., 2020; Fischer, 2018). As we have evidenced, social change is essential to protect the environment and to reduce these risks at coastal areas (Dacks et al., 2018b). Changes in human behaviours in relation to the environment are possible and can be managed (Aswani, 2011), but they require knowledge integration and exchange. The contribution from the research on matching data visualisation to stakeholder types shows a convergence on the use of infographs, maps and storytelling to visually communicate environmental management information at local coastal communities. This led to challenge the notion, as claimed by Van Deursen & Mossberger, (2018), that the digital divide is a significant barrier to data visualisation. Communicating new academic knowledge (data or information) to public authorities (that have the potential to create new environmental policies or legislation) should be prepared using visual geographical maps, and especially, visual storytelling. Furthermore, academics continue to grapple to provide relevant concepts to target audiences, specifically, local stakeholder groups, in recognisable ways (Bruine de Bruin & Bostrom, 2013; Dale et al., 2019; Lejano et al., 2021). Advancing on Brennan, (2018) that linked artists and marine scientists in drawing up a community-led map in the Scottish island community of Barra, in Scotland, our research has shown that academics would do well to share new knowledge that could potentially assist in climate change adaptation in a visual story format that appeals to local coastal communities.

The participants of our research have shown that using stories, to tell the tale behind the data, can provide stakeholders with a clear view of changes required in terms of environmental management at coastal communities. A further critical insight from the research is related to the concept of the digital divide. Of all the barriers that have been mentioned by the participants of this research, access to data and the visualisation of that data was the least prominent, even under the pandemic conditions. This research result aligns with Otioma et al., (2019) and their study of the digital divide in the urban setting of Kigali in Rwanda. They stressed that the scientific literature on the digital divide is either special levels of country, regional or between urban and rural level, lacking a focus on the "finer spatial scales", in other words, our participants were not affected by an access to digital tools even though potentially at their country scale there could be a greater digital divide. Overwhelmingly the biggest barriers to data visualisation were related to understanding the visualized information and the lack of face-to-face interactions, especially under the pandemic conditions.

In terms of the main enablers to receive data in a visual format, strong bottom-up approaches were rated highly by the research participants with regards to the COVID-19 global pandemic. The research has further shown the strong preference for mobile phone applications during the pandemic. However, storytelling and artistic maps were still preferred over computer tools as visualisation techniques. Therefore, we could surmise

that post pandemic, improved applications made for mobile phones that are visual in nature combined with storytelling and artistic maps would allow to communicate the various aspects of environmental management (and conservation) in local coastal communities as advocated for by Andrachuk et al., (2019).

The research contribution advances the knowledge on communicating data through the most suitable visualisation tool or technique matched to a specific target stakeholder group or area of experience. The data and information will thus reach the right target audience in the right format. In doing so, it will allow society to understand the need for behavioural changes in relation to climate change. Thus, a stakeholder that wants to convey a message for coastal area management, we have demonstrated not what the best tool is, but rather to which target audience a specific communication tool or technique is most suited.

5.4 Contribution to enhanced coastal management through improved knowledge integration processes in socio-ecological systems.

Throughout my doctorate I found myself in a unique position of being directly involved in international development projects looking through an academic lens. Sitting at the interface between new knowledge generation and practical implementation has allowed me to better ascertain how the gaps in the literature can potentially and practically can be bridged (or not). At the end of these years of my investigation in the pursuit of my doctorate, I can confidently propose a knowledge integration process drawing on the experiences from the field and my research: *the **S**ystemic **H**ybrid Knowledge Integr**a**tion **P**roc**es**s (SHAPES).*

The aim of SHAPES is to provide an integration process for the practical application of local, scientific and hybrid knowledge to foster harmonised socio-ecological management of coastal areas in developing countries. In this regard, SHAPES responds to Raymond et al., (2010)'s call to shift from "knowledge integration products to the development of knowledge integration processes in relation to environmental management problems". Since its publication this article has been cited a total of 627 times - as of July 2022 - with various authors responding by providing knowledge integration and exchange processes and platforms (Ainsworth et al., 2020; Azhoni et al., 2018; Coffey & O'Toole, 2012; Gaillard & Mercer, 2013; Nguyen et al., 2014; Scheffran & Battaglini, 2011). Even though proposals have been made, it seems that gaps still exist that the individual components of SHAPES can bridge.

Loch & Riechers, (2021) for example identified that further research is required in identifying the key Indigenous Knowledge Holders (IKH), which can be bridged through **SHAPES Component A**. With the key stakeholders identified, Coffey & O'Toole, (2012) call for the knowledge systems to involve "dynamic networks of multiple (intersecting) knowledge sub-systems". These systems should integrate top-down and bottom-up hybrid (Nguyen et al., 2014) knowledge systems through multistakeholder platforms (Gaillard & Mercer, 2013) (**SHAPES Component B**). Although there has been recent advances, Albuquerque et al., (2021) note that research is still required in relating bottom-up and top-down knowledge systems to ecological studies. Aisnsworth et al (2020) call for research on how action can take place following a knowledge process to integrate it within management processes (**SHAPES Component C**). Finally, the interactions and engagement processes and the fostered partnerships between the various stakeholders requires new innovative approaches to tackle environmental challenges (Kettle & Trainor, 2015). This is further reiterated by Glaser & Glaeser, (2014) who

advocate for networks of stakeholders to respond to coastal and marine challenges (**SHAPES Component D**).

SHAPES is aimed at environmental managers and project teams to guide them through the process to identify, gather, implement and integrate bottom-up and top-down co-created socio-ecological knowledge from all relevant coastal stakeholders. The four-component process can be used as a whole or in parts to satisfy a section of the project cycle. The individual components of SHAPES make up the knowledge integration system for enhanced coastal area management. The components of SHAPES are presented below covering the research gaps that have been detailed above.

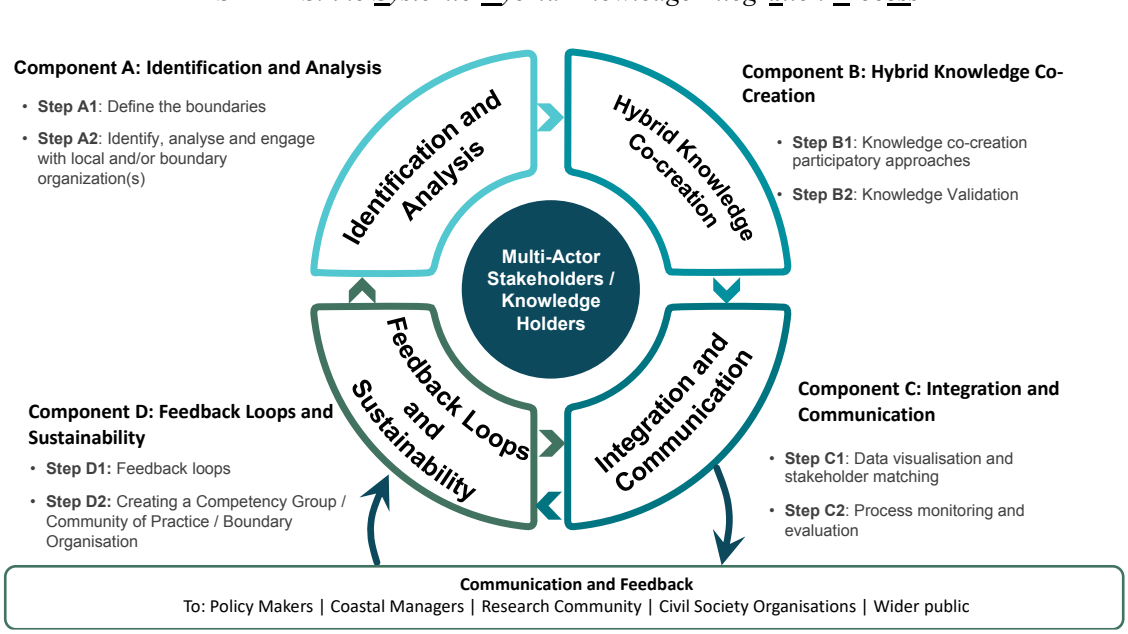


Figure 17 The Systemic Hybrid Knowledge Integration Process (SHAPES).

5.4.1 Component A: Identification and Analysis

✓ **Step A1: Define the boundaries**

An environmental project that has the boundaries defined can ensure that you engage with all the relevant actors within the project scope and the boundaries of knowledge while including the stakeholders that have a vested stake or interest in the phenomenon at study. Indeed you would ideally want to engage all possible stakeholders but in the words of Reed et al., (2009, p. 1937),"it is often not possible to include all stakeholders and a line must be drawn at some point". The boundaries to include stakeholders could be defined through a number of aspects. For instance, they can be geographically demarcated through government delineated coastal areas, protected areas or city limits, etc. (Reed et al., 2009). The timescales of the intervention can also help to delineate the boundaries of the study (i.e., only enough time to consult with *x* amount of stakeholders). The boundary of intervention could also be, and potentially most ideally, co-defined (co-define the stakeholders to be engaged through a first scoping study). The boundary criteria can also be demographically defined including nationality, age, cultural background etc. (Clarke and Clegg, 1998). A knowledge boundary can also be used as defined by Mileva Boshkoska et al., (2018) in their review paper on knowledge boundaries: i.e., networks – and the knowledge they possess and boundary objects (knowledge types).

With the boundaries defined, the next step involves the identification and engagement of local or boundary organisations.

✓ **Step A2: Identify, analyse and engage with local and boundary organization(s)**

The results provided in **chapter 2** specify the reasoning to engage with local and/or boundary organisations when extracting knowledge from the local level. Furthermore, **chapter 2** provides the details and characteristics of a boundary organisation, making it easier to identify such an organisation. However, the mechanism or processes of how to select them, how to advocate for their involvement and how to elicit engagement etc., is the subject of many research articles (Cotton & Mahroos-Alsaiari, 2015; Gramberger et al., 2015; Ielite et al., 2015; Reed et al., 2009, 2017; Sherman & Ford, 2014) and thus is not needed to be covered here.

