HEIDELBERG UNIVERSITY

MASTER THESIS

# Thesis Title

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*"Whatever source of water they can find is what they have."*

Interviewee 3

# Chapter 1

# Design and Application

The design of the roadmap along with the Project Requirements Catalogue (PRC) and its subsequent application for implementing the research aim is presented in detail in this chapter. As usual in the research design *case study*, the results partly build on each other and evaluations had to be made in the intermediate steps to allow further continuation. This results-centred chapter will therefore also have small parts of further explanations and discussions of interim results, to allow the flow of thought to follow the decisions made. Nonetheless, these parts were kept to the bare minimum, leaving major discussions to the next chapter.
In the opening section 1.1, the first research question is addressed through an adapted and extended version of the SSF taking into account the conditions of the case study area and the research aim. The developed PRC is presented in the second section of this chapter and accompanies the Six Stage Design Roadmap (SSDR). The interplay between the SSDR and the PRC can be seen in figure **??**. The last section will apply the new SSDR along with the PRC to the second research question in the context of this case study.
The full interview and questionnaire transcripts are presented in Appendix **??** and the protocol to the data analysis in Appendix **??**. The chapter concludes with a short summary containing the main findings.

## 1.1 Six Stage Design Roadmap

The stages follow the Six-Stage Framework (see section **??**) and are presented in the coming sections. The design of the roadmap is primarily based on the SSF but additionally incorporates several other CS project guidelines and experiences, information from the conducted interviews, and the wider literature. While the stages conceptually separate the design process, it is important to keep in mind, that the stages are interconnected and stages three to six may be worked on in parallel to a certain degree. The actual design procedure will be an iterative process, that mainly incorporates these last four stages. Stages one and two are primarily important in the beginning and when major changes of goals or conditions take place during the design, implementation or operation phase. This, and its interplay with the PRC can be seen in figure **??**


New and awesome, if not to say marvelous depiction of this, the universe and the meaning of life. Just day to day stuff ya know.

Stage 1 outlines the exploration phase to establish a first understanding of the problem, context and potential solutions. The second stage elaborates on how to conduct a feasibility study to evaluate the CS approach regarding the identified problem in the given context. When the feasibility of the CS approach is confirmed, the overall structure of the project is laid out in Stage 3 *Designing the Project*. This stage describes the usage of the gathered information of stage 1 and 2 to further specify the research goal, respective products to reach these goals and the activities that constitute to the products. More guidance is given to which additional data needs to be collected, assessed and integrated to lay a good foundation for the coming stages. Stage 4 is concerned about topics surrounding community building efforts and Stage 5 outlines concerns in regard to data management. The last Stage, *Stage 6 Evaluation and Iterative Improvements* underlines the importance and elaborates on the practical implementation of ongoing assessment and improvement measures.

### 1.1.1 Stage 1: Context and Problem Identification

This first Stage is the exploration phase of the overall project (CitizenScience.gov 2023). This is where the environment of this project is established, in which itself is embedded. It is aimed at identifying prevailing conditions in all areas that may be covered or touched by the project. Even if this stage does not go into too much detail, the identification efforts must be thorough and as complete as possible. Oversights in this stage can have serious consequences in later stages. To enable this identification, project boundaries must first be defined by the overall objective and the problems to be solved, which also take into account challenges, positive and negative constraints as well as resource requirements. In addition, potential key stakeholders should be involved from the beginning and comparable projects and data sets need to be carefully identified and analysed to avoid duplication. (CitizenScience.gov 2023; Fraisl et al. 2022; Minkman 2015). Based on this information, possible solutions can be derived and hypotheses or research questions formulated (Fraisl et al. 2022; Silvertown 2009). Additionally, evaluation practices and sustainability considerations should be integrated into the project as early as possible although they are only defined in detail at a later stage (Fraisl et al. 2022).

### 1.1.2 Stage 2: Citizen Science Feasibility Assessment

The Citizen Science approach is not feasible for all kinds of projects. Certain criteria should be met and the feasibility of design, implementation and operation must be ensured and tailored to the decision-making processes that the project aims to influence. Fundamentally, a CS project must contribute to achieving the defined objectives and solving the problems, while also providing benefits to the participants, e.g. in terms of knowledge, community or recreational value (ESCA (European Citizen Science Association) 2015; Fraisl et al. 2022). The feasibility assessment needs to consider various factors and constraints in more detail than in stage 1 to identify information and management gaps accordingly. The clear definition of the relevant CS sub-concepts and levels of participation is crucial for the feasibility assessment. It is also important to clearly outline the boundaries and concepts by which and within which the project is to be confined and embedded. The goal should be clarified along with potential sub-goals and related products which need to match the derived gaps and the capacity of the implementing organisation (IFRC 2017; Minkman 2015). The organisational capacity depends on financial, human and technical resources, knowledge and experiences, embedding in decision-making networks and structures, and the organisational commitment and dedication of those involved (Fraisl et al. 2022; IFRC 2017). The importance of securing (long-term) funding is also highlighted by many guidelines (Cervoni, Biro, and Beazley 2008; Minkman 2015; Sharpe and Cathy Conrad 2006; Whitelaw et al. 2003). Existing data sets and potential tools need to be analysed and assessed for suitability. In addition to the positive constraints, the (IFRC 2017) has defined negative *red flag* constraints which, when they occur, should stop further design developments until they can be resolved appropriately. Going back to the exploratory first Stage may be necessary. The *red flags* are:

- A need does not exist.
- The community does not want the project.
- Barriers and fears of: information usage, data sharing, applied technology and different cultural beliefs.
- Insufficient capacities regarding financial and human resources, knowledge, experience and phone coverage.
- No support of key stakeholders.
- No or insufficient response possibilities.

### 1.1.3 Stage 3: Structure & Design

This stage builds on the identified context and conditions of stage 1 and the feasibility study of stage 2 and creates the broader framework for more specific work in stages 4, 5, and 6. The goals and research questions are considered again and finally specified and formulated in alignment with the projects, participants and stakeholders interests and aims (C. C. Conrad and Hilchey 2011; Fraisl et al. 2022; Minkman 2015). Previous assumptions should be backed up as much as possible and made explicit (Silvertown 2009) and biases need to be addressed (ESCA (European Citizen Science Association) 2015; Fraisl et al. 2022). "Legal and ethical issues surrounding copyright, intellectual property, data sharing agreements, confidentiality, attribution, and the environmental impact of any activities" need to be considered (ESCA (European Citizen Science Association) 2015). The design need to be thoroughly embedded in the context and anchored by policies, preferably in an Integrated Water Resource Management initiative (Cervoni, Biro, and Beazley 2008; Sharpe and Cathy Conrad 2006) and ongoing FbF implementations and efforts. The 'light' IWRM *community-based water resource management* framework by (Day 2009) is recommended as a starting point as it is geared towards practical feasibility (see section 1.2.2). The integration into the FbF is done by targeting data management (stage 5) on indicators which support intended triggers and respective anticipatory actions (IFRC 2017). Adequate and scientifically justified thresholds and monitoring methods may need to be developed and triangulation data sets identified, assessed and integrated.

A structured and interconnected foundation needs to be created for the integration of communities and stakeholders (Stage 4), data management (stage 5) and evaluation and iterative improvement procedures (stage 6). Community building encompasses recruitment, training, task specifications and participant benefits, motivations, feedback mechanisms and stakeholder acknowledgements. It is also concerned with the broader frame of partaking and collaborating non-governmental organisations and government bodies at all levels (C. C. Conrad and Hilchey 2011). Data management practices should be oriented on already proven concepts of comparable projects, identify and define data collection, transmission, storage and analysis aims, formats, and types (Fraisl et al. 2022; Gualazzini 2021; IFRC 2017). Consideration also needs to be given to the ways in which the new data from this project can be publicly displayed, accessed and used to improve completeness, timeliness and overall quality of information and decision-making processes (Catherine Conrad 2006). Evaluation and iterative improvement procedures are concerned with pre-defining success metrics which should be considered during the entire project design and operation.

In this third stage, the project requirements catalogue presented in the coming section **??** is recommended for integration to reduce mental load in the further design process.

### 1.1.4 Stage 4: Community & Stakeholder

This section pertains to the identification and establishment of all relevant factors associated with the participants, community, network, and organizational and governmental stakeholders and decision-makers. Understanding participants characteristics and motivations as primary data collectors and contributors to the project is of great importance for the sustainable success of the project. Their characteristics can include, among others, the educational level, skills and demographics (Cervoni, Biro, and Beazley 2008; Fraisl et al. 2022). The motivational aspects comprise elements of interest, engagement, acknowledgements and overall gained benefits. The first set of characteristics can be addressed by training, supervision and provision of feedback, especially for new participants (ESCA (European Citizen Science Association) 2015; Fraisl et al. 2022; Minkman 2015; Sharpe and Cathy Conrad 2006). Providing feedback to the actual contributions but also in terms of how the contributions influence planning and management decision-making processes and outcomes can positively influence the motivational aspects (Catherine Conrad 2006; C. C. Conrad and Hilchey 2011; Whitelaw et al. 2003). Creating wider public engagement and interest can further enhance motivational factors such as recognition and community building (Catherine Conrad 2006). Community events and networking bring further social benefits, trust and belonging and open up opportunities to engage directly with decision-makers and make them aware of what this project is and why it exists (Catherine Conrad 2006; Fraisl et al. 2022; Sharpe and Cathy Conrad 2006). Decision-makers, such as respective water and risk related government ministries and agencies, should be integrated in the process and design right from the beginning as especially local and regional leaders can help to implement and operate the project on site (Gualazzini 2021; IFRC 2017). They can furthermore help to sensitize the community, manage expectations and inform about and support in dealing with oppositely motivated stakeholders (I1). (Catherine Conrad 2006) encourages the perspective of integrating the project into the management as an opportunity and not as a threat. Inclusion of legal and ethical guidelines should also happen in this stage, but has its focus in the upcoming stage 5 (Fraisl et al. 2022; IFRC 2017; Minkman 2015).

### 1.1.5 Stage 5: Data Management

Legal and ethical laws, guidelines, and standards especially in terms of privacy and data security need to be respected. This also includes taking into account informal, community and cultural practices during all phases of data management (IFRC 2017, p. 017). These phases encompass the planning and design, the collection on site, the transmission, storage, Quality Assurance (QA) and Quality Control (QC) as well as subsequent analysis, presentation and dissemination of the outcomes (Fraisl et al. 2022).

