MSc Thesis on

DECISION ANALYSIS SUPPORT FOR SUSTAINABLE ALLOCATION OF NEWLY-ARRIVED REFUGEES ACCORDING TO WATER SECURITY CRITERIA

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Abstract

Site selection is a critical factor in the ability to provide safe and healthy environment for refugees. At the outset of an emergency, limited resource and time create large planning uncertainties and current refugee sites' assessments based on field visit are no longer adequate. The selection of unsuitable locations triggers a number of issues such as environmental degradation, competition for scarce resources and, exploitation of water sources. These can be reduced through a rational refugee allocation decision process. The question that arises is, can the refugee allocation process be supported by a structured decision-making (SDM) approach and more specifically, by a portfolio decision analysis (PDA) model? Focusing on water security criteria, this study presents the initial phases of the SDM-approach intended to ensure a more sustainable allocation of newly-arrived refugees among new and/or existing hosing sites. To this end, a procedural tool for supporting WASH (Water, Sanitation and Hygiene) officers in the site assessment is proposed. This was obtained based on 15 semi-structured interviews and questionnaires carried out in a global stakeholder environment, in order to make the SDM framework applicable to other settings.

The generic procedural tool was tested in a case-study in south-western Uganda by applying a portfolio decision analysis model. Local and global data were combined with stakeholder preferences to predict the performance of diverse sets of alternatives. The latter were generated according to different combinations of numbers of refugees, hosting locations and percentage of water extracted from surface water, groundwater and rain water. To identify efficient portfolios, we used the Robust Portfolio Modelling - Decisions software. Results showed that overlooked solutions outperforms over the current allocation strategy. In specific, the scatter of newly arrived refugees showed the highest scores on availability of water, socio-economic costs and host communities' advantages. The proposed framework provides also options for the optimal repartition of the future water extraction among available water sources, aiming to avoid their depletion while preserving sustainable costs of the water services.

Acknowledgments

The study is part of the Deltares research program for water and subsoil, which aims to provide tools and models for decision-making to improve water security through effective management of scarce resources. Part of the financial support was provided by the Lamminga foundation.

This research could not have been realized without the support of several people.

I would like to truly thank Lisa Scholten in first place. Her guidance and sharp critiques were essential in shaping this research. I also would like to thanks my thesis committee, Erik Mostert and Bertel van de Walle for their suggestions. Further, I thank Laura Basco Carrera for helping me to set-up the project and build the needed network. I am also grateful to my colleagues in Deltares who took their time to discuss ideas and approaches. A special thanks to Murray Burt and David Njoroge from UNHCR which guided and supported me on field research respectively in Geneva and Uganda. Thanks to Fred Musinguzi, Wondayehu Belayne and Frankling Golay who guided me in the challenging environment of humanitarian interventions. Thanks to Liesiö Juuso from Helsinki University of Technology for taking the time to simulate the framework in the RPM-Decisions software. The results obtained from the software were essential to provide the stakeholders with informative decision recommendations. And finally, I would like to thank my family and friends, in particular Veikko, Amir, Rogier and Guilherme for giving me moral support and reviewing my report. Thanks to my mum, aunt and cousin, *Rosy*, *Laura* and *Mariaelena*. Their sensibility, determination and passion are always my source of inspiration and were key components to carry out this research and Master program.

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Abbreviations

AFT – Alternative-focused thinking

CRRF – Comprehensive Refugee Response Framework

DESS – Division of Emergency, Security and Supply (UNHCR)

ECMS – Emergency Capacity Management Service

GHM – Global Hydrological Model

GIS – Geographic Information System

GW – Groundwater

HQ – Headquarter

MCDA – Multi-Criteria Decision Analysis

NA – Needs Assessment

PA – Programming Algorithm

PDA – Portfolio Decision Analysis

PPRE – Preparedness Package for Refugees Emergencies

PV – Present Value

RedR – Register of Engineers for Disaster Relief

RPM – Robust Portfolio Modelling

RW – Rainwater

SA – Stakeholder Analysis

SDM – Structured Decision Making

SNARA – Sustainable Newly-Arrived Refugees Allocation

SW – Surface water

UNHCR – United Nation High Commissioner for Refugees

VFT – Value-focused thinking

WASH – Water, Sanitation and Hygiene

List of terminology

Concept	**What it is**
Value focused thinking	A good decision starts by exploring what we want (objectives) rather than identifying available alternatives.
Means-Ends objectives	Mean objectives are objectives needed to influence the outcomes while End objectives are the outcomes.
Objectives Hierarchy	Hierarchical structure in which lower level objectives are shown to concretely describe the related fundamental objectives and improve measurability.
Water Security	Reliable availability of an acceptable quantity and quality of water for health, livelihoods and production, coupled with an acceptable level of water-related risks. The definition embodies a number of issues such as water scarcity, natural disasters, food security.
Objectives (also called criteria or goals)	Concise statements of 'what matters'
Attributes	Attributes are the measures to describe the consequences of alternatives related to the selected objectives
Alternatives	The alternatives are means to achieve the objectives

1. Introduction

The refugee shelter and settlement strategy is a key component of the crisis response plan. Poor refugee allocation can lead to serious issues for water provision, hygiene, safety and resource depletion or competition with the host community. These problems escalate when refugee situations are protracted, showing the needs for substantial planning in early stages. To establish a more effective response to the refugee crisis, the United Nations High Commissioner of Refugees (UNHCR) has developed the comprehensive refugee response framework (CRRF). One of the main goals of this framework is establishing self-resilience of refugees through long-term planning. In accordance with this new comprehensive approach, water security needs to be considered in site selection, not only to meet immediate needs, but also to sustain the refugees' livelihood in the long term.