Stakeholder analysis is essential to perform in each area of intervention as the needs, influence, interest to the project, community and to each stakeholder differs from area to area and sector to sector (Jiren et al., 2022). With a deeper understanding of the stakeholder attributes, interrelations and the groupings they represent, engagement processes can be designed and targeted to these stakeholders.

The engagement with the local and/or boundary organisation(s) to elicit the required local level information should be undertaken through "boundary objects" or participatory processes. As the empirical results in **Chapter 2** demonstrate, face-to-face interaction and participatory processes are currently the better methods to identify, capture, exchange and validate local knowledge and needs.

The use of boundary objects forms part of the steps in component B where the knowledge is co-created.

5.4.2 Component B: Hybrid Knowledge Co-Creation

✓ **Step B1: Knowledge co-creation participatory approaches**

Engaging with the stakeholders through co-creation participatory processes is seen as being more effective in devising solutions to common problems and are subsequently accepted more readily (Zingraff-Hamed et al., 2020). Co-created knowledge also supports the implementation of solutions and the uptake of co-defined measures in solving environmental problems (Pagano et al., 2019).

Chapter 3 stresses the importance of combining both top-down and bottom-up knowledge, providing clear results of hybrid knowledge identifying socio-ecological system indicators at coastal areas. A result from the engagement of the stakeholders as part of this doctoral study (**Chapter 2**), emphasises the importance of implementing participatory methods where local issues can be brought forward and subsequently repeated to identify best practices of knowledge capture. In **chapter 2** boundary objects were discussed in terms of providing the tools and processes that are usually used in boundary organisations which include workshops, focus groups, reports, models, maps or events (Clark, Tomich, et al., 2016a; Guido et al., 2016). Further to these, there are a plethora of techniques to co-create knowledge with many authors focussing on new and innovative processes within environmental management.

✓ **Step B2: Knowledge Validation**

The validation of generated knowledge is a vital process to assess the effectiveness of the generated knowledge where it can be refined and if necessary reconfigured (Tessier, 2021). There have been a number of knowledge validation processes, procedures and techniques that have been reported on in the literature (Owoc et al., 1999). **Chapter 2** has also provided the empirical evidence to the theoretical findings for the use of multi-stakeholder platforms for the validation of effective stakeholder engagement and knowledge generation. Monitoring and evaluation processes methods were proposed by the consulted stakeholders in chapter 2, from the use of mobile phones to the use of online knowledge validation processes. Face-to-face engagement observing the changes at local level or local media reporting on new knowledge were further validation methods proposed by the stakeholders.

The knowledge that is co-generated and validated would require an "outlet" to ensure that the information is communicated to those outside of the knowledge generation process. If changes are to be effectuated at local level, the knowledge has to be acquired by the target audience in the right format, SHAPES Component C focusses on this aspect.

5.4.3 Component C: Integration and Communication

- ✓ **Step C1: Data visualisation and matching**

The hybrid knowledge generated within the boundary organisation (multi-stakeholder platforms) requires adequate ways for the information to be assimilated. **Chapter 4** has provided a field study and user-centred evaluations of environmental data visualisations from the perspective of multi-stakeholders including non-scientific audiences. The participants evidenced that data visualisations can hold an important key in this regard. As data and visual science communication advances, new opportunities for the transmission of ideas and information go beyond written communication (Finkler & León-Anguiano, 2019). As we begin to try and close the gap between scientific knowledge generation and societal goals, visualisation helps targeted audiences to make informed decisions with regards to environmental management (Grainger et al., 2016). **Chapter 4** has provided these advances in the knowledge on communicating data through the most suitable visualisation tool or technique matched to a specific target stakeholder group or area of experience. These new findings provide implementors of SHAPES with the target audience matched to the most suitable visualisation tool or technique.

- ✓ **Step C2: Knowledge integration and communication**

The data presented in the most suitable format for the stakeholder type needs to be communicated for the new co-created knowledge to be integrated at local coastal level. In step C1 we look at the tools and techniques in terms of knowledge communication, meanwhile step C2 focusses on the channels to integrate this knowledge. In this sense communication campaigns that are channelled, purposeful and targeted are delivered through marketing and advertising techniques – which is outside the scope of this current research. However, it is well evidenced that targeted communication campaigns related to environmental issues at coastal areas inspire change at local coastal areas (Foxwell-Norton, 2017). An abundance of communication channels can be deployed with various examples from the literature (Dean et al., 2019; Tessier, 2021).

5.4.4 Component D: Feedback Loops and Sustainability

- ✓ **Step D1: Feedback Loops**

In coastal area management, to know that the above components have had the desired effect, it is essential to know if indeed the advocated changes are moving in the right direction or if changes need to be made. The feedback loop advocated for in SHAPES is where the outputs of the various SHAPES components are circled back and used as inputs creating a circular flow of knowledge exchange between stakeholders and the natural systems. Merrill et al., (2018) demonstrated the use of feedback loops in coastal communities indicating how it improves the understanding and acceptance of changes in environmental management. Further, feedback loops in coastal area management have shown a stronger connection between the human and nature systems and thus led to more successful conservation policies (Burgos-Ayala et al., 2020). A collection of authors have proposed various models, processes and platforms to implement feedback loops with a specific focus on coastal area management that can potentially be used within the SHAPES framework (Goethel et al., 2019; Jones et al., 2020; Marzloff et al., 2021; Solé & Ariza, 2019)

- ✓ **Step D2: Creating a Competency Group / Community of Practice / Boundary Organisation**

The ability to sustain the processes of knowledge exchange can potentially provide long term benefits to the coastal communities as they adapt to the changing climate. Sustainability seems to be somewhat of an elusive goal in many environmental projects (Hallin et al., 2021) specifically in relation to interest (Andriesse et al., 2022), financing (Déséglise & Freijido, 2019) and motivation (Arnott & Lemos, 2021). The consulted stakeholders in this doctoral research have indicated the potential of boundary organisations / multi-stakeholder partnerships to build long term sustainable solutions and to bridge the knowledge and decision making gap between local level and policy making levels. These organisations create networking opportunities and new innovative approaches to partnerships and can thus resolve the challenges to long-term sustainability in coastal areas.

5.5 Further research

As the doctoral study evolved so too did the ideas and subsequently the requirements for further research. In **chapter 2**, boundary organisations are introduced and discussed. The process to set-up these organisations, the roles of the actors within them and the future responsibility the boundary organisation can take within the water and climate challenges at coastal areas offers an exciting new area to investigate.

The function of a boundary organisation (or multi-stakeholder platform) offers a multitude of possibilities to assist in solving the local coastal challenges. The needs of the stakeholders at the local level should be fed into coastal management strategies through bottom-up processes. This requirement opens a new line of research to focus on integrating the human and natural system indicators prioritised from a stakeholder point of view (**chapter 3**). Furthermore, there is a strong need to investigate the concept of weighting or indeed non-weighted indicators and subcategories in function of their importance. Further work should also focus on the visualisation of the collected indicator information to provide managers with stronger coastal zone management tools.

Data visualisation on the other hand offers coastal zone managers a clearer picture of the challenges and needs that should be overcome. Although we now know the type of visualisation tool or technique that we can use for each stakeholder target group (**chapter**

4), qualitative research is still lacking to understand the reasons behind the stakeholders' visualisation choices. Additional research into the types of messages and data visualisation required for each target audience would also ease coastal zone managers work in providing clearer messages to each target group. Overall, reaching the rural and underdeveloped areas to further assess the potential for (or the irrelevance of) a digital divide in these areas in relation to data visualization is an exciting and necessary line of research.

Finally, as the research evolved it became clear that there was an opportunity to respond to Raymond et al., (2010)s' call to provide a knowledge process for environmental management. Evidently, as a mostly theoretical process, I would be very excited to see the practical implementation of SHAPES using all or parts of the presented components. SHAPES offers a unique opportunity to holistically and systematically integrate knowledge that can co-create solutions through sustainable stakeholder cohorts that can overcome the climate challenges and provide lasting impacts at local coastal areas with a specific focus on the Global South.

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7 Annexes

7.1 Data collection protocols for the integration of bottom-up knowledge and needs (Chapter 2).

To achieve the objective in identifying barriers and possible solutions to the integration of bottom up knowledge and needs in decision making processes around local environmental issues, a focus group engagement methodology was used. The first set of engagement processes was held in Accra, Ghana within the framework of the AfriAlliance project in 2017 together with a wide range of local stakeholders. The second set of engagement processes using the World Café methodology was held in La Paz, Mexico in 2018. The protocols for the engagement sessions in Ghana and Mexico are included below.