All of these phases need to match the capacities of the organisation and of the contributing participants (IFRC 2017; Minkman 2015). Furthermore, all practices should focus on the end use and application of the data in supporting decision-making and follow the principle of data minimisation (EDPS 2023; IFRC 2017; Minkman 2015). In this stage, the planning of the data management procedures enters its detailed phase, is based on the established structure in stage 3 and results in precise methods, techniques, protocols and scripts. The methods should be simple, well-designed, peer-reviewed and standardised, while being fit for purpose (Fraisl et al. 2022; IFRC 2017; Silvertown 2009; Whitelaw et al. 2003). QA and QC procedures should ideally be integrated in every phase and follow the same high standards as the methods (Fraisl et al. 2022; Mackechnie et al. 2011;

Sharpe and Cathy Conrad 2006; Silvertown 2009). Financial and human investments and resources need to be specified and parameters about the technical infrastructure such as architecture, storage, analysis, transmission and collection protocols and methods need to be defined (Fraisl et al. 2022; Sharpe and Cathy Conrad 2006). For data collection "the least intrusive and most cost-effective method available" is recommended (IFRC 2017, p. 27). The applied tools for data collection and transmission need to meet the available resources and technical abilities of the participant on site (IFRC 2017; Minkman 2015). Network coverage should be taken into account when implementing SMS or other remote devices but the (IFRC 2017, p. 26) notes, that "it is now increasingly rare to have absolutely no network access, but a bicycle messenger or another local communication system will also work". An automated, technical remote solution should be the preferred solution, but simple SMS and phone calls directly to the relevant manager or via traditional communication networks can also work, especially in cases where transmission speed is not of utmost importance (Gualazzini 2021; IFRC 2017). The requirements for data storage solutions include secure storage, good maintenance options and high up-times. The position of the servers and the ownership of the data can lead to disagreements with local stakeholders and should be well communicated (I2). Before the analysis of the data, robust QA and QC measures should ensure high quality of the collected data (Fraisl et al. 2022; Sharpe and Cathy Conrad 2006). The integration of other data sources for information triangulation is recommended. The analysis is the centrepiece of the data management and should follow the objectives of the overall project. The outcomes should be made publicly available unless prevented by security or privacy concerns (ESCA (European Citizen Science Association) 2015; Sharpe and Cathy Conrad 2006). The type of presentation can show aggregated data, but should take into account the information needs of decision-makers. As with the issue of ownership of data, the procedures for sharing and presentation can also lead to disagreements and need to be managed sensitively. (I3)(IFRC 2017).

### 1.1.6 Stage 6: Evaluation and Iterative Improvements

Evaluation is an ongoing effort and should be considered at all phases of the project. The structure of the project should allow for evaluation procedures and subsequent implementation of the derived recommendations at all design stages and during operation (Fraisl et al. 2022; IFRC 2017). Success metrics as well as the response upon those need to be defined and agreed upon before the implementation of the project (Fraisl et al. 2022; Gualazzini 2021). The ninth principle of (ESCA (European Citizen Science Association) 2015) states, that "citizen science programmes are evaluated for their scientific output, data quality, participant experience and wider societal or policy impact". Underlying structures, practices and efforts can thus be configured and adapted into a more effective and efficient design and process. The integration of these assessments thus helps to progressively improve the use of data by decision-makers as well as the methods used (Fraisl et al. 2022).

## 1.2 Project requirements

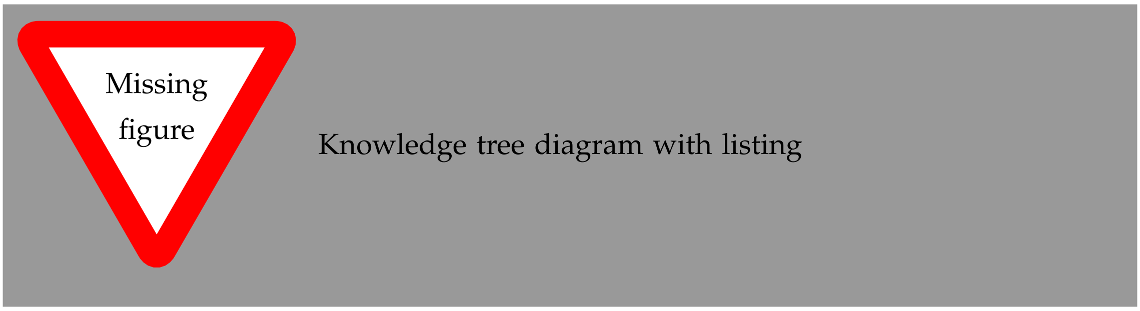
The stages of the SSDR give a good overview of what needs to be done and in what order.

The Project Requirements Catalogue (PRC) extends this process-oriented structure by listing, structuring and grouping important information requirements in line with their inter-dependencies.The catalogue of project requirements presented here is divided into four groups of information that include (Minkman 2015)'s derived goals and sub-goals and follows the layer structure of the SLMC. For each goal, products along with their required activities have been defined in line with the above roadmap.
The first group **Knowledge Base**, see figure **??** contains everything that should be known for the project. It thereby serves as a knowledge base being filled throughout the above-mentioned stages. Activities are primarily about identification and information collection. The second group **Groundwork** contains everything on which the actual implementation of the project must be based on (see figure **??**). It includes the goals *Awareness Raising, Public Education and Policy Development*. The first two goals relate to products of information and sensitization measures for the target community, contributing volunteers and involved stakeholders. Activities focus on consulting with local elders and key stakeholders, and subsequently informing and raising awareness among the entire community before the project starts. The third goal, *Policy Development* is about IWRM measures, required products and their development. The activities aim to embed these into existing local management practices and procedures through identification and agreements with all affected and involved stakeholders. In order to facilitate this, new policy developments and adjustments may be required which overlap with the third group of **Innovations**, see figure **??**. This stage is important, as "there is no one-size-fits-all approach" (Fraisl et al. 2022, p. 2) and new developments of suitable and scientifically sound methods to meet specific challenges of the project tasks will be necessarily in nearly every application to some extent and are summarised under the goal of *Method Improvements*. The last group **Management** contains all that needs to be done to successfully develop and implement a CS water source mapping and monitoring project (see figure **??**). The goal *Management Improvements* is further subdivided into products that are initially necessary once, recurrently and products that are required to embed the project in the context. The focus of the activities is on making decisions, developing procedures based on the **Groundwork** and **Knowledge Base** groups and implement developed methods from the **Innovations** group.
The order of the sections does not necessarily reflect the processing order but rather indicates dependencies whereas e.g. not everything need to be known in order to proceed with method development. The same applies to the order of products and activities (from top to bottom). However, to stay in this example, everything that, directly or indirectly, influences or is influenced by this certain method should be known. Therefore, stages 1 and 2 of the design roadmap should be completed before proceeding further with this catalogue in order to have a profound understanding of the local circumstances and their interconnectedness and interdependences.

The following sections briefly reason and describe the overall idea and content of each group. The activities are mostly already outlined in the above-described SSDR, therefore the focus lies on the products of each goal.

### 1.2.1 The Knowledge Base: What needs to be known

This Knowledge Base covers information and knowledge of all stages and is sub-divided into multiple products that each cover certain aspects of the project. The products (A), (B), (C) and (D) cover the baseline information of all stages. (A) includes information obtained in Stages 1 and 2 and, if this project is developed under an EAP, also the information from the overarching EAP assessment and feasibility study can be integrated. (B) is the repository for all information related to the Citizen Science community and participant management, (C) covers all topics of data management and QC and QA integration and (D) relates to evaluation and improvement procedures. These products consciously resemble Stages 4, 5 and 6, and should be included right at the beginning of Stage 3. The structural basis for each of the subsequent stages is laid in Stage 3, and by bundling the information from the beginning, follow-up in the subsequent stages is simplified and streamlined.
Products (E) to (H) are more specific for the mapping and monitoring of water sources in an FbF context. (E) integrates all information for the first phase of mapping and collection of key information on each water source including corresponding methods, while (F) includes all knowledge and methods on regular indicator monitoring. Together, this information enables actions on products (G) and (H). All potential AAs are first collected in product (G) and then narrowed down to those that can be triggered by thresholds related to water sources. The information about these thresholds along with triangulation data for the respective triggers is comprised in product (H).




### 1.2.2 The Groundwork: What needs to be built on

The Groundwork relates to everything, that needs to be in place, before the actual mapping and monitoring of the water sources starts. It is about giving the community all the information and knowledge to decide, manage and act primarily on their own, ideally only limited by the available physical and financial resources. Important is, that knowledge should not opposed on the communities but rather developed in close cooperation with the affected actors, their knowledge and practices. The first product (A) of the goals

*Awareness Raising & Public Educatin* (see figure **??**) is about gathering and then providing all the necessary background information to the community in order to allow them to make profound and informed decisions and contributions. Based on this, product (B) summarizes activities to address misunderstandings, reservations as well as expectations and concern handling. For this, the early involvement of community leaders or elders may be beneficial (I1). Product (C) refers to the sharing of information gathered in other phases with the community to keep their knowledge of prevailing and evolving circumstances up to date and to enable informed decision-making. In order to act on the information, product (D) summarizes the identification and transfer of information about water management and saving opportunities. Product (E) highlights the consideration, that even a single community is not homogeneous and that various groups with different interests exist within. Knowledge and measures to account for this are collected under this product.


Products A to E of goal *Policy Implementation*, figure **??**, represent (Day 2009)'s light community-based IWRM framework. The framework starts with the products (A) & (B) by identifying and assessing prevailing circumstances and requirements. From this, community water usage targets are derived and agreed upon in (C). Management guidelines, and prioritisation plans are pre-defined and implemented in products (D) and (E). Product (F) goes beyond the framework and addresses measures related to data security and privacy.


### 1.2.3 The Innovations: What needs to be invented

New innovations may be required to successfully achieve the project objectives under the given conditions and in the given context. These developments are grouped separately because the development of appropriate, scientifically sound and context-aware

methods can require a great deal of financial, material and human resources and should therefore receive specific consideration. In addition, the development of new methods is often a separate process that runs alongside the actual design and implementation efforts. However, there are now also many projects, guidelines and frameworks from which experience and best practices can be transferred. The developments can therefore also be an amalgamation of the old, tailored to new circumstances.
The products represent potential areas of such required innovations or adaptations. These can include areas of the initial and regular data collection, transmission, storage and analysis as well as, the determination of suitable thresholds, and their categorization for respective triggers.


### 1.2.4 The Management: What needs to be done

The group around management tasks is primarily concerned with the initial processes and responsibilities at the start of the project, tasks that need to be done regularly during operation, and specifications for solidly embedding the project in prevailing processes and practices. These tasks are about evaluating and processing identified and collected information to develop and make decisions about what elements, practices or structures to implement. The initial areas of concern (A) range from handling specific context related circumstances, to the development of training materials and evaluation procedures. Activities contributing to regular required products (B) are mostly concerned about providing training and supervision and implementing improvements derived from evaluations and feedback. Product (C) includes both initial and ongoing tasks, but is focused on embedding the project in the local context. It addresses the implementation of the *Groundwork* on community level and its integrations into prevailing local, regional and national structures, practices and stakeholder networks to make it relevant for decision-making.