At the outset of an emergency, limited resource and time create large planning uncertainties and current refugee sites' assessments based on field visit are no longer adequate. Currently, only a few of the water security criteria are included in the assessments and important actors are involved only after the site is selected. This gives the perception that the site location decision is only in the hands of the host government. Recent UNHCR policies try to address the problem by encouraging the implementation of preparedness actions (PPRE's). The aim of the PPRE's is to speed up the process of response, agree beforehand on the different partners' engagements and enhance an understanding of the country's capacity to act in case of emergency.

A few studies attempted to support the refugee site selection process based on GIS-based multi-criteria decision-making methods in specific case-studies. However, despite these efforts, refugee site allocation is currently still driven by an intuitive decision-making approach. This could be improved by developing a generic approach that can be applied in different host-countries.

In line with the PPRE's and the CRRF, this research seeks to support WASH officers on refugee allocation to new and/or existing camps based on water security criteria. To support the decision process, we first focus on the initial steps of rational-decision making, for the development of an analytic decision structure, which comprehensively addresses water security criteria and decision makers' goals. To develop an approach applicable to different settings, semi-structured interviews and questionnaires are carried out at the headquarter of UNHCR.

The analytic decision structure complemented by water security indicators aims to provide a procedural tool for "Sustainable Newly-Arrived Refugee Allocation" (SNARA). To test its efficiency, the structuring process was then applied to a Portfolio Decision Analysis (PDA) approach, whereby local and global data are combined with stakeholder preferences to predict the performance of sets of alternatives for a specific application case in south-western Uganda.

In the next paragraphs, the problem in analysis is defined in detailed followed by a review of the relevant literature and previous works. Then, the case study for the specific application of the PDA-model is briefly introduced, followed by the definition of the research question, objectives and the implemented approach.

1.1 Problem definition

Water is one of the most critical factors in the site selection process of refugee camps (UNHCR, 2007). This becomes even more critical in arid region, where the aim is also the protection of the water sources (CARE International, 2008). Difficulties of finding sufficient water quantities in refugee camps cause abandonment of the sites with high costs in relocating the refugees already placed and consequent delay in settling incoming flux of refugees (Bartsch & Belgacem, 2004).

According to the literature, the selection of inappropriate areas can happen for three main reasons:

1- Lack of time and money that leads to the neglect of significant indicators;
2- Important stakeholders such as humanitarian organizations are not involved from the beginning;
3- General assumption that refugees represent a problem or a burden, rather than an opportunity.

All these issues are interconnected. In most cases, refugee influxes are seen as a financial burden for receiving countries, rather than an economic opportunity (Social Humanitarian Cultural Comittee UN, 2002). Therefore, in some cases, there is not the will in investing time and money in selecting suitable locations. Important indicators are neglected and stakeholders as WASH operators, technical specialists and engineers are considered only after the site is selected. This gives the perception that the site location decision is only in the hands of the host government and actions by aid organizations rarely are going to affect the outcome (Corsellis, 2001).

In addition, an unregulated allocation of arrivals may result in the overpopulation of the camps beyond their assessed capacity. Such a large refugee concentration has a serious impact on a very fragile environment with particular regard on the water security (Barkley, 2015). In this context, conflict between local population and refugees over shared water resources can rise (Grindheim, 2013). Competition for resources needs to be addressed at the earliest stage of the decision-making, considering it as an additional criterion in the site selection process. Simultaneously, economic opportunities for the host countries should be identified, in order to consider the possible benefits that the presence of refugees in certain areas can initiate (UNHCR Standing Committee, 1997). Both aspects are overlooked in the currently available models that attempt to support the identification of suitable hosting sites.

1.2 State of the art in refugee allocation planning

Guidelines (Corsellis, 2001; Rooij, Wascher, & Paulissen, 2016; UNHCR, 2007) and toolkits (Birkeland & Vermeulen, 2009; CCM Philippines, 2007; Kelly, 2010) supports the main stakeholders in the refugee site location process, suggesting multi-sectorial factors and approaches. However, refugee camps are still often located in remote, isolated and inhospitable areas, making it impossible for refugees to contribute to the local economy and to integrate with the local population (Crisp, 2017). This is quite acceptable at the height of an emergency, but becomes unsustainable in ongoing situation causing environmental degradation, health and social issues.