7.1.1 Focus Group protocol for coastal zone stakeholders in Accra, Ghana (2017).

19th and 20th of July 2017 **10:00 – 12:00** **Protocol for moderators and general outline**	Time 2h 00min
Bottom-up knowledge identification and barriers for information flow	
QUESTION ABOUT THE CONTEXT (to be filled after the focus group) – 10’	
Information protocol (to be filled after the focus group)	
Date of focus group	19 and 20 July 2017
Name of moderator and rapporteur	David Smith, Beatriz and Ken Kinney
Participants key information (socio-demographic information) ask for a business card *Ask participants to briefly introduce themselves based on the following items*	
Organisation’s name and contact of participants, ask for business cards	Traditional Leaders o communities
Role (position) and responsibilities	Mobilization of communities for security, environmental protection and development Some of them had the role of the teachers, former worker of the EPA
Field of work	Conservation of river basins, tree planting, ensuring rules on buffer zones, rain water harvesting and management (run offs pits dug outs), energy efficient (efficient stoves) environmental education, collaborative natural resource management.
Geographical scope of your organisation Experience at international level Dependencies/offices in other countries	Northern region of Ghana (Savanna vegetation) Volta region (middle zone, deciduous forest).
Their target groups: academic/policy/public entities/ CSO’s/ business/ funding agencies / women/farmers/indigenous/youth	Local authorities – they have to negotiate with them for interactions Farmers – as they need to look for peace in the land ownership Community members_ citizens

QUESTION ABOUT KNOWLEDGE/INTEREST IN CLIMATE CHANGE AND WATER (10')
In terms, of climate change issues and water related challenges, what are the topics of **interest** for your organisation? Social conflicts, especially when there are water shortages, Tree planting and how to better make use of rivers Water management: rain water and harvesting, flooding runoffs peaks Energy efficiency: biomass, fuel from woods, etc.
Does your organisation share **knowledge** on the topic of climate change and water related challenges? Or, on the contrary, do you consider that your organisation is in general a receiver of knowledge? *Check how participants perceive if they are Knowledge providers/receivers or both.* *AS KNOWLEDGE RECEIVERS:* They also need to get informed, to do that they do networking by attending conferences, workshops. they research also in their networks. This is a very key issue from them to gather current information, updated data, as they assumed that this is the most updated data they can gather. This is at local and international level. AS KNOWLEDGE PROVIDERS: Normally knowledge to the community is addressed through them, specially how to use technologies, etc. Moreover, most of their knowledge is also demand-driven, i.e. communities let them know about their needs, knowledge etc. Within their community, they do trainings explaining how CC is threatening their communities, identification of farming practices etc. In a way that anyone can participate, create discussion. The support of the NGO's to this activity is also crucial. Concerning the trainings, they normally get what are the most important needs, based on that they prepare trainings and they ask experts afterwards to do the trainings, but the most important point is that the they are demand driven based. They say that they do workshops, and focus groups like this one where they can create discussions around topics. For specific issues they prepare trainings (i.e. capacity development) and for more general issues better to prepare discussions.

QUESTIONS ABOUT THEIR STAKEHOLDERS AND INFLUENCE (5')
Who do you consider are the **key partners** for your organisation? *i.e. organisations that you are partnering with, networking with etc. that can better help you to implement your organisation mandate.* **NGOs** at local level that can support on the knowledge exchange process because they have resources. They can provide assistance on the tasks: Friends without Boarders, The Development Institute, SNV, Action Aid, Care International, faith Basin Organizations, They can do the Climate change threat identification They also facilitate the contents of the trainings. **Governmental Agencies** at national level as they have the responsibility and mandate to protect the environment and communities: Environmental Protection Agency, Forestry Commission, etc. The made the policies, therefore they should be key partners for them Environmental protection agency has the core mandate of environmental protection. They are the stakeholders in the environment.

The district assemblies from **municipalities** should be contributing to the knowledge exchange:
They occasionally can contribute to knowledge exchange especially when they are responding to projects
But they do not have resources to do it in a long term and also they think they do not have the motivation to do that, or they just do not . They matter more for resources management.
Traditional leaders need to have the motivation to go to municipalities and discuss with them and advocate for environmental issues, but this means it is very dependent on the willingness/motivation/interest of traditional leaders to go there and talk with them.

Which of them would you say are better-positioned and/or have a strong **influence**? Why?
Please take note of at least two examples

Government Institutes and NGOs are the best positioned, NGO's can really provide support on their mandate
Decentralized Government agencies (municipalities) have knowledge but lack of resources to support communities.

QUESTIONS ABOUT THEIR WAYS OF INTERACTION/INFLUENCE (15')

In your opinion, how best do you **interact** with your partners?
Use examples: online mechanisms, face to face interaction, combination of them.

They basically mention three good ways:

Discussion, community fora, training, focus group discussion, participatory methodologies → in order to raise awareness on an issue, more general
Education at community level → to develop capacity
To be active and motivated to be able for Contribution in policy formulation at their local level (advocacy)

General discussion:

To reach the community level they do really need to move along different community activities: religious meetings (churches, mosques), markets, public announced systems, community durbars, under tree meeting, schools, in the palace, (Not systematic because of lack of resources). The problem here is that this has to be done with their "own pocket" and with their "own motivation" and it is a long process over the time. To interact with the community, they need a group of people that can support them as they cannot go alone.
This means that this is not systematic way of approaching the community, they "just go" and interact. They think they could plan it but with resources, without them they just go when there is a urgent/emergence issue (like a flooding, etc.), also is when they find the motivation to go. You only talk when there is an issue to talk about, if the topic is not urgent then the is forgotten, even if climate change is a long term issue and permanent one.

When sharing/gathering climate change knowledge together with your partners, **how easy** do you find this process?

Use religious meetings, markets, public announced systems, community durbars, under tree meeting, schools, in the palace, (Not systematic because of lack of resources)→ This means that this is not systematic way of approaching the community, they "just go" and interact. They think they could plan it but with resources, without them they just go when there is an urgent/emergence issue (like a flooding, etc.), also is when they find the motivation to go. You only talk when there is an issue to talk about, if the topic is not urgent then it is forgot, even if climate change is a long term issue and permanent one.

How to find more resources?
First barrier is that a very **cross-cutting** issue that needs coordination from all, and this is not happening.
The practical interventions that we need to undertake might be clear, and with "**projects**" they can find a way for finance them. At local level, governments respond to projects, but local cohesion should be reached through community level education.
Other issue is about **awareness** on that resources should be put in there: it happens that governments and communities might happen that they do not really understand that resources (monetary and skills) should be put in place. It becomes then a problem of creating awareness in education/sensitization stage, so that the younger generation can get more ready and more aware on the need on how resources can be mobilized also for transversal issues.
There is a need for local level awareness to appreciate they common problems and have a buy-in by the community also to ensure local ownership for the solution of climate related problems. Mobilization of local resources base on awareness of the implication of effects of climate change on water.
They also discussed about paying taxes system, using taxes also for this. But people is discouraged on this system because they do not see effect at local level from the taxes payment.

What would you say is the best proof/best examples in order to show that you have **effectively engaged** with your partners? *To establish an initiative together, to share common agendas, to be in the same project, etc.*

When the issues directly affect them, e.g. pollution of common water resources. If the issue really affects/impacts the community, they can easily get engaged. Communities needs to see specifically what they can do at their own, and do not talk at general level. For example, if there is a situation of water pollution, then communities can get easily engaged to see how they can keep on using water.

Also, there should be a follow up process, a repetitive situation to keep sure communities got the point, therefore they mentioned that occasional events needs also to be used as a "window of opportunity" for capacity development, creation awareness, etc.

<u>Trustable sources of information:</u>
They truly trust on the repetition of information, i.e. when different organisations, NGO's or experts have mentioned the same problem several times with the same message is when the community start trusting on the information gathered.
Communities also are more confident if the info is not coming out from the same sources, i.e. if it is always that traditional leaders are the only ones transferring the info, they can start not trusting it
Communities also look very much on the personality of the "trainer", "facilitator", etc. also how NGO's for instance are introduce to the community from them. Also what are the footprints that the NGOs left in the community.

NGO's could be the more trustable sources of information because:
There is a legal proof as they have to register their activity in the government
Communities know that they are there to help, and without any other reason that help.

Effective engagement proof also make partnerships with the NGO's, as an effective way to guarantee effective engagement

In the context of climate change challenges, reaching the local level is crucial. In your opinion, what is the best way of identifying **bottom-up** water related needs?

Community leaders and NGO'Ss need to get involved, and traditional leaders should ensure that local needs are also addressed to policy creation.

So far this is being done through motivation of NGOs and traditional leaders. They also think that this is not finally reflected by foreign cultures that do not fully understand the governance schemes of the traditional systems.

Child education is also a key for a bottom-up approach, so for the next generation they, as a community can better be skilled to provide their needs.

Do you think that your institution is **well prepared** to afford climate change and water related challenges?
(explore information needs, and also information that is well shared?

It is a mandate from traditional leaders to ensure this preparedness.

In northern Ghana experiencing extremes of CC, flood and draught, (resilience being build) draught management and flood management has made them more and more aware on what they should do to be better prepare, more adapted, less vulnerable

Most part of Ghana are less prepared due to a resistance to change, lack of technical knowhow (low capacity to act) and available technology. They discussed about the resistance of people to change their daily lives, they just want to keep living quietly, and adoption of new practices and technology makes them think that this "peace" can be broken. Communities might be aware that they need to use certain technology to overcome a certain problem, but they are not really eager to take action and change practices → rejection to change, rejection to adopt a new technology, commodity of the people.

They discussed about the example of agricultural productivity, that communities used to think that more hectares are better to produce more, and they do not really know that they can be more productive with same or even less crop hectares.

DISCUSSION ON HOW OVERCOME KNOWLEDGE FRAGMENTATION (10')

Why, in your opinion, is knowledge not being effectively shared?
Note to interviewer: Reasons for fragmentation could be: lack of resources, lack of communication, language barriers, governance structures, cultural beliefs, etc.

Not use of communication technologies:
High penetration of telephony but not wide application for water and CC. there is a high potential for telephone based applications for share information to Water and CC.
Use of local radio stations.
Local community communication centre.
Media is not ready prepared to transfer information
Low level of networking actions, like creating partnerships with your key partners, exactly like their three taking action to participate in this focus group, as they could really exchange their points of view with other traditional leaders as they were doing. This is something very valuable and not all of them are ready to do so.
Also the culture of participation (also linked to the idiosyncrasy of the population) is a problem because in this country people expect to get paid for their time invested in this kind of participatory actions, but it should not be like that. There should be a substantial change on the expectations of the people to contribute for knowledge exchange so we all can improve.
Another barriers is the need of the governments to take them seriously as they perceived they are bothering policy makers instead of making them to act for change of practices and policy adoption.