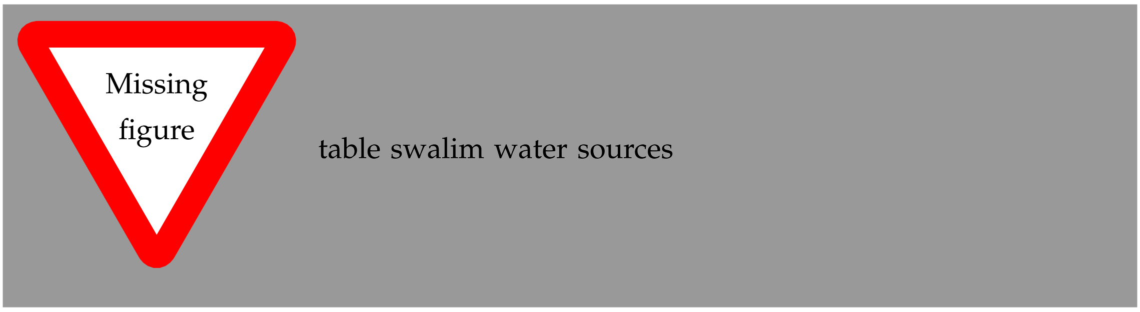
## 1.3 Framework Application: Focus Somaliland

In this part, by applying the roadmap and project requirements described above, the second research question of this thesis is tackled in order to ultimately achieve the overall aim of the research. Therefore, the results in this section are primarily geared towards identifying and implementing adequate water level monitoring of the water source type of berkads in order to trigger respective Anticipatory Actions. The third stage is structured following the project requirement catalogue. The Stages 4 to 6 refer their findings to the catalogue. However, because of their specific foci, they are not structured according to the catalogue. The above already displayed tree-diagrams can also additionally be found in the respective GitHub repository in Appendix **??**. This provides the reader with a simultaneous reference option, as the products and activities will only be mentioned by their abbreviations and not by their full name, to enhance readability.

### 1.3.1 Stage 1: Context and Problem Identification

The brief water source data analysis along with given context, resource restrictions, stakeholders and comparable projects as well as problem and goal statements of the interviewees are covered in this first stage. It also builds on the preceding case study area section **??** in chapter **??**.
The current drought and water scarcity situation in Somaliland has now lasted five years and has greatly impacted the water sector in Somaliland in terms of quantity and quality (I1). I1 describes the current crisis as *"huge and response activities are being overwhelmed by the need"* which will lead to *"commercialization and overpricing of fresh water"* further exacerbating the situation. This was underlined by I3 who describes the current water situation of the rural population as *"whatever source of water they can find is what they have"*. I3 further mentions, that the people sometimes *won't have enough water to wash their hands"* or for other necessary things and that *"they [then] don't think of what kind of water they can get, whether it's bad or something like that"* but only focus on having at least something to drink. Increased water shortage because of bad quality was also reported in the literature (see section **??**). Water can potentially be contaminated at all stages of the water collection process, from the initial abstraction of water, through transport and storage, to the use of the water (I3). Water quality is difficult to assess on site, as the the colour is not a good indicator and other parameters can only be determined technically which required equipment and training (I1, I3). Furthermore, I3 confirms the reports in literature that contamination of water in berkads, through their shared use with animals, can happen even before water withdrawal. This depends very much on the construction method and how it is used. The rehabilitation as well as training how to adequately use a berkad are already activities of the SRCS (I3) and besides the water quality, the quantity also depends on the kind of construction and of withdrawal. According to I3, supply period can range from one month to half a year, so information on these parameters is crucial for estimating the potential duration of supply (I3).
Water monitoring and management is not seen as a problem in urban areas as there is

an agency responsible for water supply but the problem is primarily located in rural and nomad areas, where 70 % of the people live, according to I3. (Somalia 2021), on the other hand, estimates an urban and semi-urban, sedentary population rate of 53 %.
The selection of beneficiaries for response activities of the SRCS are currently conducted on the basis of a preceding joint priority setting with the government. This prioritisation is based on *"assumed vulnerability per community based on Number of Internally Displayed Person (IDP) camps in the area, number of women headed families, predicted IPC classifications etc."* (I1.2). Anticipatory Actions have not been implemented due to the *"already prevailing crisis"* where the *"needs are [already] dire and the current SRCS's focus is on response mechanisms to address the already visible impacts of drought"* (I1.2). Thus, the overall *"end goal [of this project] will be to counter water shortages"* (I1) proactively but *"there has been any actions yet due to the fact that there is no water monitoring and trigger mechanism in place"* (I1). The monitoring was itself hampered by the fact that *"Berkads location data is currently missing"* (I1). This statement compares well with the experience of the current project team working on the EAP implementation and the assessment of available data sets (EAP project team, personal communication, 04.03.2022).
Table **??** shows all available data sets of water sources in Somaliland, provided by SWALIM.




The spatial distribution of the datasets across Somalia is relatively balanced, with focal points in the regions with many or larger settlements. Based on the SWALIM settlement data set, there are currently 2123 settlements in Somaliland. These settlement data are mostly from the years 2002 and 2006. The total number of water sources varies greatly between all datasets. The timeliness of the data also has a wide range, from relatively few pieces of data from 2019 in the 2020 dataset to data from the 1980s in the same dataset is much represented. The 2022 dataset misses information about timeliness altogether and the other datasets all have many blank entries as well. Furthermore, many water sources are labelled as 'abandoned' or 'non-functional', e.g. in the 2022 dataset those are 147 out of 685.
The data sets are fed by many sources and actors e.g. FAOSWALIM or other UN organisation, MoWR, NADFOR and other NGOs which constructed some water sources in some communities (I1). These actors, along with the community and their elders, local government representatives, SRCS and their volunteers and private berkad owners are also the potential stakeholders of the mapping and monitoring of berkads. Here, I1 notes, that besides the SRCS, the MoWR, NADFOR and the constructing NGOs are the most important stakeholders. The MoWR and NGOs have the technical expertise in

construction, rehabilitation and monitoring and NADFOR has a comparable community level programme for monitoring *"livestock body condition, market prices as well as weather variables"* (I1).
Other comparable programmes exist from OCHA, BRCiS and the CBS programme run by the Ministry of Health, the SRCS and the NRC. While these projects may broadly be comparable in terms of focus on AAs, none of the Interviewees know of a project that conducts similar things to this works aim (I1, I2, I3). I2 also suggests that the projects are close enough to each other to pass on experiences and recommendations, e.g. from the MoH to the MoWR, in order to overcome initial scepticism and reluctance.
Challenges, limitations and requirements are mentioned in areas of privately owned berkads, community expectation handling and the dissolution of misconceptions as well as potentially already overstretched SRCS staff and volunteers (I1). I1 mentioned, that private owners of berkads may prevent the volunteer from gaining access to their berkad which would result in less information on the one hand but also in tension in the community on the other. Giving information from the community to someone else may also generally require some explanation (I2). Furthermore, some *"information on past details per particular geographical areas"* (I1.2) can be difficult to access, as *"Somalis are highly mobile communities"* (I1.2). The monitoring could furthermore develop *"hugh expectations from the communities as there is the ongoing drought. Whenever there is monitoring of resources, communities believe this should be followed up by instant aid"* (I1).
Addressing some of the challenges mentioned above, the *"community elders should be engaged before the start of the mapping and monitoring as they will help dispel misconceptions about the project"* (I1) and the *"ministry of water resources should be in the loop during the entire project duration"* (I1). Nonetheless, the *"community and SRCS goals match as both focus on closing the knowledge [gap] currently existing"* (I1) in regard to the number, status of ownership, location and capacity of the berkads per community, district and regional level. This will *"inform decision-makers on the priority areas to focus on"* (I1). Therefore, I1 expects that this information from the site triangulated with weather forecasts can help to form robust triggers to take appropriate and informed Anticipatory Actions before critical water levels are reached.

### 1.3.2 Stage 2: Assess the feasibility of the Citizen Science approach.

In this stage, the practical capacities, and applicability and suitability of the CBM and MCS approach for community-based water monitoring were examined in this context. The SRCS has 249 paid employees, of which 30 work in the risk management and Anticipatory Action domain and an additional 1500 volunteers are "evenly spread" across the country (I1). I3 emphasises the *"good relations and good reputation"* that SRCS has within the communities, making them *"one of the most trusted organizations in the country"* which helps to do programs at community level. The 'feasibility study on Potential Use of FbF for SRCS' (SCRS 2022, p. 44) recognizes a *strong national organization* with a *strong*

*volunteer base at community level* that *provides monitoring and hazard warning capacities*. Furthermore, *highly skilled and experienced management staff at coordination and Branch levels* is stated. Nonetheless, *minimal domestic resource mobilization* and a *lack of meteorological, geospatial analysis, data management and IT staff* has also been detected.
This lack of resources and digital capacities was addressed in the CBS project by the NRC and their NYSS platform. Generally, CBS is *nothing new in itself and often used in health contexts* (I2). CBS in Somaliland started in Burao in 2018 with 75 community volunteers, as cholera had broken out in the same region in 2017 (I3). After the pilot was successful, CBS has since been extended to all regions but *SRCS only focusses on hot spot areas where they expect outbreaks to happen* (I3). This development took place over the course of a year with much feedback from the SRCS and NYSS is now *"very effective and very supportive"* (I3). The Ministry of Health (MoH) was and is *constantly in the loop to decide together what, how, when and who* and could gain good experiences with NYSS over the years (I2). By now, NYSS is well embedded in the local conditions and *"mobile teams [...] can be deployed immediately within hours so they can do the response"* (I3) in collaboration with other partners such as the *"government, MoH, WHO, and other sister RCRC organisations* (I3).
I2 mentions, that the monitoring of water sources *would fit well thematically, because it [low water levels and poor water quality] is a health risk* and that although it would require some adjustments and considerations, it would organically expand technical expertise and functionality as it is not *radically new*. Besides NYSS, being methodologically similar but different in thematic orientation, several other projects could be identified in literature, that are oriented towards the same topic but differ in their implementation and operation procedures (compare section **??**). It can be deduced from this that CBM and MCS can in principle be applied to the thematic issue. Furthermore, (Fraisl et al. 2022) themselves describe approaches that focus on the "in situ monitoring" of water resources and at the same time benefit the respective participant as adequate for the use of a Citizen Science approach. SRCS does not pay their volunteers but provides training and covers travel expenses as incentives. Moreover, volunteers are generally well regarded and are selected by the community itself. Intrinsic motivation is therefore present (I2, I3).
(Fraisl et al. 2022) prerequisites are thus fulfilled, and the key objectives of the RCRC's CBS preliminary assessment can be answered positively. The task is applicable within a CS approach and the SRCS is an adequate partner with sufficient capacities and experiences to implement the mapping and monitoring approach. The project can thus be further developed in stage 3.