In recent research, emergency humanitarian logistics optimization models have been regarded as an important tool in the disaster facility location problems (Caunhye, Nie, & Pokharel, 2012). According to Boonmee, Arimura, & Asada (2017) most objectives, in the facility location optimization model, have focused on minimum time, minimum cost, minimum distance, minimum number of located facilities and coverage by a maximum number of demand points. Objectives developed by integrating the facility location problem with the resource allocation problem are missing. Further, according to the same authors, environmental effects are neglected in the multi-objective models.

The formulation of optimization models in emergency settings strongly depends on the context in analysis. Among the reviewed shelter location optimization models for humanitarian logistic, no one has been framed in relation to the refugee crisis. The most prevalent disaster investigations were found to be earthquakes, hurricanes, floods, dam inundations, and epidemics (Boonmee et al., 2017). These disasters typically create internal displacement before reaching a level where people are forced to cross borders. However, the word “refugee” describes people fleeing war or persecution, which have crossed an international border as their return to home can be dangerous (UNHCR, 2016a). This different state of emergency results in different priorities and settings of the shelter location decision problem (e.g. planning time horizon, resource competition, environmental degradation), which are not tackled in the humanitarian emergency optimization models currently proposed in literature.

A few studies address the issue of locating refugee camps. Their methodologies are framed according to a GIS-based Multiple-Criteria decision analyses (GIS-based MCDA). Çetinkaya et al. (2016) developed a model to identify new potential locations for refugee camps in south-eastern Turkey. The fuzzy analytic hierarchy process (FAHP) method was used to prioritise the criteria, while technique for ordering preference by similarity to ideal solution (TOPSIS) methods were used to rank potential sites. Similarly, Mong, Nelson, & Oni (2014) proposed a GIS based methodology for the site selection process of refugee camps in Uganda. Environmental and social factors were identified for evaluating the different performances of the alternatives and two different scenarios were used. Spink (2015) presented a GIS-methodology for generating a suitability maps in support of refugee site selection process in Nigeria. Five different criteria were considered and a ranking system was applied in order to score the different alternatives.

All criteria identified by the above-methodologies are based on information that is not always available to the government. Generally, in developing countries, very limited data are accessible to carry out a comprehensive water analysis. Global databases and/or remote sensing imageries can be an important support in this process. The integration of global data sources for the qualitative and quantitative measurements of water security attributes is also an unexplored research direction that need further investigation.

In addition, the reviewed methods do not promote the engagement of main stakeholders in the site-selection process, missing the opportunities to enrich the methodology through their knowledge while improving the overall performance of the analysis. The interaction between refugees and local population in sharing available resources is also neglected, being unable to predict possible competition or depletion of the resources. Finally, another disadvantage of these methods is the impossibility to identify and evaluate opportunities for the local communities as well as the host government. Refugees embody a significant flow of resources in the form of international humanitarian assistance, economic assets and human capital (Jacobsen, 2002; Whitaker, 1999). Being able to identify risk and possible opportunities already at an early stage of the refugee allocations might increase the probability to reduce cost and rise the benefits to host countries (Ennead Lab, 2016).

This research pursues to address the limited use of optimization models in emergency humanitarian logistics for refugee crises. The analysis in this thesis contributes to the current literature by assessing the applicability of the SDM-approach and PDA model to a new topic: the spatial allocation of newly arrived refugees in host-countries. The scope of the study is limited to only include water security criteria in de SDM-approach. In addition, we want to validate if a generic decision framework can be implemented in host-counties using global databases and open data sources. The interaction between refugees and local communities is also explored on the basis of water criteria, identifying competitions and opportunities.

1.3 Refugee allocation approach in Uganda

Uganda is one of the main hosting countries in the World. Around 1.4 million people from neighboring countries are hosted in refugee settlements and other refugee influxes are expected, mainly from South Sudan and the Democratic Republic of Congo (REACH, 2018b). In response to the protracted refugee crisis, the Ugandan government is implementing a progressive refugee policy, which is framed in the 2006 Refugees Act and the 2010 Refugees Regulations. According to this policy, refugees have property rights, freedom of movement and the right to work. In addition, land for shelter and agriculture purpose is provided to each refugee family (Varalakshmi et al., 2016).

This innovative approach is based on the idea that refugees are economic actors (development approach) rather than beneficiaries of aid (humanitarian approach) (The World Bank, 2016). As refugees are entitled to work, they can actively contribute to the national economy. In addition, the humanitarian assistance for refugees creates significant economic benefits for the local economy through the provision of services and the consumption of local goods.

Despite Uganda's progressive refugee policy and the contribution of refugees to the local economy, the refugee impact poses risks to the areas. The high rate of refugee influx is compromising the limited local resources, including water and firewood. Competition for resources is creating tensions between the refugees and host communities.

Because of the complex situation, we chose the refugee allocation decision problem in south-western Uganda as a case-study for the application of the PDA-model. There, Nakivale refugee settlement was selected by the Office of the Prime Minister (OPM) and UNHCR as potential location for the accommodation of around 10,000 newly arrived refugees, in response to a potential influx from the Democratic Republic of Congo. However, an increase in the population of the settlement can exacerbate the current water scarcity condition. Therefore, the Ugandan government and UNHCR sub-office want to explore different allocation options in the Rwizi basin.