In which ways is your organisation contributing to overcome knowledge fragmentation on climate and water?
How can your organisation, overcome fragmentation in the best way possible, in the future?
In terms of resources and skills: are they generating water and/or climate knowledge? Are they using it?
In terms of communication actions: are they active in networking? How? Are they active in communication? How? (online, offline, etc.)

They should find a way to systematize their way of interacting with the community
They should also get better partnership with NGO's especially for fund raisings as NGO's know how to write proposal and make applications. (meaning international and local NGOS)
They should also exchange more between different communities and learn from others.
Communication tools and skills are also a way of improving, for example high performance of use of phone but low performance on the use of App related to climate change → that should be a way of getting data, but not all them have smart phones to do it.

WRAP UP:

- ✓ WHY KNOWLEDGE IS NOT BEING EFFECTIVELY SHARED: causes of knowledge fragmentation?
- ✓ Problem with local authorities
- ✓ Community awareness need to get more educated that community problems matter and they should be motivated to contribute
- ✓ Not enough resources for them to systematized processes for knowledge Exchange and not only related to specific events
- ✓ SUCCESFUL WAY OF INTERACTION:
- ✓ FOLLOW up PROCESSES to ensure that people is engaged, ensure about education over the generations (slow process but more safe).
- ✓ Networking: with other communities to Exchange knowledge, partnering with other NGO's for trainings and for drafting proposals together.

The analysis of the information gathered from the stakeholders are included in the results in **Section 2.5.**

Focus Groups on Day 1: 19th July 2017 (Woman and Youth Groups, Farmers and NGOs)



Focus Groups on Day 1: 20h July 2017 (Traditional Leaders and Local Authorities)

7.1.2 World Café protocol for coastal zone stakeholders in La Paz, Mexico (2018)

30 de Enero 2018	Duración
8:00 – 10:00	2h 00min
Guía para moderadores y descripción general de la sesión	

Mejora de la gestión integrada de los recursos hídricos en la Paz

World Café

Número total de participantes esperado: 15
Tiempo total disponible: 2 horas
Objetivo de la sesión: Identificar acciones para comprender mejor los retos locales relacionados con el agua y los impactos de cambio climático. Estas acciones irían encaminadas a favorecer la implementación de un Plan GIRH y la mejora del conocimiento ciudadano del estado de los recursos hídricos en La Paz.

Tiempo disponible:

Duración	Sección	Tipo
5’	Introducción (Lucia Frausto)	Plenario
5’	Presentación de WaterClima LAC (David Smith)	Plenario
5’	Establecer participantes en las tablas (moderadores para ayudar en la distribución)	-
1:30h (3 rounds x 30’)	World Café	Grupos
15’	Concluir	Plenario

Sesión de Introducción
Presentación por Lucia Frausto (5min) Principales temas de tratar en la presentación. – Introducción de la sesión – Objetivo de la sesión – Los principales problemas sociales de la gestión del agua en La Paz
Presentación por David Smith (5min) – Antecedentes de WaterClima LAC – Que se ha hecho en La Paz con el proyecto WaterClima LAC

– Explicación de la dinámica de la sesión del World Café.

Dinámica
Los participantes asistentes se dividirán en grupos más pequeños para discutir de manera abierta los temas en cada mesa. La sesión seguirá la metodología del World Café que dividirá a los participantes en un máximo de 3 grupos. Los participantes podrán elegir libremente a cuál de los 3 grupos les gustaría unirse, sin embargo, se buscará una distribución igual del número en cada grupo.

Tiempo asignado por discusión en cada mesa: 3 rondas de 30min cada ronda.

ROLES	
MODERADOR GENERAL	Dar la bienvenida y explicar el proceso brevemente - Mantener el control de todo el proceso y apoyar a los moderadores de cada mesa - Controlar el tiempo general de la dinámica - Señalar el cambio de ronda (cada 30 minutos) y recordar 5' antes de cada ronda a cada moderador de las mesas - Tomar fotos
MODERADORES DE MESAS	En general en tus mesas: – Bienvenida e introducción de los participantes al grupo y un resumen de los objetivos de la mesa en cada una de las rondas. – Compartir la esencia de la conversación de cada grupo de discusión y asegurarse que todas las voces sean escuchadas – Responsable de cerrar la discusión, cambiar de tema y buscar acuerdos de los participantes. – En cada ronda: o Primera ronda: elaborar la discusión usando una guía específica para cada mesa (ver a continuación). o En la 2da, 3ra y ronda, resumir muy brevemente cuáles fueron los resultados de las rondas anteriores. – Presentar la conclusión de su mesa en la sección de recapitulación final utilizando solo 2 'para los aspectos más destacados.
Reporteros (si es posible)	- Tomar notas o recopilar ideas de los participantes en unos post-its y ayude al moderador a organizar la mesa. - Apoyar al moderador en la discusión y controlar el tiempo.

MATERIAL DE APOYO PARA LAS MESAS
Rotuladores: 6 en total (2 colores cada uno)
Posters tamaño A1(pizarra pequeñas de pie)
Post-it (6 paquetes)
3 Cartulina con títulos de mesa en cada mesa (cartulina de colores)
Bolis
Silbato
Celo, tijeras, bluetack

Mesa discusiones

***Mesa 1**: Identificación de los necesidades locales para una mejor implementación de GIRH*

Moderador: David Smith

Reportero/a:

Objetivo de la mesa:
Identificar acciones encaminadas a la mjora en la identificación y comprensión de las necesidades y desafíos a nivel local y consecuentemente identificar las barreras y soluciones potenciales y existentes en la comunicación de estos desafíos locales, buscando un método de identificación de abajo hacia arriba.

Contexto
Muchos problemas relacionados con el agua y el cambio climático son locales y, por lo tanto, se necesitan soluciones locales, consecuentemente, es importante implementar un enfoque local. De todos modos, la adecuada identificación de éstas necesidades y retos a nivel local no es siempre fácil. Tomando como ejemplo el contexto de La Paz, nos guastaría identificar la mejor manera de comprender bien los problemas o retos relacionado con el agua o los recursos naturales que tienen un barrio u otro o el sector agrícola, las zonas rurales o las zonas costeras. Uno de las principales razones de no comprender bien de estos retos esta relacionado con la dificultad de identificar bien los actores clave (entidades, actores, personas) en conocimiento local. Una vez que estos actores clave están identificados, así como los retos sociales, biofísicos o económicos se observan, también, limitaciones en el flujo de conocimiento y información de abajo hacia arriba y *vice versa*. Un ejemplo de estas limitaciones de un efectivo flujo de información esta relacionado con la implementación de los micromedidores y la necesidad de tener un sistema tarifario que refleje la realidad.

Preguntas a realizar:
1. En La Paz, ¿qué acciones se pueden realizar para identificar mejor las necesidades y retos a nivel local en el contexto de la gestión de recursos hídricos? ¿Cómo se pueden identificar los actores clave en conocimiento local?
2. ¿Cuáles son las barreras de comunicación que existen para comunicar desde el ámbito local las necesidad en relación con la gestión hídrica o la gestión de impactos del cambio climático hacia los tomadores de decisión?
3. ¿Cuáles son las soluciones existentes o potenciales que favorecen esa comunicación?

Dinámica (3 rondas de 30' cada una)

- Ronda 1 (30'):
  - Muy breve introducción de los integrantes de cada mesa: nombre e institución.
  - Explicar el contexto
  - Explicar el objetivo de la mesa
  - 10' brainstorming individual de (1) Acciones; (2) Barreras (3) Soluciones: Una acción, barrera y solución en post-its separados. Identificar acciones que ustedes pueden hacer y soluciones que sugieren que hagan otros
  - 10' de deliberación conjunta sobre acciones propuesta

- Ronda 2 (30')
  - Explicar el contexto
  - Explicar el objetivo de la mesa
  - Hacer un resumen de resultados de la ronda anterior

- Deliberación y propuesta de acciones, barreras y soluciones conjunta entre todos. Una acción, barrera y solución por post-it.

- Ronda 3 (30')
  - Explicar el contexto
  - Explicar el objetivo de la mesa
  - Hacer un resumen de resultados de la ronda anterior
  - Deliberación y propuesta de acciones conjunta entre todos. Una acción, barrera y solución por post-it.
  - Priorización de acciones, barreras y soluciones.

Resultado esperado: ***en la pizarra debiera aparecer***

Acciones para identificar los expertos	Barreras	Soluciones
		

Mesa 2: Implementabilidad del Plan GIRH.

Moderador/a:
Reportero/a:

Objetivo
Identificar acciones que podrían realizar los organismos que representan los participantes para favorecer la implementación de un Plan GIRH.

Contexto

En la región La Paz no existe un programa integral de gestión de agua que se ve motivado porque la toma de decisiones no es homogénea en los sectores involucrados que tengan una visión integral del ciclo del agua incluyendo riesgos del cambio climático.
Aunque La Paz suele considerarse principalmente como urbano, el entorno rural y la expansión urbana hacen necesario la inclusión de la comunidad rural en la gestión de los recursos hídricos. En este sentido El Comité Técnico de Agua Subterránea (COTAS) contempla el trabajar con las comunidades rurales. La expansión del centro urbano supone el uso de tierra que hubiera sido destinado a la agricultura. Precisamente esta expansión está siendo hacia el sur de la región dónde se estiman mayores recursos hídricos. La comunidad rural no se está injiriendo adecuadamente en la toma de decisiones de este desarrollo urbano. Por ahora su única participación es a través de COTAS.