### 1.3.3 Stage 3: Designing the Project

This stage is grouped into the four project requirement groups and lays the structure for the coming stages. The overall project aim to counter water shortages proactively is majorly hampered by missing information about the water source type berkad. Therefore, up-to-date information on water sources in Somaliland is needed. In particular, there is a lack of information on the important Berkad water sources (compare stage 1.3.1). Therefore, the focus of this project will be on gathering information about this specific water source type (I1). See chapter **??** for further information about this water source type. I1 also named and chronologically ordered the most important fields of action that need to be realised in order to achieve this goal:

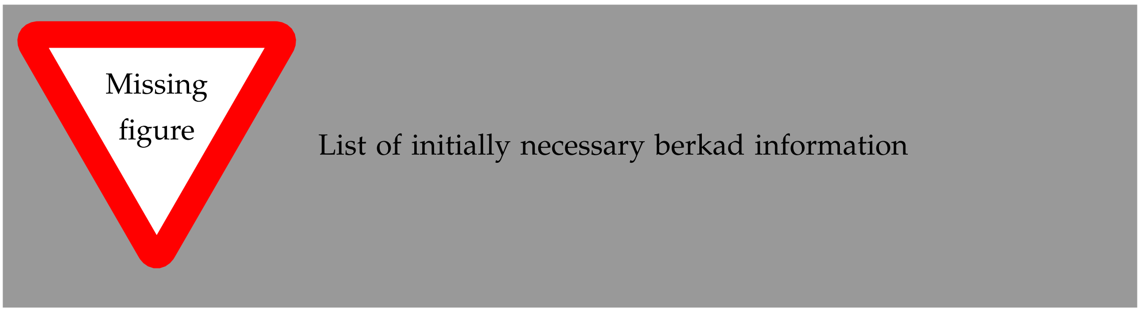
1. Volunteer briefing and training
2. Community sensitization
3. Locating and gathering key information about berkads
4. Determining respective Anticipatory Actions (own addition)
5. Determination of the water level thresholds
6. Monitoring of the water level
7. Triggering AAs based on pre-defined threshold

I1 highlights the importance of the actions 2, 3 and 7 as critical for the overall success of the project. For the design stage, I1 emphasises the determination of the threshold, Anticipatory Actions and respective trigger. As I1 draws his judgement from his work as the local program manager and coordinator, this project followed these priorities during the design process. This process is grouped by the project requirement catalogue in the following. The structure of each group follows the order of the products and respective activities, emphasis was given to the activities which contribute directly to the above mentioned priorities. To minimise repetition in the scope of this work, already covered areas are only referred to and not again outlined in detail.

**The Assemblage: Knowledge Building**

The majority of the activities of product (A) were already covered by previous stages and chapters. (A1) was extensively outlined in section **??**. (A2) and (A3) were covered by Stage 1 1.3.1, 1.3.2 and section **??**. (A4) on the one hand will influence decision-making in the SRCS but further integration into e.g. governmental procedures could not be covered by this work. Activities A5 and A6 could also only be touched upon, but especially the topic of integration of local knowledge holds a lot of potential (see **??**).
Product (B) could partly be covered by stage 2 1.3.2. Results so far suggest that the network and individual volunteers are adequately trained, motivated and managed for the monitoring task, which laid the basis for Stage 4. In terms of adequate data management (C), feasible technical solutions could be identified from other projects and their practical applicability was demonstrated by the successful CBS program of the SRCS (C1). Further exploration in Stage 5 was thus possible. (D) current evaluation and improvement procedures could be identified and are further described in Stage 6.
(E1) initially important information about each berkad is summarized in figure **??**. This compilation is based on section **??**, and knowledge of I1, I2, and I3. The left, bold side

are the information highlighted by the interviewees and summarize the key information. The right side displays information, that may be nice to know for further analysis, but is not regarded as critical for this project.



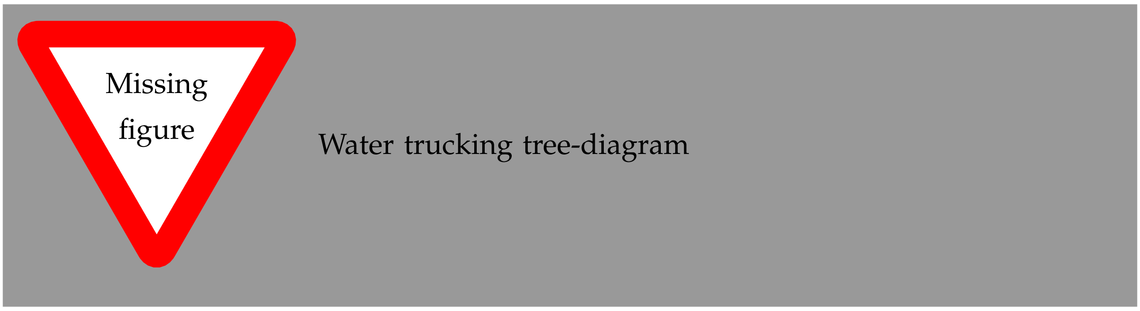

In terms of (E2), location, storage capacity and construction information need to be identified initially and might need to be updated when e.g. the berkad is rehabilitated. These information will be gathered by SRCS professionals and therefore does not need to be included in the regular monitoring routine. (E2) a report about the condition of the berkad may only be necessary once a year (I1.2) while the number of people and animals may need a weekly or monthly reporting interval, depending on the fluctuation strength (I1.2). This information should be kept comparatively up to date, as the high mobility of Somalis means that this number can change relatively regularly and has a great influence on the amount of water abstraction (I1.2).
(F1) the water level of the berkad was named as constantly changing indicator which should be monitored in a weekly interval (I1.2). The realisability and adequacy of this reporting frequency was also supported by I2 (F2). (F3) The data sets for the data triangulation are adopted from the overarching EAP and have not yet been determined at the time of writing.
Potential AAs that can be triggered in correspondence with a the surveyed information and certain water level threshold are listed below (G).

- Informing about water rationalisation and saving opportunities
- Information dissemination of climate and weather forecasts
- Distribution of drought-resistant crops
- Rehabilitation of berkads before the rainy season
- Compensate private berkad owners to access their water
- Timely distribution of cash to enable communities to buy and stock fresh water
- Timely distribution of water purification tablets
- Water trucking

Raising awareness and information dissemination need to be the foundation of this (see Groundwork **??**, I1.2). The distribution of drought-resistant crops and other agricultural related actions need to be coordinated with the Ministry of Agricultural Development

(MoAD). The rehabilitation of berkads before the rainy season needs to be related to seasonal triggers as this actions will help to store available rain water and won't directly help in times of acute water shortages. I1.2 notes, that the involvement of private berkad owners *"could be limited as they are more concerned about their business models i.e selling of the water and preserving their berkads than being part of the overall response/Anticipatory Action mechanism"*. Nevertheless, I1.2 sees potential in working with private berkad owners and suggests e.g. the rehabilitation of their berkads *"in return for their involvement in response and Anticipatory Action activities"* as viable AA. The distribution of cash is a widely applied AA in FbF projects and can help in many cases. Distribution of water vouchers is an alternative to direct cash and has already been used successfully in Somaliland (see section **??**). Water purification tables and information for waterborne disease prevention are already disseminated by the SRCS volunteers together with hygiene and health promotion activities but could be better targeted by more timely and localised information (I3). The required lead time, tangible and intangible resources, information requirements and involved roles (G2 & G3) of these AAs are illustrated in figure **??**.


This list is not comprehensive and needs to be refined for each AA, which is illustrated in figure **??** for the AA *water trucking*.




Water trucking is a common measure to cope with acute water shortage in Somaliland (I1.2, I2). Information for water water trucking comes, thus far, from SRCS assessments, from the community themselves, government agencies, FSNAU or other NGOs (I3). This type of information transmission can be timely and may be incomplete. The water transport itself can take a long time and can be relatively expensive due to the distance and high demand (I1, I3). It is financed by various stakeholders, including the community themselves and private donors (I3). Self-financed water trucking is especially common in the beginning of the initial phase of drought but if the people cannot afford to buy water any more and their livestock becomes weak or dies, *"[...] this is the time they talk to*

*the other NGOs or the government and say we need support [...]"* (I3). Currently, the following prioritisation of water trucking by the regional and national stakeholders is primarily based on government decisions and focusses on the most vulnerable communities (I3). This decision-making process could not be explained in more detail by (I3) other than it is a *joint effort by all stakeholders*. The SRCS does not truck water themselves (I1.2).
(H1) potential water level thresholds were suggested by I1.

- Empty (no water at all)
- Critical (1 day of water supply remaining)
- Low (3 days of water supply remaining)
- Middle (5 days of water supply remaining)
- High (full capacity)

I1 further specified the *Low* category to trigger the AA of *water trucking* (H2). These water levels either require local knowledge about how long the water will last or require the analysis of the exact or categorized water level with the known berkads capacity. The first option would outsource the triangulation of available resources and amount abstraction to the communities predictions. I1.2 notes, that *"these kinds of predictions are good as communities usually have their own control measures to ensure equitable distribution of water e.g. how many containers per family etc. The berkads are usually locked to ensure there is controlled access to the water stored"*. The second requires good information about the berkad itself and a feasible method to interpolate this with the regularly measured information. (Gualazzini 2021) however, proposed more seasonal focussed threshold levels for berkads (see chapter **??**). (H3) the short-term thresholds may be feasible to short-term and fast AAs, whereas seasonal information may trigger AAs such as the rehabilitation of berkads and information campaigns.

#### The Groundwork: Laying the foundation

Volunteer briefing and training together with following sensitization of the community are the first two measures that lay the foundation for the implementation of this project (see 1.3.3, I1). (A1) major challenges could be identified in community expectation handling and the involvement of private berkad owners (I1, I2). I1 suggested, the early engagement of community elders to address community internal issues and the continuous involvement of the MoWR for organisational and stakeholder management. Awareness-raising activities and dissemination of information may include knowledge of water quality improvement techniques, water conservation strategies, early warnings and a detailed explanation of the reasons for regular water level reporting before the start of the project (I1, I2). It also needs to be *communicated, discussed and decided beforehand*, what happens in cases when thresholds are reached but no response is possible (I2). *Otherwise, it could fall back negatively on the SRCS and the Volunteer* (I2). Furthermore, I1.2 highlights

the importance, to establish *"a robust feedback and complaints mechanism that ensures communities can easily relay their feedback.* right from the start. The development and implementation of products (A2), (B), (C), (D), and (E) must happen in close collaboration with local stakeholders and were thus out of scope of this work. Nonetheless, the work with the community should be fruitful as their goal to *"ascertain whether these water bodies are able to withstand the demand during drought periods"* overlap with the project goals (I1).
The integration of the light IWRM framework developed by (Day 2009) was presented in section **??** and needs to be further discussed with local stakeholders and interrelated with prevailing procedures.