1.4 Research Question

In order to overcome the listed issues, the study aims to answer the following research question:

How to allocate incoming refugees in existing or new camps, according to a multi-criteria portfolio analysis based on a rapid water security assessment?

With the purpose of better defining the study process, the question can be divided into sub-questions:

1. How to develop a generic procedural tool for the SNARA decision problem?
2. How can the SNARA decision structure be implemented in the PDA model for a specific case, e.g. Uganda?
3. Which recommendation can we give on the base of the PDA approach in the specific case?
4. Which global data and open sources can support the framework, by providing the spatial information needed for the evaluation of the different criteria?
5. How generalizable are the results and the method and what would need to be done when applying it to another case?

1.5 Objectives

The general objectives are: (I) the application of the SDM-procedure to the spatial allocation of newly arrived refugees (SNARA) for the development of a generalizable objectives hierarchy, and (II) the use of the PDA method to support the SNARA decision process in south-western Uganda.

Specific objectives for the development of a generalizable objectives hierarchy to the SNARA problem are:

a) Identify the "typical" key decision-makers, and their objectives and priorities in the site selection process and refugee allocation. Compare the identified decision-makers with the ones in the study case, to determine whether they match.
b) Identify the water security assessment indicators related to the analysed objectives;
c) Investigate if the current global models and open-access data sources are adequate for estimating the identified indicators, assessing water security condition in the area in analysis;
d) Investigate which global models and open-access data sources can be integrated to the developed optimization model;
e) Identify competitions on water resources and economic opportunities related to the water system. Investigate which indicators are suitable in identifying them;
f) Investigate how the approach can be applied generically to different study cases.

Specific objectives for supporting the SNARA decision process in south-western Uganda are:

g) Formulate the refugees' allocation decision process as a PDA problem;
h) Identify the feasible non-dominated portfolios. Investigate the performance of the optimum portfolio compare to the other portfolios;
i) Compare the identified portfolios with the current allocation strategy;

In structuring the decision problem, the analysed water security criteria include only those relating to the WASH mandate. Therefore, in this research, we do not address the analysis of water-related hazards in the site selection decision process in south-western Uganda.

1.6 Approach

The initial three steps of the rational decision-making approach (also named structured decision-making (SDM); Gregory et al., 2012) are used to structure the general SNARA decision problem. Pursuing this methodology, the decision context is first defined by implementing both a need assessment and a stakeholder analysis. Second, the objectives are identified according to the following iterative stepwise approach: (i) identification of criteria from the literature; (ii) distinction among ends and means objectives; (iii) development of a preliminary objectives hierarchy; (vi) testing of the identified objectives with the stakeholders; (v) modification of the objectives hierarchy. Finally, generic attributes for the SDM framework are investigated, looking at well-established indicators in water security assessments and UNHCR guidelines. Available global databases and open sources are analysed and used to guide the decision-makers in implementing the SDM framework for specific applications.

The generic SNARA objectives hierarchy is then tested in the Ugandan case study by implementing a PDA model. Through the investigation of the local decision context, the SNARA decision objectives are reviewed. The decision structure is complemented by attributes, which are needed to quantitatively describe the consequences of alternatives on the selected criteria. The attribute selection is mainly driven by data availability, as this is a limiting factor. Subsequently, the decision alternatives are identified through the combinations of numbers of refugees, hosting locations and percentage of water extracted from surface water, groundwater, and rain water. These alternatives are then combined in portfolios according to logical interdependencies (Lahtinen, Hamalainen, & Liesio, 2017). A value model is built using the collected information on the specific study case, which is used together with a linear additive model to obtain an overall consequence value for each portfolio. Finally, the set of efficient portfolios is solved by using the RPM-Decisions software.

1.7 Structure of the Report

The report is structured as follows. In Chapter 2, a theoretical background for this research is provided. First, the UNHCR policies which we refer to in the research are shortly presented. Thereafter, the relevant literature on structured decision making and portfolio decision analysis is reviewed, providing the reader with a sufficient background to understand the methodological decisions that drive the next sections.

In Chapter 3, the generic procedural tool for the SNARA decision-making process is developed. First, the methodology adopted is explained, by describing the application of the initial steps (1-3) of the Structured-Decision Making (SDM) process to the SNARA process. Then, for each step the results are shown, guiding the reader through the clarification of the decision context (step 1), the definition of the objectives according to a literature review, questionnaire, and interviews (step 2) and the identification of the attributes (step 3). Global and local data sources are cited to guide in the application of the problem structure for different geographic areas. The chapter concludes with a discussion on the obtained results. Subsequently, Chapter 4 illustrates how the SNARA objectives' hierarchy was applied to the decision problem in the Rwizi Catchment (Uganda) and how the decision-making process was framed as Portfolio Decision Analysis model. First, the used analytical procedure is clarified for each step of the PDA-model. Then, the results are described and discussed. Finally, conclusions are drawn by answering the five research questions, followed by recommendations for future work (Chapter 5).

Because the field of research introduces a wide range of terminologies, an overview of the used concepts is presented at the beginning of the report (‘list of terminology’). These concepts are further explained in the literature review.