Desde WaterClima se han hecho estas acciones:
- Estudio de gestión integral del agua Subterránea.
- Modelo del flujo de agua subterránea. Determinación de tarifas autosuficientes para el organismo operador de agua potable.

Preguntas a realizar:

1. ¿Qué acciones pueden realizar vuestras instituciones para favorecer la implementabilidad del Plan GIRH?
2. ¿En qué plazo: medio-corto-largo?
3. Para cada acción propuesta, ¿qué otros organismos debieran estar involucrados?

Dinámica (3 rondas de 30' cada una)

- Ronda 1 (30'):
    - Muy breve introducción de los integrantes de cada mesa: nombre e institución.
    - Explicar el contexto
    - Explicar el objetivo de la mesa
    - 10' brainstorming individual de acciones: Una acción un post-it, en cada post it poner plazo y otros actores que podrían formar parte de la acción propuesta.
    - 10' de deliberación conjunta sobre acciones propuesta

- Ronda 2 (30')

- Explicar el contexto
- Explicar el objetivo de la mesa
- Hacer un resumen de resultados de la ronda anterior
- Deliberación y propuesta de acciones conjunta entre todos. Una acción un post-it, en cada post it poner plazo y otros actores que podrían formar parte de la acción propuesta.

- Ronda 3 (30')
  - Explicar el contexto
  - Explicar el objetivo de la mesa
  - Hacer un resumen de resultados de la ronda anterior
  - Deliberación y propuesta de acciones conjunta entre todos. Una acción un post-it, en cada post it poner plazo y otros actores que podrían formar parte de la acción propuesta.
  - Priorización de acciones por factibilidad.

Resultado esperado: ***en la pizarra debiera aparecer***

ACCIONES A CORTO PLAZO	ACCIONES A MEDIO PLAZO	ACCIONES A LARGO PLAZO
		

Mesa 3: Mejora del conocimiento ciudadano sobre recursos hídricos.

Moderador/a:
Reportero/a:

Objetivo
Identificar acciones que podrían realizar los organismos que representan los participantes para favorecer el conocimiento ciudadano del estado de los recursos hídricos en La Paz y especialmente del estado de gestión del acuífero.

Contexto
A través de las reuniones y cursos de capacitación, se ha fomentado el conocimiento ciudadano del entorno de la situación del acuífero de La Paz, ya que en la fase inicial se estimaba como uno de los retos principales. Actualmente se puede decir que hay un mayor conocimiento de los programas y planes que rigen la administración del agua.
Hoy en día hay más motivación de aprender y aportar a la construcción del conocimiento compartido, bien práctico y útil, y ha sido impulsado desde diversas instituciones como pueden ser asociaciones dedicadas a promover conocimiento ciudadano o desde instituciones educativas formales.

Preguntas a realizar:

1. ¿Qué acciones pueden realizar las instituciones de ustedes para favorecer el conocimiento ciudadano sobre los recursos hídricos?
2. ¿En qué plazo: medio-corto-largo?
3. Para cada acción propuesta, ¿qué otros organismos debieran estar involucrados?

Dinámica (3 rondas de 30' cada una)

- Ronda 1 (30'):
  - Muy breve introducción de los integrantes de cada mesa: nombre e institución.
  - Explicar el contexto
  - Explicar el objetivo de la mesa
  - 10' Brainstorming individual de acciones: Una acción un post-it, en cada post-it poner plazo y otros actores que podrían formar parte de la acción propuesta.
  - 10' de deliberación conjunta sobre acciones propuesta

- Ronda 2 (30')
  - Explicar el contexto
  - Explicar el objetivo de la mesa
  - Hacer un resumen de resultados de la ronda anterior
  - Deliberación y propuesta de acciones conjunta entre todos. Una acción un post-it, en cada post it poner plazo y otros actores que podrían formar parte de la acción propuesta.

- Ronda 3 (30')

- Explicar el contexto
- Explicar el objetivo de la mesa
- Hacer un resumen de resultados de la ronda anterior
- Deliberación y propuesta de acciones conjunta entre todos. Una acción un post-it, en cada post it poner plazo y otros actores que podrían formar parte de la acción propuesta.
- Priorización de acciones por factibilidad.

Resultado esperado: ***en la pizarra debiera aparecer***

ACCIONES A CORTO PLAZO	ACCIONES A MEDIO PLAZO	ACCIONES A LARGO PLAZO

➢ **Puesta en común y cierre**

✓ 15min para que cada mesa tome 5min para presentar sus resultados.

✓ Explicación de qué se hará con los resultados y agradecimiento.

Organisation and implementation of the World Café for coastal zone stakeholders in La Paz, Mexico (2018)



7.2 Data collection protocol for practical stakeholder-based indicators for coastal monitoring frameworks (Chapter 3).

To achieve the objective in defining a set of practical environemtnal systema indicators for the theoretical to the empirical that indicates the overall health of the environmental system a focus group was implemented in Accra, Ghana in 2019.

Focus Groups protocol PhD Ghana

Date and time:8th of March 2019

1. **What is a Focus group?**

A small group of people whose opinions about something (such as a politician or a new product) are studied to learn the opinions that can be expected from a larger group

2. **Rules of a Focus group**

The focus group process will follow a number of open questions included below, as a guide to orient the moderator. It is important to keep in mind that these are guide questions to the moderator that should be used to generate a conversation.

Two limitations to be reminded of:

- Ask on behalf of the organisation the interviewee representant
- Contextualize question in the areas of water and climate change issues.

During the discussion the representants should speak one at a time, we want to ensure that everyone has an opportunity to give their views

- Respect the opinions of others - everyone's views are valid although you might not agree with them
- There are no right or wrong answers – we just want to know what you think
- Notes will be taken but everything that is said will be kept confidential – no names will be put against comments
- If anyone has any specific questions that do not relate to the discussion, there will be an opportunity at the end of the meeting

3. **Roles and responsibilities**

Facilitators	David Smith
Participants	Stakeholders related to coastal zone management in Ghana

4. **Template Focus Group (2h)**

Introduce the Context and the Problem

Good morning, Thank you for your participation and dedicating 90min of your time. First of all, please sign the consent sheet that informs you about this study in detail and how after the data will be used in an aggregated format and never with an individual perspective, and that you allow me to record the conversation for transcriptions purposes and because this will facilitate my role as moderator and rapporteur at the same time. You are also completely free to leave the discussion at any point.

The dynamic of the discussion will be that I will be asking you questions, and for each of these questions

we will open a conversation where each of you will be able to give your opinion at your convenience, and the others intervene to show agreement or disagreements, to make a related comment, reflection, etc.

We ask you to give sincere answers and keep the tone in a friendly discussion. I will be here to moderate the discussion, re-orient to the related issue if the conversation loses the focus and change to the next question when needed.

Let me take an opportunity to explain my PhD and what my objectives and expected results are:

Give Presentation.

Procedural issues:

- To ask for permission to record the conversation

Questions

Objective of the Focus Group

1. To define a set of criteria to choose practical environmental system indicators that can be used to show the overall health of the environmental system

2. To assess the challenges of an empirical integrated environmental system approach in particular in relation to the visualisation opportunities in the context of climate change in coastal areas.

The focus of the study is on the coastal areas of Ghana. Specifically with relation to Environmental management issues and climate adaptation.

The Focus Group questions will relate to the following main points.

- Metrics or indicators related to environmental system management in coastal areas. Environmental system refers to the following parameters (Environment, governance, social, economic)
- Can environmental aspects be better managed or stakeholders made better aware of local issues through visualizing the data from the indicators / metrics

What is an indicator?
An indicator aids in revealing trends and simplifying complex phenomena by providing information that simplifies reality. The information gained from indicators is used to disclose social, environmental or economic phenomena and to establish connections between them; it also provides a basis for influencing and controlling such phenomena. Indicators can be used either to describe a situation or trend (descriptive indicators) or to provide an assessment of progress towards established objectives and targets (performance indicators). Commonly these two types of indicators (descriptive and performance) are used together: we could measure a phenomenon with the latter, whilst using the former to obtain additional explanation. There are inevitably limitations in the use of indicator frameworks. Indicators are useful as a way of representing reality, but the real world is far too complex to be fully captured by an underlying framework or system of indicators. Indicators have been developed and designed by a number of global organisations to track changes over time.

Climate change indicators are tools to assess, visualize and communicate the impacts of climate change on species and communities.

Nine different indices of sustainable development were selected, comprising the Change in Wealth Index (CWI), Ecological Footprint (EF), Environmental Performance Index (EPI), Environmental Sustainability Index (ESI), Genuine Savings Index (GSI), Global Well-Being Index (GWI), Happy Planet Index (HPI), Human Development Index (HDI) and Sustainable Society Index (SSI). Each index was first assessed for its relative ability to measure the economic, environmental and social dimensions of sustainable development. (Strezov, 2016)

What is visualisation?

Effective visualisations are vital when trying to synthesise and communicate intangible (multi-dimensional, multi-scale, complex or abstract) information to audiences unfamiliar with the subject matter (McInerny et al., 2014; Meirelles, 2013). However, the risk is real in many professional contexts that visualisation systems fail to engage end users, by focusing on model and data integration at the expense of knowledge exchange and the provision of usable tools.

To see the data, there are different tools and technologies that can be used so that decisions can be made or awareness achieved.