### The Innovations: Developments and Improvements

Besides the identification of a way to integrate IWRM practices into local procedures and structures, more technical solutions were also required to be developed or adapted. (A1) important primary information about the water source berkad could be identified by the method of expert interviews. (B1) and (C1) could be identified through interviews and literature analysis, where (B1) will either be a kind of categorised yardstick or a local estimation based on experience or a combination of both. However, a thorough assessment and subsequent adjustment of the practical suitability will only be possible in a pilot study. This is especially true for their evaluation (A2) and (B1). Several data management methods could be identified in literature, see sections **??** and **??**, and applied in practice by other projects see sections **??** and **??**. The desk-based evaluation (D1) has shown advantages and disadvantages for all potential methods, from simple to very dedicated implementations, thus allowing an informed decision in the coming chapter.

### The Management: Mapping & Monitoring

This last group of the project requirement catalogue comprises activities for evaluation and decision-making on the pre-identified conditions in the preceding sections. Though, due to the overarching ongoing EAP development and no possibility to conduct studies on site, no decision or on site evaluation could be made in the context of this work. Nevertheless, a lot of information and good practice could be gathered and organised appropriately in the presented groups in the previous phases which will greatly facilitate future evaluation and decision-making.
Nonetheless, a first draft of possible codes were developed for (1) a data based application and (2) a more local knowledge based version:

$$1. Weekly : \# WaterSourceID \# WaterLevel \# Functioning / Accessible$$

or

$$2. Weekly : \# WaterSourceID \# PredictedSupplyDuration \# Functioning / Accessible$$

$$1.Monthly : \blacksquare\#WaterSourceID\,\#\,Numberofdependentpeople\#\,Numberofdependentanimals$$

$$2.Monthly : \blacksquare\#WaterSourceID\,\#\,DailyAmountofWithdrawal$$

$$1.Annually : \blacksquare\#\#WaterSourceID\,\#\,WaterSourceCondition$$

$$2.Annually : \blacksquare\#\#WaterSourceID\,\#\,WaterSourceCondition$$

Hereby, the *Water Source ID* may be a composite of regional, district, and community identifiers along with a specific water source number. The *Water Level* or *Predicted Supply Duration* refers to the amount of water that is still available and the *Functioning/Accessible* code may indicate if the source is functioning and/or accessible to the community. These two indicators could be combined in one number, as there are only four possible combination possibilities. With this, social and technical aspects could be monitored. The monthly codes relate to the amount of withdrawal and thus takes account of potentially changing demand conditions. The *Water Source Condition* is difficult to limit on one number and more might be necessary as there are many different factors that can influence the condition (see figure **??**). The number of codes is deliberately confined by a maximum of three codes, as this was the recommendation and limitation by I2. The codes may only be seen as recommendations and will need to be evaluated and adapted in the future work.

### 1.3.4 Stage 4: Community Building

In the context of this project, the community volunteers of the SRCS are the contributing participants and their 'community' is the SRCS. The findings of this section contribute to the knowledge base primarily in areas (A4) to (A6) and (B) and form the basis for the participant and community related products and activities of the *Groundwork* and *Management* group. The volunteers are commonly not recruited by the SRCS in the common sense but rather chosen by the community (I3). Therefore, they are commonly not primarily selected on the basis of their education or skills, but on the basis of the community's own criteria (I3). The decision on who becomes a volunteer is generally made by the community committee and their elders (I2). I3 notes that volunteers generally have a *"good reputation in the community"*. *"After the selection, SRCS is doing a small assessment about e.g. reading and writing skills and then provide training to them"* (I3) according to their tasks. Besides the social prestige, this training is also the primary extrinsic incentive to become a volunteer as the volunteers are not compensated otherwise (I2). Thus, volunteers need to be intrinsically motivated and *"willing to be a volunteer"* (I3). After the training, the volunteers are send back to their communities and start working there (I3). Volunteers are *mostly women as they stay in the community and do not travel as much as men* (I2). The work includes raising awareness about health and prevention hazards and informing about mitigation measures, as well as directly responding to them and, in the

context of CBS, reporting (I3). Currently, in case of water shortage, volunteers educate people on how to prevent waterborne diseases by providing hygiene and health education and distributing water purification tablets. (I3).
Preliminary trainings, supervision and regular refreshers are seen, especially in the beginning, as important and as a great success factor by I2 and I3. In the CBS program, refreshers were conducted in a monthly interval but is no longer necessary in that frequency as the *volunteers know their business by now* (I2). Nonetheless, supervisors still validate and clarify reports, e.g. via phone or on-site visits. As already described in stage 1.3.2, SRCS spends a lot of time on community bond building and thus generally has a very good reputation with the communities (I2, I3). This greatly facilitates the information flow and response together with other stakeholders such as the MoH or NGOs (I2).

### 1.3.5 Stage 5: Data Management

Data management was first mentioned in the context of Mobile Crowdsensing in section **??** and more specifically in terms of Community-based Surveillance and NYSS in sections **??** and **??**. In stage 1.3.2, the implementation of CBM and MCS was reasoned and the integration of the NYSS platform in the CBS program was further described.
This section contributes to the *Knowledge Base* in (C) but also influences the selection of AAs and trigger thresholds, as the data management capacities set the frame for the collection of respective indicators. It is less important for the products of the *Groundwork* but most developments of the *Innovations* group facilitate this stage. The actual implementation and its technical capacities will also strongly influence *Management* in regard to all data related developments and decisions.
I2 stated, that NYSS may be a good fit for the water level monitoring, when the primary orientation is on early warning and Anticipatory Action and not on general data collection. Discussions about the possibility to use NYSS are still ongoing at the time of writing. The potential integration of NYSS, together with its dedicated implementation, makes NYSS the preferred MCS platform for this project and it was therefore further explored in this stage. However, less automated and technical processes such as simple SMS or calls directly to the respective supervisor with manual data entry are also possible and common practice in many cbs projects (I2). The predecessor of NYSS itself was less automated and the evaluation was done with Microsoft Office (I2). These simpler processes are, apart from the higher manual effort, mostly very comparable to the integration with NYSS in the areas of planning, implementation and evaluation, only less automatized.
I2 mentions in regard to the server location in Ireland and data ownership by the National Society and the location of the servers outside of Somaliland did not resonate well with the MoH and required a lot of communication. The progress made here could also be translated from the MoH to the MoWR.
The method of data collection via coded SMS should also work for monitoring water

levels, whereas *one to three codes for regular monitoring should be alright but not more, as more codes make it more complicated and will narrow down the choice which Volunteer to take* (I2). Sending photos would possibly also work with this thematic focus, but would require smartphones and internet connection on the side of the collector. Though, I2 is *not supporting the distribution of smartphones for 'several reasons'*. However, less frequent transmissions with more codes would be possible through further aggregation. Therefore, the regular weekly water level monitoring as well as the seasonal major data collection would be facilitated by this method (I2). Small code explanations in local language and with images would need to be developed to give orientation and reference to the volunteer (I2).

The reports need to be validated and it *should be communicated, that reports will be checked by the supervisor in order to prevent false reports in hope of more water. If this happens frequently, a solution must be conceptualized* (I2). Despite all of these similarities of the approaches, I2 mentions, that the integration of the requirements of this project into NYSS will be work and that it needs to be discussed who does it and who pays for it.

The data collected within the NYSS platform, could recently be fused with other MoH data sets but that was *challenging and a lot of work* (I2). This shows, that while the automatic integration with other data, e.g. from the Ministry can be *laborious and complicated*(I2), it is possible. This would enable the (automatic) triangulation with "meteorological forecasts and local knowledge" (I1.2) already mentioned in previous chapters.

### 1.3.6 Stage 6: Evaluation

Evaluation is often referred to as an ongoing effort and the need to structurally integrate it at all stages was highlighted frequently in the above stages. From problem definition, through subsequent conceptualisation and design together with the community and stakeholders involved, to operation with regular training, supervision and feedback on each report, there is an opportunity for feedback and evaluation at every stage of the project (I2, I3). However, concrete measures of success still need to be defined with stakeholders before implementation. An evaluation of the implementation and operation could not yet be carried out, but there were already several iterations and improvements in the design phase, which could be implemented well with the present framework.

Evaluation practices are also already part of the organisational culture and procedures of the SRCS. This is particularly evident in the monthly meetings with the communities and in the CBS implementation, which includes many feedback, evaluation and monitoring procedures. In addition, all interviewees mention the high investments of the SRCS in communication and feedback processes. I2 states, that *SRCS are no rookies. They know how to communicate as it is a big part of their culture.*

## 1.4 Summary Results + key lessons learned (?)

The results presented findings for the design of a community-based participatory water source monitoring approach, its improvement and subsequent application. The design roadmap adjusted and expanded (Fraisl et al. 2022) Six-Stage Framework to the prevailing conditions and context of the study area and project foci. The structure and respective thematic focus of the SSF have been retained, but expanded to include additional guidance, including best practices from the IFRC and the local BRCiS initiative. The first stage explores the overall context, the problem and derives initial approaches to solutions. The second stage assesses the feasibility of the Citizen Science approach in the given context. It goes into more detail, defines goals along with sub-goals and explores the actual possibility and capacities for a successful design, implementation and operation of a CS project. Only when this phase has been successfully completed, the requirements have been met and no *red flags* have been encountered, will the next phases be considered. Stage 3 *Designing the project* further specifies the previous findings and clearly focusses on the actual required products and activities to reach the goals. The overall structure is laid out by utilising the project requirement catalogue. Stages 4 to 6 go into more detail in terms of community building, data management, and evaluation and improvement practices respectively.

The mentioned project requirement catalog in stage 3 is presented in the second section of this chapter and is one result of this work. The catalogue was developed in addition to the above process oriented design roadmap in order to better structure and order the actual information to reduce cognitive overload. The catalogue is grouped into four groups namely *Knowledge Base*, *Groundwork*, *Innovations* and *Management*. Each of these groups incorporates one or more of the derived goals of Citizen Science by (Minkman 2015) and is design with the help of the Seven-layer model of collaboration. The defined products and activities are derived from the design roadmap, literature, guidelines, identified projects and conducted interviews. The *Knowledge Base* provides an overview of all topics for which information needs to be obtained and groups them loosely in order of their dependencies. The group *Groundwork* is concerned with the educational, social and political foundation in which the actual project should be embedded. *Innovations* covers all new developments that need to be made in order to adjust the framework to the local context and *Management* summarizes all other developments and decisions that are required in the previous groups.