2. Literature Review

According to the research question and the objectives mentioned above, a literature review was carried out. This provides the necessary background and relevant theory for the study. First the UNHCR policies are presented to better understand the context in which the SDM-approach needs to be framed. Secondly, the theory behind the SDM-approach and PDA model is explained, which helps to understand the chosen methodology and the results. Finally, a brief insight on the definition of water security, stakeholder analysis and needs assessment is provided to clarify related concepts and approaches.

2.1 UNHCR Policies

2.1.1 The building block of preparedness: the contingency plan

According to the UNHCR Emergency Handbook (2015), the delivery of emergency aid requires a significant amount of time. The planning of interventions before the occurrence of a crisis is an important phase for being able to quickly respond to an incoming emergency. To this end, UNHCR's *Policy on Emergency Preparedness and Response* (UNHCR, 2018b) seeks to support refugee host countries in situations at risk of a humanitarian emergency in which urgent and advanced preparedness actions and operational response are required.

The policy defines three levels of emergency (Table 1) based on the existing capacity of the country and the Regional Bureau(x) concerned, in light of the expected magnitude, complexity or consequences of the emergency (UNHCR, 2017a).

Table 1. Level of emergencies (elaborated from UNHCR, 2017a)

Emergency level 1: Proactive preparedness	It is activated to trigger active preparations for a likely humanitarian emergency. Preparedness actions are undertaken in the operation(s) concerned, with the support of the relevant Regional Bureau, the Division of Emergency, Security and Supply (DESS) and other support services as needed. These may include preparedness missions and human, financial and material support.
Emergency Level 2: Stepped-up Bureau support	It applies to a situation in which additional support and resources, mainly from the concerned Regional Bureau, are required for the operation to be able to respond in a timely and effective manner. Upon declaration of a Level 2 emergency, the Bureau is authorized to mobilize and/or re-allocate resources available under its auspices and may seek specific support from Headquarters Divisions.
Emergency Level 3: Whole-of-UNHCR Response	The activation of this level signifies an exceptionally serious situation in which the scale, pace, complexity or consequences of the crisis exceed the existing response capacities of the country operation and Regional Bureau(x) concerned, and call for a corporate, whole-of-UNHCR response. The declaration of this level of emergency automatically triggers the establishment of Headquarters coordination mechanisms, deployment of staff and supplies, access to additional financial resources, real-time reporting and follow-up mechanism.

The Policy requires UNHCR's offices to implement the *Preparedness Package for Refugee Emergencies* (PPRE) framework, seeking to support the main stakeholders in preparing systematic actions related to specified levels of risk. The main objective is to ensure a good emergency preparedness through the development of "building blocks", laying the foundation of an emergency response (Figure 1).

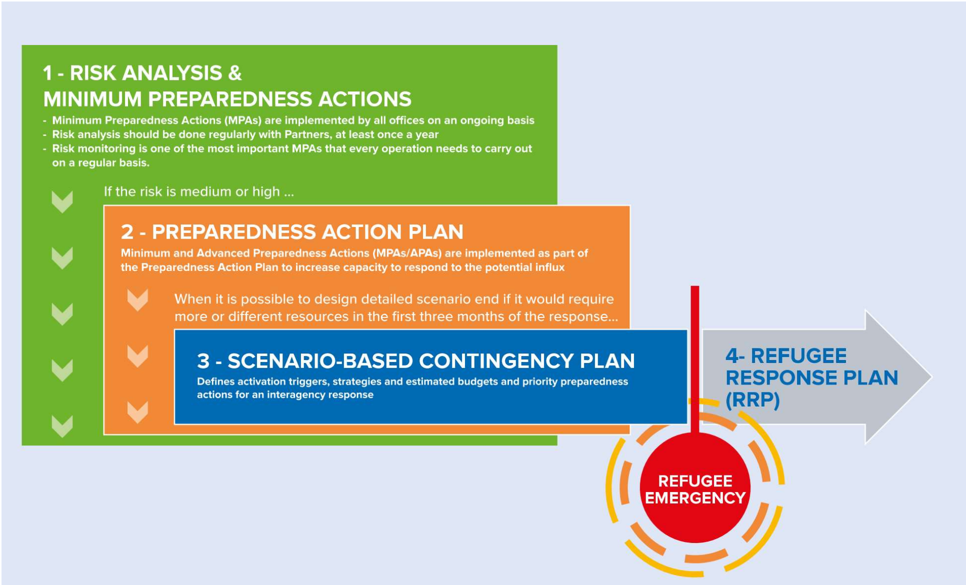

Figure 1. Building blocks of preparedness (UNHCR, 2007)

Among the suggested phases, the contingency plan is implemented as part of the advanced preparedness actions (APAs), when the risk of emergency is considered high. It defines a response strategy with actions to be taken, specifying whom, where, and with which resources. The plan is used as the basis for the response plan and the donor appeal at the outset of an emergency.

A key component in the contingency plan is the refugee shelter and settlement strategy. The decisions taken are hard to reverse. Cultural and socio-economic factors should be included in the site selection and an analysis of the capacity of the host country is needed. According to the latter and the number of refugees arriving, the option to open new camps is evaluated.