- theory of social network analysis i
- using a range of network analytic tools (e.g., visual displays of networks, quadratic assignment procedure, Procrustes analysis, component analysis, and centralities)
- The sustainable livelihoods framework (SLF) visualisation
- Media Efficacy Return on Investment Tool (MERIT)
- Visualisation of data through Augmented Reality (AR)
- social network analysis is used and the relationship within the urban agglomeration is expressed by using the UCINET6.0 and NETDRAW software
- Wickens' SEEV model incorporates four mechanisms of attentional guidance—stimulus salience, effort, expectancy, and information value—along with a probabilistic choice mechanism to predict the steady-state distribution of attention over multiple information channels
- the possibility of using social network analysis and visualization as a tool for qualitative research in human geography
- three step visualization tool, here called Green Performance Map (GPM)
- UMEP (Urban Multi-scale Environmental Predictor), a city-based climate service tool, combines models and tools essential for climate simulations. Applications are presented to illustrate UMEP's potential in the identification of heat waves and cold waves; the impact of green infrastructure on runoff; the effects of buildings on human thermal stress; solar energy production; and the impact of human activities on heat emissions.
- Neighbourhood Sustainability Assessment Tools
- The Disaster Risk Index

The focus groups will ideally be divided as follows:

Focus Group 1: 10:00 – 12:00

- Representatives from the Stakeholder group NGOs (2 representatives)
- Representatives from the Stakeholder group Woman's Group (2 representatives)

Focus Group 2: 12:30 – 14:30

- Representatives from the Stakeholder group Government Institutions (2 representatives)
- Representatives from the Stakeholder group Traditional leaders (2 representatives)

Objective of the question	Questions (tentative)
Indicators	
To know what the level of power or influence the stakeholder has over management in coastal areas	What are the principle environmental challenges in the coastal areas of Ghana?
	In what areas of these challenges do you or your organization work on?
Stakeholders level of knowledge on indicators in coastal areas management	How much do you know about IWRM and ICZM. What is your opinion on these management systems? (if any)
Stakeholders level of knowledge on current environmental management in coastal areas	What is your opinion on the manner in which coastal areas are currently being managed?
Stakeholders level of knowledge on indicators in coastal areas management	Are you aware if there is a systematized? indicator / metric-based integrated environmental management system in place in the coastal areas of Ghana?
To know if the stakeholders would use or could gain value for an indicator based management system	How would you use an indicator based management system to the benefit of your organisation and the people you represent?
The stakeholders provide a list of criteria they I could use to select all the indicators.	There are many types of indicators that currently exist from cultural, social, financial, economic, governance etc. But what in your opinion should be the criteria used to choose an indicator that would be helpful to visualise? *types of criteria that could be used - easy to measure? - data available (at both temporal or spacial scales)? - indicator well known or is it relatively new and difficult to understand? - Is it an indicator that shows tendencies over time? - Is it an indicator that can be visualised? - Can the indicator provide a response to a specific objective related to sustainability or ICZM.
Visualisation	

In the opinion of the stakeholders what type of tool or technology would their stakeholders use to visualise data	Now, if we had to visualise the information / data from these indicators or metrics, have you see data visualized in other ways or in other ambits that you liked and what did you like about it? What type of visualisation tool or technique do you think would bring the greatest impact (awareness) to your stakeholder group?
After the presentation they will be aware that data visualisation will help decision makers and to increase awareness on climate change issues at local level.	In your opinion, are there other reasons why data should be viewed?
To have an idea of who the visualisation of the information should be targeted towards.	Which stakeholder groups in your opinion should be targeted to visualise this data? Only policy makers? Spatial level?
To know what aspects would be necessary to be visualized.	What data in your opinion would be useful to visualise? Spacial, temporal, environmental, governance, network of stakeholders, etc.
Challenges to view or use this type of visualisation	What are the main barriers to use the different data visualisation tools/techniques?
Challenges to view or use this type of visulisation	How do you think you can overcome these challenges / barriers?
To know if there is any benefit in visualising data for the stakeholder groups	What is the likelihood of your organisation or the people you represent benefitting from a visualisation tool or technique?
To know if there is any type of visualisation tool or technique that favours one over the other.	What type of visualisation tool or technique do you think would bring the greatest impact (awareness of coastal management issues) to the people you represent?

Closing

Summarize major findings with them
Explanation of the next steps

- All results from the focus group will be analysed in an aggregated way and presented in a report.
- We will organise workshops at each of the demo-sites and the results here will be used to better frame the issues to be discussed. Those are all the questions that we wanted to ask.

- The recording will be deleted once we have reviewed the answers and aggregated the results. We will not keep any records on file.

Thank you for your time!

Focus Groups held in Accra, Ghana (2019)



7.3 Data collection questions for the survey on stakeholder matched data visualisation tools and techniques (Chapter 4)

https://www.surveymonkey.com/r/2YL5T6T

ASSESSING INDICATORS FOR ENVIRONMENTAL SYSTEM MANAGEMENT APPROACHES AND VISUALISATION

INTRODUCTION

This short survey forms part of a study on environmental indicators at coastal regions where system approaches to environmental management that integrate environmental, social, economic and governance elements within the ecological system are increasingly adopted by local managers and policy makers. Your answers will help to guide my PhD investigation that is focussed on the use of these indicators for coastal environmental management, especially regarding visualisation techniques and applications. The objective of this questionnaire is to gain insights on the priorities and feasibility of the use of indicators for water management.

The questionnaire is designed to only take 10 minutes of your time.

If you decide to participate in this survey, your name, organisational affiliation and email address will NOT be distributed nor held for other purposes other than research. The information will be held in the strictest confidence. The results are necessary to achieve the main objective of my PhD.

RESPONDENTS DATA

1: Your area of expertise (Multiple Choice)

- ☐ Integrated Water Resource Management
- ☐ Food Security / Agriculture
- ☐ Human Capacity Development
- ☐ Climate Change Adaptation and Mitigation
- ☐ Water and Climate Data monitoring, collection, forecasting and analysis
- ☐ Other (please specify):

2: Which of the following major groups of stakeholders are you a part of? (Multiple Choice)

- ☐ Academia/education (research centres, universities, etc.)
- ☐ Local/regional authorities
- ☐ National authorities (governments, ministries)
- ☐ Implementing agencies (utilities, public agencies, etc.)
- ☐ Business/private sector (SME's, companies, industry, etc.)
- ☐ Finance (donors, funding agencies, Banks, philanthropists, etc.)
- ☐ Civil society (CSO's, consumers/users' associations, NGOs, etc.)
- ☐ Women's groups
- ☐ Children and Youth groups
- ☐ Indigenous people groups
- ☐ Farmers associations
- ☐ Other (please specify):

3: Years of experience at coastal regions in Africa (Multiple Choice)

More than 10 years
Between 5 and 10 years
Less than 5 years
No experience

4: Region of Africa where you are from or where you have experience in the coastal areas (Multiple Choice)

North Africa
West Africa
East Africa
Southern Africa
Central Africa

5: GENDER

- Female
- Male
- I don't wish to state

6: Age group

- <20 years
- 20-29 years
- 30-39 years
- 40-49 years
- 50-55 years
- 56-64 years
- 65+ years

7: Your education level (Multiple Choice)

- PhD
- Second stage of tertiary education (Masters)
- First stage of tertiary education (bachelor's degree)
- Post-secondary non-tertiary education
- Upper secondary education
- Lower secondary education or second stage of basic education
- Primary education or first stage of basic education
- Pre-primary education
- No Formal Education

A. DATA VISULISATION

A1. Which of the following types of visualisations would be best suited for your sector, the scientific community and other non-scientific communities? (1 = Not at all suitable – 5 = Extremely suitable)

Type of visualisation	My sector	Scientific Communities	Other non-scientific communities
Graphs	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Maps	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Infographics	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Visual storytelling	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Narrative-based visualisation	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Artistic maps	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Videos	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5

C1. What objective do you have in visualising data regarding the indicator categories mentioned in the questions below? (more than 1 answer is possible)

- To make better management decisions
- To show trends
- To understand what is happening at a particular level (international, national, regional, local)
- To communicate information
- To create policies based on visualised information
- To present a range of possible outcomes and to plan / develop scenarios

Other

C3. Please mention other types of visualisation approaches that you deem potentially helpful to support your work.

C4. Considering the current global situation of the COVID-19 pandemic and taking into account your responses to the above questions, in your opinion, should the type of visualisations of data change in respect to the information regarding the pandemic?

Yes
No

If yes, in what way?

In your experience and from your geographic coastal area, what visualisation techniques have seemed to work well to communicate various aspects of the COVID-19 pandemic to the local coastal communities.

Including its current status, the gravity of the situation and the expected behaviour of the community in respect thereof.

1 = Not at all well
5 = Exceptionally well

Type of visualisation	
Graphs	1 2 3 4 5
Maps	1 2 3 4 5
Infographics	1 2 3 4 5
Visual storytelling	1 2 3 4 5
Narrative-based visualisation	1 2 3 4 5
Artistic maps	1 2 3 4 5
Videos	1 2 3 4 5

Other

What barriers do coastal communities have in transmitting their local needs (in this case in coastal areas) during a global pandemic.

B. THE RELEVANCE OF THE CATEGORIES OF INDICATORS

B.1. Please rate for the importance of your work the development of indicators in each of the following themes (1 least Important – 5 Most Important). Feel free to repeat a rating, if necessary.

- Built Environment
- Social
- Socio-Economic
- Economic
- Systemic (or holistic)
- Governance
- Biophysical

B.2. Built Environment sub-categories
Please rate the importance of each of these sub-categories for your work (1 least Important – 5 Most Important) (Note: in brackets are the types of indicators that can be included in each category)

- Infrastructure (e.g. roads, buildings, basic services)
- Mitigation (e.g. changes made to the built environment to avoid climate change impacts)
- Adaptation (e.g. climate resilient buildings)

Please list other relevant sub-categories of indicators of the built environment that are not mentioned above

B.3. Social-economic sub-categories
Please rate each sub-category with a score from 1 to 5 according to their relative importance for your work (1 least Important – 5 Most Important) (Note: in brackets are the types of indicators that can be included in each category)

- Community livelihood (*e.g. livelihood diversity, gender equality, fishing community growth, subsistence vs commercial fishing, community tourism income, changes in spending power*)
- Household livelihood (*e.g. relative income, income stability and diversity, no. of assets, asset ownership, material wealth*)

Please list other relevant sub-categories of socioeconomic indicators that are not mentioned above

B. 4. Social sub-categories
Please rate each sub-category with a score from 1 to 5 according to their relative importance to your work (1 least Important – 5 Most Important). (Note: in brackets are the types of indicators that can be included in each category)
.