The third section finally applies the design roadmap together with the project requirements catalogue on this projects' research question. The problem and context investigation (stage 1) along with the feasibility assessment (stage 2) defined a problem with a possible solution through a CS project. The project requirement catalogue could successfully be applied in the third stage to help structure and order the design process. This framework was subsequently deepened in the following stages. The design could continue until closer consolidation with local stakeholders and communities was required, which was not possible due to limited resources and time as well as the impracticability of on-site investigations due to the current situation. Higher-level decisions in EAP development that have not yet been made also limited this project in some aspects. Nevertheless, a good and orderly knowledge base, structure and conceptual basis for a first pilot study could be established.

# Chapter 2

# Discussion and Reasoning

This study aimed to design and test an approach for community-based participatory mapping and monitoring of water sources in a water-scarce and resource-limited setting in collaboration with the Somalia Red Crescent Society. The ultimate goal was to facilitate respective Anticipatory Actions in the context of Forecast based Financing and to improve water management and accessibility in underserved communities. To achieve this aim, four research objectives were formulated, including a comprehensive literature review to identify and evaluate principles for community-based participatory mapping and monitoring, assessing the feasibility of the approach in the given context, developing a replicable and adaptable framework based on the identified guidelines, and applying the framework to create a roadmap for implementation.

The literature and data analysis revealed the high complexity of the context and could determine gaps in the data situation on water sources as well as the project and framework landscape in regard to Citizen Science approaches in the given context for the implementation in a FbF project. However, the general feasibility of the approach for the project was suggested through further analysis. Building on this positive assessment, the identified frameworks and guidelines were adapted and expanded to ultimately lead to the development of a new replicable and adaptable framework for a community-based participatory water source mapping and monitoring in the context of Forecast based Financing. Its application on this specific case area resulted in a roadmap for the practical implementation of the project. This roadmap includes goals and sub-goals, required products and respective activities.

In this discussion chapter, the focus is on reflecting on the main findings and contributions of this study and discuss their implications for further developments and practical applications. In detail, each research objective is addressed in turn and its relevance to the research aim is discussed. Finally, limitations and challenges encountered during the research process are named and considered.

1. RQ

## 2.1 Literature, Project and Data Analysis

## 2.2 A Replicable and Adaptable Framework

"All models are wrong, but some are useful" George E.P. Box

While this statement was made in regard to statistical models, the consideration of the trade-off between generalisation and specialisation is also crucial in the design of frameworks. Highly general principles and characteristics up to highly specialised projects can be found in the literature (see section **??**). The development of the SSDR has tried to find a balance between the focus on drought, FbF and citizen involvement in Somaliland while also staying adaptable to other, yet comparable projects.
Surprising was, that while a manifold of general guidelines, characteristics and quality criteria for Citizen Science projects exist, no grouped and ordered requirements list along potential CS goals could be found. While this is unexpected, as it is no radically new insight, but merely a different framing of more or less the same information, it could be explained by the limited time of practitioners to publish concrete information. This lack of time for publication was also mentioned by I2 but no peer-reviewed study could be found to either underline or falsify this assumption. However, an interweaving of the more often encountered process-oriented approach with a specific, yet adaptable requirements catalogue was found to be manageable and, as also later discussed in more detail, well applicable.
In the following, the general development of the SSDR is discussed and the challenges encountered and potential solutions are considered in more detail, looking first at the SSF and then at the PRC. When considering the SSDR and PRC frameworks, it is crucial to acknowledge that they provide only limited perspectives on the complex reality of design processes. This research primarily adopted a process- and requirements-oriented approach in designing and conceptualising the design roadmap. Other perspectives, such as resource, behavioural network or stakeholder networks, cultural norms and values, as well as the communication network perspective may play a role in certain aspects, but are of secondary importance in this work.
Challenges in conceptualising the new framework primarily laid in information availability and transferability. Several CBM, MCS, CBS, CBWM and other risk related CS frameworks and respective guidelines could be identified but none of them exactly matched the intended application (see section **??**). While "there is no one-size-fits-all approach" (Fraisl et al. 2022, p. 2), the existing frameworks either focussed on different thematics, contexts, had different participation levels, different goals or a combination of the above (see sections **??**, **??** and **??**). This is consistent with (Butte et al. 2022)'s and (Carrion et al. 2020)'s findings that existing frameworks guiding the development of water security data collection projects are often very specific and limited to certain factors, in many cases also not taking socio-economic factors into account. At the same time, frameworks like the on from (Butte et al. 2022; eu-citizen.science 2023; CitizenScience.gov 2023) and others were too broad, to be more than general guidelines. This lack of information was also present

in a lessened form in relation to Drought FbF. In addition to these case study related domains, there are currently further gaps in knowledge when in comes to the application of the FbF approach on the slow-onset hazard of drought. Generally, the concept of FbF is now well established in regard to fast-onset disasters, but the drought use case is relatively new (2020) and not yet well researched, which severely limits the amount of guidelines and frameworks available for this particular application (see section **??**). Thus the FbF approach for drought is still in its infancy itself and while it was to be expected that the literature on Somaliland would be limited, that it would be so severely limited was still somewhat surprising (see section **??**). The lack of local and directly related information was overcome by transferring the above information sources through interpolation with experiences from preliminary work on other, roughly comparable local projects. While such a transfer does not replace direct local knowledge, it can give a first approximation.

Besides the information availability, the novelty and breadth of the CS field led to further challenges which emerged in this work in terms of blurred variables and definitional acuity. While many principles, characteristics and guidelines cover a multitude of design variables, (Kirschke et al. 2022) highlight, that the concrete influence and inter-relations of these has not yet been studied in much detail. This leads to a limited understanding of their influences and impacts for success. This lack of understanding also became apparent in this work and prevented more accurate attribution in the design phase. Though, this might not be as relevant once the project is implemented because then it is then more important that it works and not primarily why.

Most of the guidance identified in the literature analysis and later also integrated suggest primarily positive constraints (see sections **??** and 1.1). The assessment guidelines of the (IFRC 2017) were the only identified guideline formulating concrete *red flags*. This was unexpected, as negative constraints can clearly enhance the formulation of conceptual and practical boundaries. These *red flags* were included in the assessment in Stage 2, as they represent a stronger barrier than positive constraints and thus support a more careful assessment. However, (ESCA et al. 2020, p. 1) argues, that because of the various fields of application, disciplinaries and cultural contexts, defining a "universal set of rules for exclusion or inclusion is difficult, and might even limit the advancement of the field". Besides the integration of the *red flags*, this was taken into account by keeping the SSF relatively general and mainly implementing more precise requirements for the applied case in the PRC.

In the following, major design decision for the SSDR are shortly outlined and reasoned. The decision to build on (Fraisl et al. 2022)'s Six-Stage Framework was primarily driven by its timeliness, comprehensiveness and focus on environmental issues as it was clear, that a more social and local component can be integrated from the SRCS's experiences with CBS. The results indicate, that the interpolation of these two approaches was useful, especially in consideration of personal data. While observing natural phenomena at the

level of data collection did not raise too many privacy concerns for (Fraisl et al. 2022), this was almost the opposite for CBS (IFRC 2017). Applying these contrasting perspectives to the issue of water sources was thus able to address both the physical and social components well by considering trade-offs between the two 'extremes'. This observation was further supported over the course of this work, when the iterative integration of other guidelines from several divergent foci into the existing framework could be implemented smoothly and only minor revisions had to be made. This goes along (McGowan et al. 2022) findings, that the success factors of CBS are closely linked to the general principles of participatory community engagement and may therefore be transferred to other participatory surveillance preparedness activities.
In the application of the SSF as basis for this design and implementation roadmap creation, some adjustments were made. The main overall adaptation were the shortening of the iteration cycle by the first two stages. It became clear, that the exploration and assessment stages do not need to be regularly integrated in the iterative design once the third Stage is reached (see figure **??**). Nonetheless, when new fundamental findings or discoveries are made, it may be necessary to partly go back to Stage 1. The same also applies to Stage 2, when one of the defined *red flags* is violated in the further course of the work. Further adaptation were made in the integration of the feasibility assessment and *red flags* of the IFRC in Stage 2, the integration of the PRC and IWRM framework in Stage 3 and the focus on iterative improvements in Stage 6. The applicability of these changes could not be evaluated due to time and resource constraints but all adjustments were based on experiences and studies of already conducted or peer-reviewed work and integrated well with the overall framework (see section 1.1).

The reasons, specifics and their implications of the Project Requirements Catalogue are discussed in this final part, of the section which addresses the first research question. The development and integration of the PRC attempted to address some of the shortcomings of the process-oriented SSDR. These shortcomings became apparent right at the beginning of the application in the third stage. It was increasingly difficult to keep an overview of the actual project requirements and their interdependencies in terms of subject matter and temporal constraints (see section 1.2.1). Furthermore, CBS, CBWM and other approaches have strongly emphasised the importance of embedding the project into prevailing social and decision-making conditions and procedures, which became apparent to be under-represented in the SSF (see section 1.2.2). The results of the CBS analysis also highlighted the high time and resource requirements, which were needed for the development and adaptation of methods and techniques to start with the CBS project in Somaliland. This goes along with (García et al. 2021)'s findings, that some adjustments and tailoring always need to be done when implementing a new project (see section 1.2.3). Together with the emerging need to structure smaller developments and create an overview of decision dependencies, a fourth area of management became apparent that needed to be addressed (see section 1.2.4).

The emphasis of the top most layers, the *Goal-, Products-, and Activities-Layer* (see section **??**) is reasoned by overall time and resource constraints along with the realisation that the latter four layers *methods, techniques, tools and scripts* are too detailed for a relatively general framework. However, it needs to be acknowledged, that the thematic focus of the SLMC is not on CS and that the goals derived by (Minkman 2015) were primarily focussed on being potential goals of the project itself, and not meant to guide the conceptual phase. Nonetheless, the overall design pattern of the SLMC together with the formulated goals could support the conceptualisation considerably. The close integration of Minkman's goals in this conceptual way may also bring about their 'automatic' consideration during the design, which might lead to a greater breadth of output.
The PRC structure is closer related to the case study area as the SSF but should still be adaptable to other contexts as the high level products mostly relate to general parts of the project and not to concrete techniques or tools. However, the PRC should not be separated from the SSDR as many products are addressed by activities mentioned in this framework, which are not specifically mentioned again in the PRC. Its final applicability can only be evaluated in practices but generally, formulating project requirements in detail is nothing new and should also benefit a CS project approach (Wiegers and Beatty 2013; Young 2001; Young 2006). Due to the generally iterative nature of this framework, both classical and agile development practices can be applied, with the latter possibly having the advantage (Conforto et al. 2014; *Manifesto for Agile Software Development* 2022).