Partnership is central to a successful contingency planning process, due to the commitments with regards to future actions. While the Policy requires UNHCR's offices to implement the PPRE's methods and components, partner agencies and government counterparts are not under a similar obligation.

2.1.2 Comprehensive Refugee Response Framework (CRRF)

The Comprehensive Refugee Response Framework (CRRF) is based on four core objectives (UNHCR, 2017b), as follows:

Table 2. Objectives of the CRRF

1. Ease pressure on the host countries involved;	Increase support and assistance to host countries, including sharing international responsibility.
2. Enhance refugee self-reliance;	Include refugees in national development plans and invest in the future of refugees and local communities.
3. Expand access to third-country solutions;	Wider opportunities for refugees through resettlement and complementary pathways.
4. Support conditions in countries of origin for return in safety and dignity.	Support measures to encourage voluntary and informed repatriation, reintegration and reconciliation.

One of the innovative aspects of the framework is the alignment of the refugee response with the sustainable development goals and national development plans. From the beginning, refugees need to be included in the host communities through access to education and labour markets. By enabling skills and self-resilience, refugees can contribute to local economies while fuelling the development of the communities hosting them. This shifts the conceptualization of the refugee situation from humanitarian to development challenges.

In addition, the CRRF has helped to expand the base of engagement through a whole-of-society approach. Forward-looking plans can be implemented only with effective partnerships between host governments including ministries, UN Agencies, development actors, the private sector, NGOs, financial institutions, and civil society.

2.2 Introduction to Decision Analysis

Decision analysis refers to systematic approaches used to addressing and evaluating important choice (Ralph L. Keeney, 1982). The goal is to support decision-makers to make rational decisions. Multi-Criteria Decision Analysis (MCDA) techniques helps in structuring decision problems, in making explicit the multiple and conflicting criteria and in identifying rational and justifiable decisions (Eisenfuhr, Weber, & Langer, 2010; Mendoza & Martins, 2006). This approach enhances the transparency of decision making and mutual commitment to the way forward. The structure of the decision process can be easily communicated to the stakeholders, improving the efficiency of later implementation phases and the accountability of decision-makers (Salo, Keisler, & Morton, 2011). However, as outlined by Gregory et al., (2012), the MCDA techniques underemphasize the initial steps of the problem structuring process. A clear definition of the problem and an active engagement of stakeholders in the generation of objectives are indeed crucial in any decision (Bond, Carlson, & Keeney, 2010; Ralph L. Keeney, 2008). A rational decision process (also called structured decision making; Gregory et al., 2012) looks more carefully at these aspects by providing analytical methods and tools for their inclusion. This structuring process may then be followed by a formal MCDA, by combining model and stakeholder preferences in a logical manner to evaluate the alternatives.

Different types of decision problems require the use of different MCDA approaches. When the intention is not to sort or rank only one alternative, but rather to identify a subset of items (a portfolio) from a choice set, the standard MCDA models are not sufficient. Many MCDA approaches for portfolio modelling can be used according to the available information and the general goals. Selecting the best approach is not a trivial task (Barbati, Greco, Kadziński, & Słowiński, 2017). Lahtinen, Hamalainen, & Liesio (2017) identified five approaches suitable for environmental management decisions. Among them, the portfolio decision analysis (PDA) is currently most commonly used in resource allocation problems (Ollila, 2013).

2.2.1 Rational decision process

Effective problem structuring is critically important for any MCDA as it helps to discipline thinking and to make decisions more transparent (Lienert, Scholten, Egger, & Maurer, 2014; Marttunen, Lienert, & Belton, 2017). Following a rational decision making process, a well-structured problem is the starting point. In this first step, the following questions need to be answered: “What is the problem or the set of problems that should be addressed?”, “Who is involved?”,” What concerns are included?”,” What options are possible?”, “What are goals of decision makers?” (Gregory et al., 2012). Through these questions, the scope and boundaries of the decision problem are clarified.

Subsequently, rational decision-making requires a clear understanding of the objectives (also defined in this report with the term “criteria”). When determining the system of objectives for the given decision problem, appropriate attributes have to be identified, allowing for the measurement of the extent to which the objectives are achieved (Eisenfuhr, Weber, & Langer, 2010). This step seeks to describe the consequences of each alternative and to balance their pros and cons (Ralph L. Keeney & Gregory, 2005).

Then, alternatives are generated by thinking about how to better achieve the identified objectives. As Ralph L. Keeney (1996) suggested, this process helps in widening the range of alternatives and in identifying missing objectives. The last two steps are: (I) to estimate the consequences and, with respect to them, (II) to identify decision makers' subjective[1] preferences (Eisenfuhr et al., 2010; Gregory et al., 2012; Ralph L. Keeney & Raiffa, 1993; Lienert et al., 2014). According to the preference information, each attribute receives an importance weight and a value function transforms attribute levels to a neutral scale (Lienert et al., 2014; Liesiö, Mild, & Salo, 2007). The attributes are combined according to the adopted aggregation method (the linear additive value model), obtaining an overall value for each alternative. The decision alternatives that achieve the highest values are proposed and discussed with the decision makers.