- **General Community Demographic Information** (1- 2- 3- 4 -5)
- **Adaptation** (*e.g. communities ability to adapt to climate technology*) (1- 2- 3- 4 -5)
- **Communication** (e.g. *accessibility, campaigns and mechanisms)* (1- 2- 3- 4 -5)
- **Community Education Level** (e.g. *literacy, youth and adult education and formal and informal education)* (1- 2- 3- 4 -5)
- **Community Access to basic services** (e.g. *Commuting, Health services, Water, Irrigation, Electricity, to Vote)* (1- 2- 3- 4 -5)
- **Community Knowledge** (e.g. *Local Ecological Knowledge)* (1- 2- 3- 4 -5)
- **Community Security** (*General Public security; Storm Evacuation; availability of Warning Systems; Adaptive Capacity; Flood Risk*) (1- 2- 3- 4 -5)
- **Community Health** (*Leisure time and activities; Human health; Substance abuse; Wastewater and Food*) (1- 2- 3- 4 -5)
- **Community Togetherness** (*participation in activities, number of conflicts and number of connections)* (1- 2- 3- 4 -5)

Please list other relevant sub-categories / topics of social indicators that are not mentioned above

B 5. Systemic Sub-categories
Please rate each sub-category with a score from 1 to 5 according to their relative importance for your work(1 least Important – 5 Most Important) (Note: in brackets are the types of indicators that can be included in each category)

- Systemic Management Systems (e.g. *Disaster preparation and management; community-based management system; programmes in place to replace indigenous flora and fauna that benefit the entire system; Are the local management plans adaptive?*)
- Transfer, access and exchange of information (e.g. *information flow between Government and local community; Full systemic information available to farmers; Knowledge of the relationship between local flora and fauna; processes in place for bringing together the environmental, economic and social data)*
- Stakeholder engagements (e.g. S*takeholder groups involved in community meetings; fora where all stakeholders can exchange knowledge)*
- Technology use for systemic management (e.g. *fishermen access to technology*)
- Institutional support (e.g. *environmental services and support of institutional ecosystems)*

Please list other relevant sub-categories of systemic indicators that are not mentioned above

B.6. Governance sub-categories
Please rate each sub-category with a score from 1 to 5 according to their relative importance for your work (1 least Important – 5 Most Important) (Note: in brackets are the types of indicators that can be included in each category)

- The governance of local Cooperatives (*e.g. Do cooperatives exist at local level; how many there, how are they governed*)
- Governance (Control) (*e.g. coastal habitat areas that is protected; Species protection; marine protected areas*)
- Local, relevant policies (*e.g. land management; Fishing*)
- Implementation of relevant laws (*e.g. fishing laws implemented, sand mining laws implemented etc*.)
- Local Institutions (*e.g. existence; stability; support*)

Please list other relevant sub-categories of governance indicators that are not mentioned above

B7. Economic sub-categories
Mark each category with a score from 1 to 5 in order of importance (1 least Important – 5 Most Important)

- Income (*e.g. income percentage from fishing and crops*)
- Economic Adaptation indicators to a changing climate (*e.g. changing to climate resilient crops; rainfed to irrigation crops; changing economic activities*)
- Household Economics (*e.g. spending power, number of income sources etc.)*

Please list other relevant sub-categories of economic indicators that are not mentioned above

B8. Biophysical indicators
Mark each category with a score from 1 to 5 according to their relative importance for your work (1 least Important – 5 Most Important)

- Climatic Conditions (*e.g. flooding, droughts, rainfall)*
- Ocean Temperature (*e.g. changes in temperature*)
- Water (*e.g quality parameters and quantity*)
- Pollution (*e.g Air, Water, Soil etc.)*
- Soil (*e.g. quality; changes in salinity*)
- Fishing (*e.g. changes in fish stock, catch size etc.)*
- Flora (*e.g. forest coverage; mangroves; reef coverage etc.)*
- Fauna (*e.g. biodiversity, species counts, quality etc*.)

Please list other categories that you see as important that are not mentioned above

The information from this survey will be aggregated with other results to draw general conclusions and to define a set of environmental indicator categories and sub-categories

If you would like to receive the results of this work, I will be happy to send you a copy if you add your email address below.

THANK YOU VERY MUCH FOR YOUR TIME
Please press DONE to finish

7.3.1 Glossary of terms offered to survey respondents as response options

Topic	Term	Code SPSS	Description included in the Survey
Visualization tools	Graphs	Graphs	Mathematical diagram which shows the relationship between two or more sets.
	Maps	Maps	Representation of physical characteristics of the Earth (e.g. rivers and mountains), or displaying of geospatial data (e.g., 'likelihood' maps or representations of forecasts")
	Infographics (information graphic)	Infographs	Representation of information in a graphic format designed to make the data easily understandable at a glance)
	Visual storytelling | Narrative-based visualisation | Visual narrative	Storytelling	A story told using still photography, illustration, or video, and can be enhanced with graphics, music, voice and other audio (telling stories with data graphics. i.e. constructing a storyline through data).
	Artistic interactive maps	Artistic	More imaginative maps, where the human is always present in the land. They are aesthetic, autographic, imaginative and subjective. These graphs are often hand drawn.
	Computerised tool | Web-based tool	Computer	Computerised tool or web-based, interactive tools and interfaces
	Mobile application	Mobile	Mobile Phone applications
Barriers and enablers to data visualisation	Decision making	Decision	To make better management decisions or environmental decision-making, creating policies with this information
	Showing data trends	Trends	To show trends: for instance to gain a greater understanding to what is happening at a particular level (international, national, regional, local)
	Communicate	Communicate	To communicate information
	Presenting scenarios	Scenarios	To present a range of possible outcomes and to plan / develop scenarios
	Knowledge gap	Knowledgegap	Knowledge gap from those wanting to communicate the data with regards to the different tools and techniques that are available for use.
	Understanding	Understanding	Lack of understanding of how to interpret the visualisation tool or technique from the target audience
	Lack of cultural awareness	Cultural	Lack of cultural awareness in communicating through the different tools or techniques for data visualisation
	Inability to present information	Adequate	Scientists not able to present the information in adequate visualisation tool or technique for the target audience.
	Donor requirements	Donor	Requirements and/or contractural outputs from Donor funding, organisation department, university, that hinder the divergence to use other(new) data visualisations tools and techniques
	Type of data	Data	The type of data type and/or personal preferences could hinder trying new data visualisation techniques

Barriers and enablers caused by the global pandemic		Capacity	The lack of capacity of local institutions to transmit effective visualisation communications
	Lack of trust	Trust	Lack of trust of the visualised information received
	Complexity of information	Complexity	Complexity of the visualised information
	Lack of interest	Interest	Lack of interest in trying to understand the visualised information
	Using new concepts	Language	The use of difficult language, new concepts or jargon with regards to a new disease not yet experienced.
	Not adapted to the culture	Cultural	Visualised information not adapted to the Cultural settings: for example the concept of personal space (for social distancing measures) varies between cultures and between different social settings.
	Complex social structures	Structure	Complex social structures that may require different visualisation techniques for different stakeholder groups.
	Face-to-face interactions	F2F	Face-to-face interactions such as communities of practices (COP) or community fora that cannot be held due to social distancing to show the visual information
	Lack of access	Access	Lack of adequate access to digital tools and technologies
	Institutional support	Institutional	Strong institutional capacity of local institutions to transmit effective visualisation communication
	Trust	Trust	Trust of the visualised information received
	Trust in the government	TrustGov	Trust in the central government
	Online interactions	Online	Online interaction mechanisms to transmit visually the pandemic data
	Bottom-up approaches	Bottom-up	Strong bottom-up approaches that have allowed for traditional and indigenous needs to be considered when transferring visual information.
	High understanding	Understanding	High understanding and/or interest of the visual data received.

Supplementary material 3 – Correlations

		Graphs	Maps	Infographs	Storytelling	Artistic	Computer	Mobile
Academia	CC	-0,116	-0,004	-0,259	-0,151	0,002	0,033	-0,041
	Sig.	0,411	0,977	0,073	0,288	0,989	0,813	0,770
	N	40	40	40	40	40	40	40
Public	CC	-0,020	0,158	0,028	-0,127	-0,112	0,020	-0,061
	Sig.	0,886	0,275	0,845	0,371	0,428	0,886	0,668
	N	40	40	40	40	40	40	40
CSO	CC	0,262	-0,171	0,081	0,079	0,012	-0,019	0,097
	Sig.	0,063	0,237	0,573	0,580	0,932	0,890	0,491
	N	40	40	40	40	40	40	40
Business	CC	-0,117	0,006	0,252	.297*	0,129	-0,053	0,024
	Sig.	0,405	0,966	0,081	0,037	0,361	0,708	0,868
	N	40	40	40	40	40	40	40

Note:
CC = Correlation Coefficient
Sig = Significance (2-tailed)
N = number
Green highlight indicates a statistical positive correlation. Orange highlight indicates a statistical negative correlation. The sector column refers to the origin sector stakeholder groups, the sector row indicates the target sector stakeholders and the type of visualisation technique. The columns within the different visualization approaches refer to the rating provided by each origin stakeholder to the target stakeholder using the Likert scale rating (1 to 9) that they attributed.