Besides the above mentioned challenges in the design phase and the general limitations named in the last section of this chapter, the work will also encounter challenges in the implementation and operation phases. In the (practical) application of this framework, some adjustments will be necessary and as it was the case of this work, time and resource constraints will be imposed by overarching projects or conditions, making some compromises inevitable. This is discussed in the next section in the case of creating a roadmap for implementation in Somaliland.

was könnte schiefgehen? über Zeit stabil? –> jein. Mit stage 6 schon. metaperspektive konnte selbst unter dem Fokus auf Somalia nicht letztlich zugezurrt werden - viel allgemein gehalten. Einfach ein riesen topic. not surprising aber wichtig.

https://data.jrc.ec.europa.eu/dataset/jrc-citsci-10004 ja well. auch wenige Wasser data so far so good. Lot's of it can also be derived by logical thinking, but: special juicy findings!

vor und nachteile dieser 6 stages Aufteilung? -> iteration was more between the last four. not all 6. no other requirements catalogue could be found in the sources. some lists, some hints, but nothing really structured -> use my fking systematic thinking man. complex adaptive systems - critical parts? critical stakeholders? critical stages? could all be different for every project. funding? may also work or not.

open data. Its own huge discussion. data quality relate to other studies. Look in the book -> some stuff CBDRR, CBWM and so on.. questions from other studies sparked this? e.g. global inequality of studies

Acknowledging the importance of bidirectionality of information, these systems simultaneously share findings back with the users. ([McNeil et al., 2022, p. 1](zotero://select/groups/4773535/iter ([pdf](zotero://open-pdf/groups/4773535/items/4YG35TC6?page=1annotation=IC6W8R3B))

The first RQ is addressed in this section by discussing the literature and project analysis along with the SSDR and PRC. The development of a replicable and adaptable framework for community-based participatory water source mapping and monitoring with the aim of facilitating AA in the context of Forecast based Financing

## 2.3 Feasibility Assessment

2. Objective + 2. RQ Results indicated that.. the ministry might be.. because of.. based on experiences of.. Unexpected findings in this application were the issue about the server location in Ireland, the competition between the NGOs and the MoH's initially negative attitude towards the inclusion of CBS due to oversupply by international NGOs. Furthermore, the highlighted heterogeneity in the community and the stakeholders themselves in regard to the response but also to the implementation of the project. Results indicated, that local stakeholders such as the private berkad owners or private water vendors may not be in favour of this project. The inclusion of financial interests of all parties involved was also mentioned by Minkman. However, it was only mentioned by her and may therefore not be common knowledge. In general, the bias of the more applied guidelines seems to have some dangers, as can be illustrated by this example.

in regard to some details, interview were unexpected.

Nonetheless, good project management will be required to account for initial adjustments, trade-off considerations and changes over time.

clear: kein Selbstläufer. Ein groSSer Haufen an Arbeit. how influential is the culture?

Stage 6: output, quality, participant experience and impact -> evaluation practices may be difficult. Bias towards positive results

privacy concerns for the open data pledge.. not everybody will be a friend..

The buy in off all stakeholders but specifically of the government bodies is often highlighted server

many other organisations

contradicting stuff

Since the feasibility had to be determined before this work could move on to address the other research objectives and questions, the second objective to *assess the feasibility of the*

*Citizen Science approach in the given context by identifying potential challenges and opportunities for successful implementation, and to propose recommendations for addressing these challenges* was an interim result of the work. Based on the developed framework in section 1.1.2 the feasibility was already assessed in sections 1.3.1 and 1.3.2. This assessment combined and applied general, international guidance from many projects and studies with local experiences with the CBS program. It is believed that, even though no dedicated pilot study could be conducted, this combination and interpolation of experiences can reasonably suggest the feasibility of the CS concept for this application. However, this claim can ultimately only be verified or falsified by a pilot study on site. Furthermore, several challenges such as the embedding into local decision-making and processes, actual tailoring to local conditions and clarifying financial capacities could not further be investigated due to the limited amount of interviews with local stakeholders and ongoing developments of the superordinate project.

Due to the already conducted discussion in section 1.3.2 and challenges that cannot be investigated further in this context, the remaining part of this section focusses more on how, why and in what order this assessment was realised as it is believed that this holds more value to the reader than iterating over the discussion again.

Since, to the best of my knowledge, no work has been conducted with the combination of methods, goals and context of this work, there was no concrete existing guidance to assess the feasibility of this approach to achieve the research's aim in the first place. The lack of suitable frameworks for this project made it thus necessary to work on the development of the framework and its application step by step and not only chronologically, at least to some extent. This was facilitated by the iterative working approach, which made it possible to first sketch out possible solutions and then deepen them when the conditions were met accordingly. This was also the case in addressing the second objective and the early conduction of the feasibility assessment is also recommended by multiple other guidelines (CitizenScience.gov 2023; García et al. 2021; IFRC 2017; IFRC, RCCC, and GRC 2023; Minkman 2015).

The Six-Stage Framework and Seven-layer model of collaboration were adopted at an early stage of the work to have a general direction for the development. To conduct the assessment, the third research objective had to be somewhat anticipated in order to provide an initial framework for the structured feasibility assessment. This framework, now conceptually integrated in the second stage of the design roadmap (see section 1.1.2) was in the beginning primarily a combination of the SSF's second stage and the feasibility assessment of the CBS of the IFRC. The final feasibility assessment took place on the current basis, which was further underpinned with some additional guidelines, best practices and knowledge of the interviewees over the course of multiple iterations.

When designing a framework for or directly assessing the feasibility of CS, it becomes clear that *feasibility* depends on a variety of factors, but also that there are no clear rules that must be followed. Each CS project is somewhat special and the flexible concept also allows for several adaptations (see section **??**). Therefore, the feasibility is not assessed by a specific set of rules, but rather how well it relates to general principles and factors

of success. This makes sense in the way, that what specifically works in e.g. (Minkman 2015)'s approach in the Netherlands may not be feasible in Somaliland, e.g. the use of smartphone sensors as the rural population in Somaliland has few smartphones and internet coverage is poor. Assessing challenges and opportunities is thus a highly specific and local task and depends on many factors.
Nonetheless, the ECSA along with many other associations and studies developed CS principles and characteristics that support the successful design, implementation and operation of a CS project. Furthermore, a CBS project was already successfully implemented and in operation for several years within the context and the SRCS but focused on a different topic. This, again highlights the thorough analysis of local comparable projects, mentioned in stage 1, section 1.1.1. The actual feasibility assessment therefore focussed primarily on the differences between the CBS and the potential water source mapping and monitoring project.

4. Objective + 4. RQ

## 2.4 Application

any surprising findings? –> e.g. there might be people, that have an interest in this project not working. Private vendors of water trucking e.g.? what about those. more power to the people -> less power to others. Problems?

interesting:

server location in Ireland

publication of the water source locations -> in regard to the history. it is, in the end a critical infrastructure

This landscape demonstrated the breadth of applicability of participatory surveillance, from tick identification in photographs, to One Health apps used by community members, to trained volunteers reporting invasive plant pests, ([McNeil et al., 2022, p. 8](zotero://select/groups ([pdf](zotero://open-pdf/groups/4773535/items/4YG35TC6?page=8annotation=AQ46ELFM))

The fourth research objective to *apply the adapted and developed framework to establish a roadmap for the implementation of a water source mapping and monitoring approach to trigger appropriate anticipatory actions to address water shortages* has already been partially addressed under the first two objectives. Stage 1 was primarily addressed by the first research objective which explored much of the underlying concepts, context, prevailing problems and also carved out potential solutions. Stage 2, the feasibility assessment, was addressed with the second research objective. Therefore, this section concentrates on the stages three to six.
In stage 3, the subdivision into the PRC was helpful to reduce cognitive overload and highlight chronological and thematic (inter-) dependencies. In terms of knowledge, the

PRC helped to structure the identified information from stages 1 and 2, which additionally helped to make knowledge gaps, such as e.g. missing detailed knowledge about local decision-making procedures, obvious. As it is was not feasible to gather these information in the scope of this work, it was therefore simplified to concentrate on those areas, that could be tackled. For example, it became clear that the initial mapping, which includes gathering other key information about the berkad, cannot be done by local volunteers as the knowledge and technical equipment requirements are too high for most. Thus the initial mapping needs to be conducted by the SRCS professionals who are already experienced and don't need further guidance for the process. Nonetheless, gathering the information that is initially required was feasible in the context of the work and thus focussed on. The knowledge gathered was thus more broad than deep and in most cases requires further investigation, especially in relation to local conditions. For example, in the case of the AA of water trucking, see figure **??** in section 1.3.3, requirements could be listed, but their actual specification is only possible on the ground with local stakeholders.

Close and early cooperation with other local actors in the area of embedding the project in conceptual water management practice was also suggested as important by the interviewees (see section 1.3.3). This compares well with common recommendations for CS projects (see section **??**). To facilitate this, a light IWRM framework which was also already tested in other local circumstances could be identified in (Day 2009)'s adaptation. Yet, the same limitations apply here, as the actual feasibility can only assessed on the ground. Nonetheless, the willingness and experience of local managers to implement those concepts could be identified, which suggests at least a good initial situation for the successful embedding of the project into local management practices. The great importance of deep local embedding is also highlighted by (Gualazzini 2021) because even if the information gathered is good and timely, it still needs to be incorporated in decision-making and acted upon.

Besides the conceptual groundwork directly on site, innovations for the determination and collection of water level thresholds are required. The gathered information suggest, that there are two potential ways to assess the water level (see section 1.3.3). The technical measuring and transmission of the actual water height would require the knowledge about the exact capacity and size of the berkad to assess the water level. Although this method would provide a more objective measurement, local knowledge of the potential duration of water supply was also found to be good with a Berkad (see section 1.3.3). Both approaches do not contradict each other and could also be used together. This would also allow a good basis over time for evaluating the quality of the assessment of local which could what could then improve local water management. In addition to the quantity of water, its quality was also considered very important, but no locally feasible approach to assessing quality could be identified. This supports the importance of providing a sound knowledge foundation about contamination prevention and water management practices to the community. This is also supported by several other studies (Daniel et al. 2020; Huang et al. 2020; Tariq et al. 2021; WMO 2013). Research in this field is still ongoing (Tariq et al. 2021) and (Delaire et al. 2017) cost estimations suggest, that even with current equipment, costs are minimal in relation to achieving the SDG 6.1 of safe water for all.