In terms of structuring criteria, two different approaches can be identified in literature: (1) alternative-focused thinking and value-focused thinking. In the first approach, criteria are defined according to the characteristics that distinguish alternatives (e.g, Montibeller, Franco, Lord, & Iglesias, 2008). In the second approach, instead, evaluation criteria reflect strategic objectives of the decision makers. Following the **value-focus thinking** of Ralph L. Keeney (2008), the objectives need to be explicated first and subsequently, the alternatives are identified. In the second step, the generation of the alternatives can also support the articulation of the values, thereby applying an iterative approach (Ralph L. Keeney, 1996).

In summary, a rational decision-making process goes through seven different steps: (1) define the problem; (2) generate objectives; (3) Identify the attributes; (4) generate alternatives; (5) rate each alternative on each criterion; (6) weight the criteria; (7) compute the optimal decision(s) (Bazerman & Moore, 2009; Eisenfuhr, Weber, & Langer, 2010; Gregory et al., 2012; Lienert, Scholten, Egger, & Maurer, 2014). If the alternative-focused thinking approach is used instead of the value-focused thinking approach, step 2 and 4 switch positions. Each step is described in detail below.

(1) Define decision context

In the *problem definition*, the goal is to identify and define the "right" problem (Bazerman & Moore, 2009; Eisenfuhr et al., 2010). Three mistakes are commonly made by decision makers: (1) the definition of the problem in terms of a proposed solution; (2) the lack of a wide problem picture; and (3) the characterization of the problem through its symptoms (Bazerman & Moore, 2009).

In this phase, the stakeholder involvement is important to be able to comprehensively include different perspectives on the problem in analysis (Lahtinen, Hamalainen, & Liesio, 2017). Different methods for stakeholder engagement are suggested by Phillips & Bana E Costa (2007), such as decision structuring dialogue, decision analysis interviews and decision conferences.

(2) Generate objectives

In the second step of the rational decision process, objectives are identified. Objectives represent desires that the decision-makers aim to achieve by making a decision (Bond, Carlson, & Keeney, 2008). According to Bond, Carlson, & Keeney, (2010) and Eisenfuhr et al., (2010), identification of such objectives is a prerequisite for:

1. Finding or generating new (unknown or unrecognized) alternatives;
2. Evaluating the performance of the available alternatives;
3. Gaining an impression of which alternatives might be superior.

However, individuals are not naturally able to develop a comprehensive set of decision objectives (Bond et al., 2008; Bond, Carlson, & Keeney, 2010). Two distinct impediments to the generation of decision objectives were identified by the authors: (1) individuals do not think broadly enough about the range of relevant objectives, and (2) do not think deeply enough to articulate every objective within the range that is considered. Consequently, decision-makers respond to complexity by simplifying their environment (Bond et

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[1] According to Eisenfuhr, Weber, & Langer (2010), expectations and preferences are inherently subjective. This means that every decision maker can expect and like whatever he wants. However, preferences need to be consistent with the principle of rationality.

al., 2008). This narrow mental representation prevents them for considering a comprehensive set of objectives. Stimuli from outsiders can be of great help in articulating personal or organizational objectives that would otherwise be overlooked (Eisenfuhr, Weber, & Langer, 2010). The application of systematic methods can improve the generation process by stimulating broader and deeper elaboration of factors relevant to the decision. Bond, Carlson, & Keeney, 2008 and 2010 propose four systematic methods which are shown in Figure 2.