Which of the following types of visualisation techniques would be best suited (bring the greatest awareness and understanding) to communicate natural and human system indicators for coastal areas in your sector? (1 = Not at all suitable – 9 = Extremely suitable)

Mean values of the Likert scale per Stakeholder types

	Graphs	Maps	Infographs	Storytelling	Artistic	Computer	Mobile
Academic	6,18	7,65	7,18	6,82	6,76	6,88	6,71
Business	5,80	7,60	8,60	8,60	7,40	6,40	7,00
CSO	7,75	5,63	7,88	7,38	6,25	6,00	7,38
Public	5,90	7,50	6,60	6,00	5,70	6,00	5,10
Total	6,38	7,20	7,35	6,95	6,48	6,43	6,48

Supplementary Material 4: Labels to Figure 4

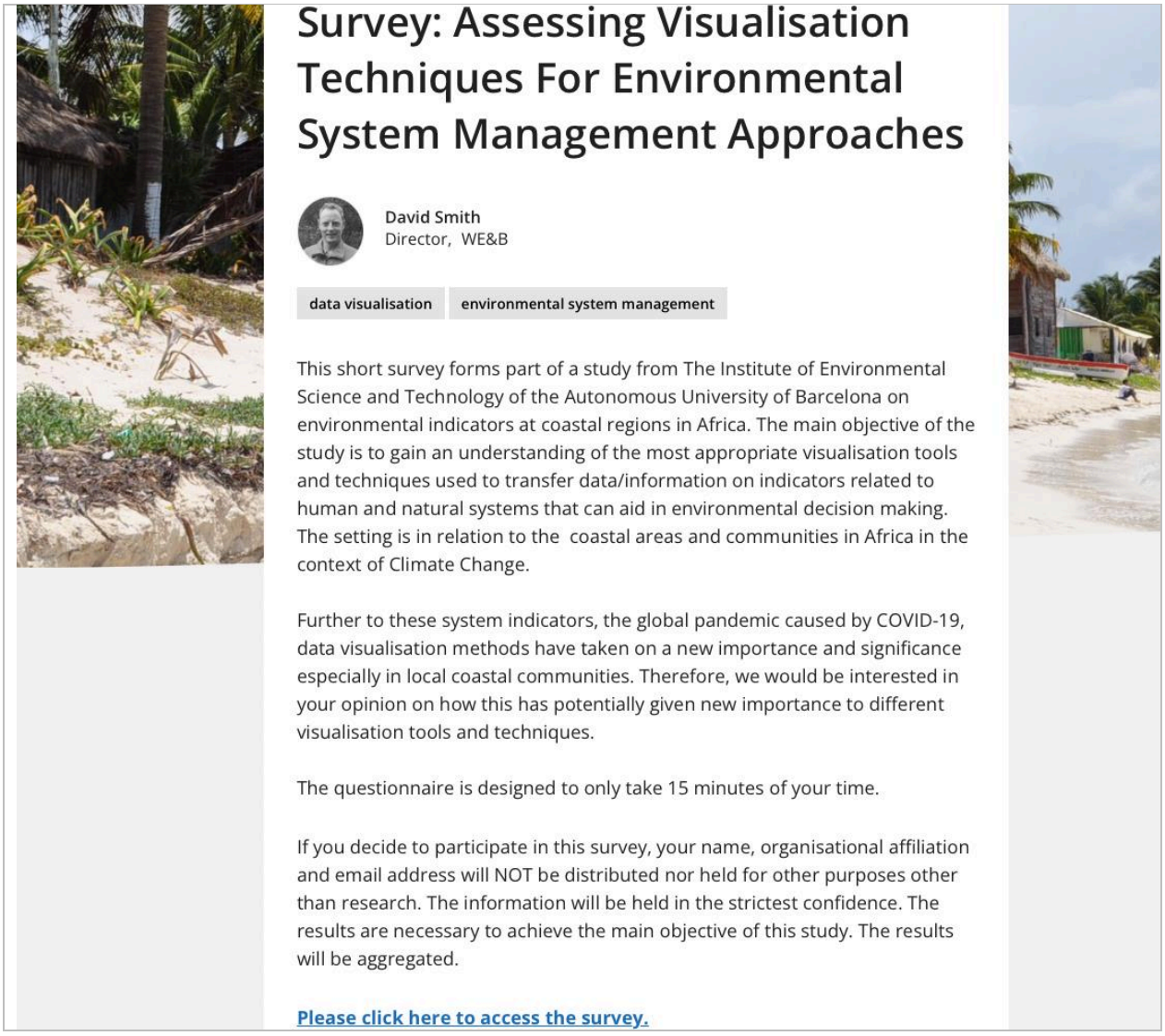
Labels (a)
Understanding: Lack of understanding of how to interpret the visualisation tool or technique from the target audience;
Knowledge Gap: Knowledge gap from those wanting to communicate the data with regards to the different tools and techniques that are available for use;
Adequate: Scientists not able to present the information in adequate visualisation tool or technique for the target audience;
Data: The type of data type and/or personal preferences could hinder trying new data visualisation techniques;
Culture: Lack of cultural awareness in communicating through the different tools or techniques for data visualisation;
Donor: Requirements and/or contractual outputs from Donor funding, organisation department, university, that hinder the divergence to use other(new) data visualisations tools and techniques.

Labels (b):
Mobile: Mobile Phone applications;
Storytelling: Visual storytelling or Narrative-based visualisation. A visual narrative (also visual storytelling) is a story told using still photography, illustration, or video, and can be enhanced with graphics, music, voice and other audio (telling stories with data graphics. i.e. constructing a storyline through data);
Artistic: Artistic maps interactive (these are more imaginative maps, where the human is always present in the land. They are aesthetic, autographic, imaginative and subjective. These graphs are often hand drawn);
Computer: Computerised tool or web-based, interactive tools and interfaces;
Infographs: Infographics (information graphic) is a representation of information in a graphic format designed to make the data easily understandable at a glance);
Maps: Maps (representing physical characteristics of the Earth (e.g. rivers and mountains). To display geospatial data 'likelihood' maps or representations of forecasts");
Graphs: Graphs (a mathematical diagram which shows the relationship between two or more sets)

Labels (c):
Face-to-Face: Face-to-face interactions such as communities of practices (COP) or community fora that cannot be held due to social distancing to show the visual information;
Language: The use of difficult language, new concepts or jargon with regards to a new disease not yet experienced;
Cultural: Visualised information not adapted to the cultural settings: for example the concept of personal space (for social distancing measures) varies between cultures and between different social settings;
Structure: Complex social structures that may require different visualisation techniques for different stakeholder groups;
Complexity: Complexity of the visualised information;
Interest: Lack of interest in trying to understand the visualised information;
Trust: Lack of trust of the visualised information received;
Capacity of local institutions: The lack of capacity of local institutions to transmit effective visualisation communications;
Access: Lack of adequate access to digital tools and technologies.

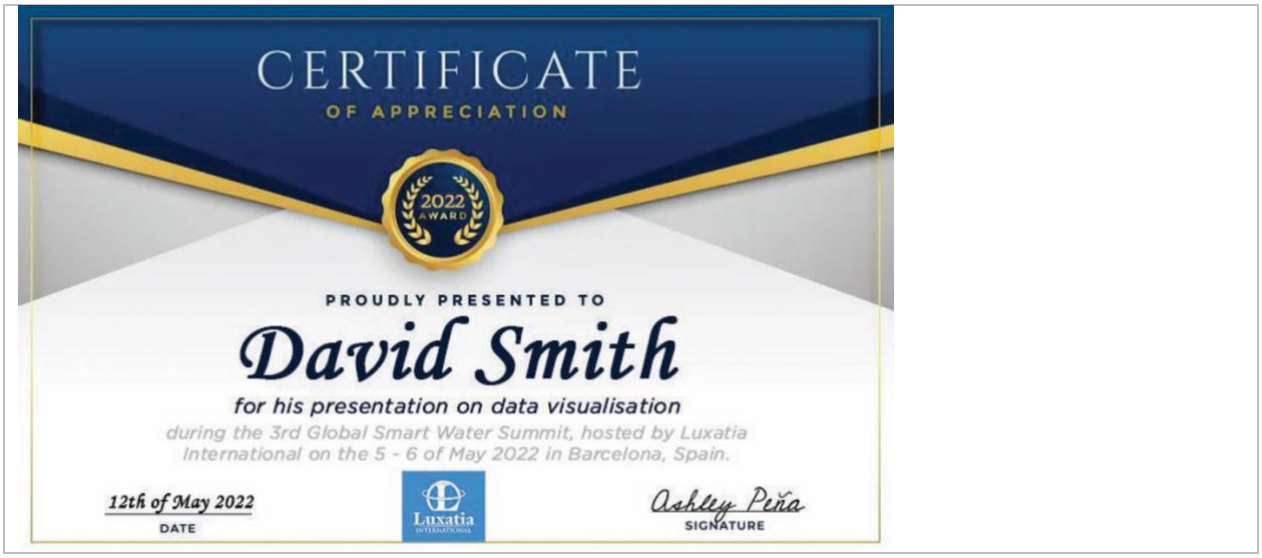
Labels (d):
Bottom-up: Strong bottom-up approaches that have allowed for traditional and indigenous needs to be considered when transferring visual information;
Institutional: Strong institutional capacity of local institutions to transmit effective visualisation communication;
Understanding: High understanding and/or interest of the visual data received;
TrustGov: Trust in the central government;
Trust: Trust of the visualised information received;
Online: Online interaction mechanisms to transmit visually the pandemic data

7.3.2 Screen grab of the survey advertised on the AfriAlliance platform



7.3.3 Screen Grab of the AfriAlliance MOOC where the participants were invited to participate in the Survey

7.3.4 Certificate of participation in presenting the results of the Chapter 4 research in an international conference.



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