While no management decision or concrete developments could be made in the scope of this work, the results suggest some additional considerations. In the case of deciding for a specific water source monitoring strategy, all accessible water sources in a community should be monitored, as the largest, e.g. a ballay, is not necessarily the one that can withstand a period of drought the longest. Physical as well as social access factors need to be considered in terms of actual water withdrawal and monitoring when deciding on the actual monitoring routine see section 1.3.3. Furthermore, the results support the feasibility and usefulness of a staggered trigger as proposed by (RCRC 2020) for triggering on water level thresholds as both, a seasonal and a short-term assessment are possible. In terms of AAs, the results mostly supported the feasibility of water trucking and cash transfer AAs (see section **??** and 1.3.3), which compares well with (Gettliffe 2021) findings. Yet, when comparing this finding with the statements of the interviewees from section 1.3.1 that water is often over prized in times of scarcity and with the statement of (OCHA 2020) that markets need to be operational to permit this handling of the demand, distributions of cash or water vouchers may not always be feasible as AA. Besides the social factors (Birch 2008) further highlights that impact on natural ecosystems through water availability for animals need to be considered when addressing water shortages. The community building aspect in stage 4 was mainly focussed on assessing the capacities of the SRCS. The findings suggested good capacities and high experiences in the area of community engagement as well as volunteer training and supervision (see section 1.3.4 and 1.3.2). This was to be expected, as the SRCS already implemented a comparable project and was also found to be performing well within the framework of the overarching FbF project. Findings of Stage 5 *Data management* support the technical practicability of the project. The solution of the implemented CBS project with the NYSS platform was found to be very dedicated and technically adaptable to the new requirements. Currently, discussions about the adaptation are ongoing on management level. In addition to this very automated and already well-rehearsed system, however, several other potential systems could be identified which, although not quite as advanced or tailored, would also suffice for the application for the time being (see section 1.3.5and **??**).

A major concern of data collected by CS is their quality and accuracy. This is well addressed in the current CBS program with initial and refresher trainings, close supervision and further verifications when necessary. Together with the built-in automatic checks in NYSS, measures of QC and QA are well considered. It is expected that these mechanisms can be translated to the new project largely addressing quality concerns right from the start. Constructed validity needs to be addressed by further data triangulation, as the simple measurement of the water level itself does not proof, that the underlying reason for low water levels is indeed a drought but could also be reasoned by social factors (see section **??**). Evaluation practices are integrated in every stage but due to no actual implementation and operation, evaluation could not be conducted. Nonetheless, the design

process, due to its iterative processes underwent several evaluations and piecemeal improvements itself suggesting good adaptability and upgradeability.
The overall application of the developed framework worked well and the combination of the SSF together with the PRC based on the SLMC could provide good guidance while also remaining flexible to incorporate new, unexpected findings. Yet, the entire power of the SLMC could not be exploited as the coming layers were too detailed and most of those need to be determined in closer collaboration with the team and the local stakeholders. Nonetheless, based on the positive experiences with the first three stages, it is believed that the following layers will also prove fruitful to potential future developments.
The application also supports the findings of (García et al. 2021) and (C. T. Conrad and Daoust 2008) that a framework should be used but also highlights the need to adapt this framework the actual projects conditions and goal. Furthermore, the work suggests that a respective implementation of a Citizen Science project is not only theoretically feasible but practically implementable. While an end to end establishment of an implementation roadmap was not feasible in the context of this work due to several information, resource and time constraints, a sound foundation could be laid for further practical implementation in the scope of a pilot study. Yet, important questions need to be answered on management level and not all indicators are in favour of a practical application. For example, the RCRC is generally not recommending its National Societies to implement their own data gathering strategies as this would, under normal circumstances over-burden and exceed costs (RCRC 2020). Therefore, (RCRC 2020) generally recommends to found the triggers and information on already gathered information by other stakeholders or international organisations. As suggested by the results, this is not feasible in this context. Furthermore, the analysis of the CBS approach and other projects together with the feasibility assessment and conducted application of this work suggest that CS can be reasonable and cost-effective approach to gather relevant information. This is also supported by (Aceves-Bueno et al. 2015) and (Minkman 2015) findings. Timely and accurate data can support the appropriate Anticipatory Actions to be tailored, making mitigation and response potentially more streamlined, efficient and effective.

Besides the high demands and complexity of the CS project design itself, this process also highlighted, that CS is not a silver bullet itself but comes with various advantages and disadvantages. While the final application may seem appealing, as a lot of the work is done by the contributing citizens, particularly the design and implementation poses a lot of requirements in time, skill, and resources. This complexity is also mentioned by (Fraisl et al. 2022) and (Minkman 2015) highlighting the statement, that Citizen Science one of many methods and its used should be well considered.

## 2.5 Limitations

In any research project, limitations are an important aspect to consider and some were already addressed in the above discussion. Yet, there are further limitations that need to be acknowledged. The literature review did not follow a strict formal structure and that comparable projects may have been overlooked, although unlikely, cannot be ruled out. Nonetheless, this exploratory approach also allowed for the discovery of many, formerly unknown aspects and contributed many insights to the study. The subsequent in depth literature review, although not formal, was detailed and extended and was able to identify and close some gaps. However, the generally sparse literature on Somaliland limited the desk-based collection of information about local conditions. Furthermore, this work has also not addressed the integration or application of local and/or indigenous knowledge or the further use of VGI, to the extent that this would have been possible in principle. Although both areas are very interesting, this was either not the focus of this work or, the case of available water source datasets and VGI an in-depth analysis had been deemed unsuitable due to the poor quality identified early on. Nevertheless, insights could be gained from the data using more refined methods in future work. On the theoretical level of the contextual basis, the concepts mentioned, such as water security, drought or Citizen Science, are extremely complex and highly debated topics. Discussing them in detail would have exceeded the scope of this thesis, which is why focal points were set according to the priority of this work.

The inclusive nature of the exploratory approach, was thus tried to be addressed by information triangulation from other studies but it made for a generally more consensual work and fewer contradictory findings. This, together with the inclusion of most relatable studies and projects into the framework itself, also made for a relatively homogeneous discussion due to the lack of contradictory findings. It is expected that this comparison with other work will be possible in the future as more CS projects are carried out in a similar context and with similar objectives.

The critique of the case study research type, its challenge to execute, significant documentation efforts and complex nature also had certain shares in this work. Nevertheless, its strength of being rich, detailed and contextual also contributed positively. The generalisability of the understanding gained through actual application can be considered low, but the applicability of the framework developed can be expected to be transferable to other comparable contexts.

An attempt was made to improve internal validity through the iterative design, reciprocal reviews and triangulation of multiple sources of information, but despite great efforts, it is hardly possible to establish causal relationships in such a complex environment. Constructed validity of the framework is believed to be reasonable due the extensive triangulation of resources but can only be tested in a practical examination. The importance of data triangulation was also noted and integrated in the actual application. Interviews always add a human factor which can complicate repeatability but clear procedures and documentation were established to account for this as best as possible. The expert and

snowball sampling strategy itself worked well, but was severely limited by other factors. The interviews always had to be arranged and signed off by senior managers, and the already tense situation with ongoing response activities and parallel FbF development in Somaliland made the availability of interviewees even scarcer. This resulted in a relatively low sample of interviewees, limiting the otherwise strength of a case study to incorporate a multitude of perspectives on one area of interest. Here, interviews especially with representatives of NADFOR, the MoWR and MoH as well as BRCiS and OCHA mights have been fruitful. The conversion of one interview into a questionnaire hindered direct clarification and follow-up questions in the interview, but this could be compensated for by a second questionnaire. Since a lot of information could be drawn from the answers and the interview could not have taken place otherwise, this can ultimately be seen as a good compromise.
Overall, the study was conducted under difficult conditions in a case study area known for its complex and difficult environment. The generally limited time and resources available in the context of a Master's thesis further constrained the study and the focus on just the development of the framework might have been beneficial. Nevertheless, it is believed that the study conducted was ultimately able to provide a good theoretical and structural basis for a potential practical implementation of this approach. Furthermore, this study contributes to the general ongoing discourse of Citizen Science-projects by adding a work from a currently underrepresented region. It is to be expected that in the further process of this discourse many of the limitations mentioned here can be addressed and overcome.

context, restrictions, stakeholders, comparable projects

commercialization of fresh water -> overpricing

water quality –> close link to health –> contamination is a huge deal (in all stages) construction and awareness raising and so on already activities -> one could build on that

data issues also with basic stuff as urban population.. (between official and I3) priority setting -> a difficult issue -> vulnerability and so on.. ggf. link to dashboard of 510? number von IDP camps (from which source?) only number? and a bit more.. response vs. anticipatory actions.. huge issue in drought response/actions - but: is it that important? lack of knowledge -> lack of action (based on I)

dataset -> why not more analysis -> it is basically unusable. How exactly unusable was hat the primary question. doesn't mean there is no value in those data sets though high level of disfunctional stuff - and why abandoned? the reason could be interesting

Ministries are often mentioned as important use experiences of stakeholders in other projects

124: challenges etc.

private owner $_{>}preventaccess - whatelse$?

cultural awareness -> elders and so on.. but: the SRCS know what they are doing

SRCS well embedded: low resources and knowledge CBS with partner NRC -> will possibly also need a technical partner for this one pilot study and on the ground development NYSS would be a good partner

what would hinder this project being addressed by other approaches? –> satellite not feasible because of roofs and small size, local sensors because of technical requirements

SRCS does not pay -> long term incentives are the motivation to help -> should be given by community selected RCRC volunteers

initial information is key -> the way to get it was not mentioned so far + list of it

priorities 2,3, and 7 (sensitization, initial key information, triggering action) government could kill this project right from the start - very important for the success (!!)

local knowledge

discuss the code. after I inserted it.

cash distribution (also in Lesotho and Niger) + tablet distribution for water related diseases + potential relation to diseases(?) in the platform.. (?) Though, (Gualazzini 2021) notes, that cash distributions and water vouchers require a functioning market.

Direct water transport is considered as the last solution to mitigate water scarcity as it is resource intensive.

cycle of self-help reduces future coping capacities –> risk / vulnerability assessment is important -> also clear measures of decision-making upon those information

trigger and AA –> short-term (water trucking) and long-term (berkad rehabilitation)

-> communities have their own management systems.. what and how are those and how could those relate? training expectation handling private berkad owners

no possible response -> the overall role of the international community (?) -> day 2009 local application

- technical methods need to be tested. Theory is good and well but come on..

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