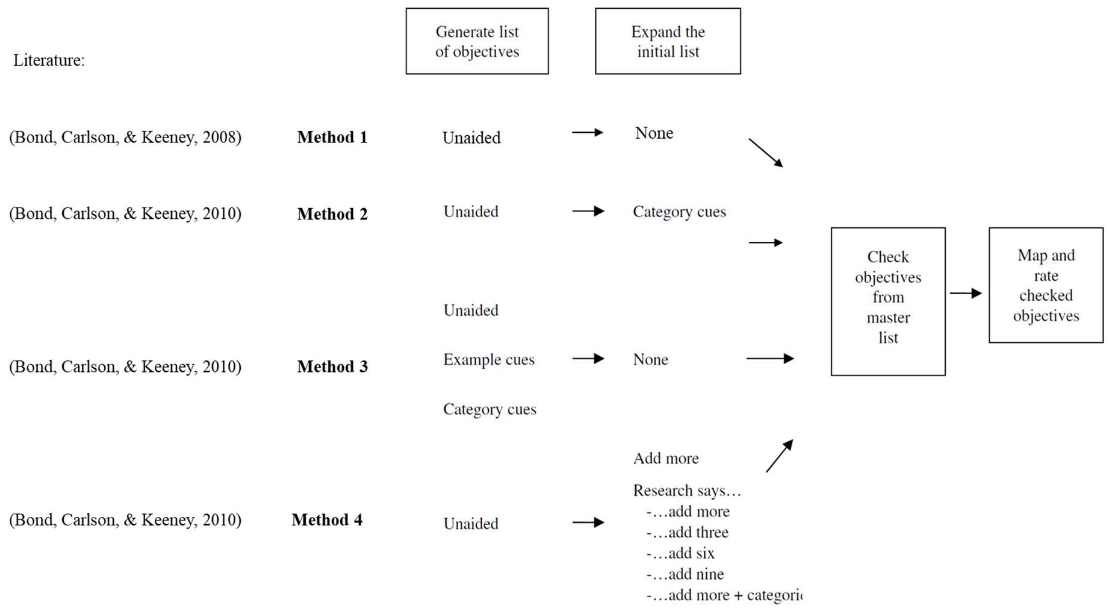

Figure 2. Systematic approaches for elicitations of decision objectives

Crucial for the generation of objectives is the distinction among ends and means objectives. The first represent desires that are an end in themselves for the situation and provide the basis to evaluate the alternatives. Conversely, means objectives facilitate the achievement of objectives (Bond et al., 2008). To distinguish them, it is important to understand "Why is that objective important?". If the answer is the importance of the objective itself, the objective is an ends in the problem context. Otherwise, the objective is a mean for achieving one or more fundamental objectives. A structured decision tool, helpful in clarifying the relationship between means and ends objectives, is the **means-ends network** (Eisenfuhr, Weber, & Langer, 2010; Gregory et al., 2012).

Another useful tool for generating fundamental objectives is the **objectives hierarchy**, which helps in describing the identified objectives more concretely by breaking them down into lower-level objectives (top-down approach) or aggregating them into higher-level objectives (bottom-up approach). The top-down approach is used when there is a clear idea of the important aspects that characterize the decision problem. Contrarily, the bottom-up approach is suggested if little is known (Eisenfuhr, Weber, & Langer, 2010).

The final generated system of objectives needs to fulfil several requirements. It should be *comprehensive* by covering all fundamental aspects of the consequences that are considered relevant, *non-redundant* by avoiding overlapping or double counting, *specific* and *concise* by avoiding too generic and unnecessary or ambiguous objectives. Finally, it is preferable that the objectives are *independent* with respect to the attribute levels of the remaining objectives (Bond, Carlson, & Keeney, 2008; Eisenfuhr et al., 2010). The latter allows the use of an additive multi-attribute value function. Better clarified objectives help to define the basis for the identification of appropriate attributes.

(3) Identify attributes

Attributes are needed to quantify the performance of the alternatives in achieving each objective (Bazerman & Moore, 2009; Eisenfuhr et al., 2010; Gregory et al., 2012; Ralph L. Keeney & Gregory, 2005; Lahtinen, Hamalainen, & Liesio, 2017). There are three different types of attributes: natural, constructed and proxy attributes (Ralph L. Keeney & Gregory, 2005). Natural attributes are preferred over proxy attributes as they directly measure the degree to which an objective is met. Contrarily, proxy attributes measure the level of a parameter which is assumed to be directly connected to the objective. Finally, constructed attributes directly measure the achievement of an objective using a scale specifically constructed for the analysed decision.

(4) Generate alternatives

In the fourth step, the identification of possible alternatives is required. This process can be time consuming. However, it is important to be aware that an optimal search continues only until the cost of the search outweighs the value of the added information (Bazerman & Moore, 2009). If too many alternatives are generated, two different approaches can be used. A common approach is the shortlisting of the alternatives through screening, economic, or optimization models. A second approach is based on grouping alternatives in packages or areas (Morton, Keisler, & Salo, 2016). If, on the other hand, not enough alternatives are generated, different creativity techniques can be used to widen the usual narrow range of alternatives (e.g., Ralph L. Keeney, 1996).

Following the value-focused thinking, defining objectives and generating alternatives have to be done through an iterative approach. The objectives guide the generation of alternatives, while the latter helps in identifying missing objectives (Gregory et al., 2012; Ralph L. Keeney, 1996, 2008).

(5) Preference elicitation: scoring and weighting

Quantitative methods are needed when the paired comparison of alternatives is not sufficient to identify solutions. This happens especially when decisions need to be taken considering multiple objectives. Therefore, it is important to investigate the preferences of decision-makers. This allows for the modelling of values and the expression of trade-offs. A common model value is the linear additive value function, in which the elicitation of the decision maker’s preferences consists of two phases: scoring and weighting (Ollila, 2013).

In the first phase, a value function is used to transform the attribute level into a neutral scale, generally between 0 and 1. The chosen value function can be monotonic linear, convex or concave (Eisenfuhr, Weber, & Langer, 2010) and can be determined by various methods such as the direct-rating method, difference standard sequence technique, and bisection method (Eisenfuhr et al., 2010; Gregory et al., 2012).

In the second phase, the weights are assigned to each criteria, according to the relative value that each decision-maker places on them. Attribute weights are computed based on the selected weighting method. These methods can be classified into objective and subjective (Roszkowska, 2013). The objective methods use objective information for mathematical calculation of the weights. In the subjective methods, weights are instead identified on the basis of criteria preference information, intuition or judgement of decision-makers. The ranking ordering method, the trade-off method, and the swing method are only some of the systematic subjective approaches. In case of incomplete preference elicitation on alternatives, the ranking ordering method results in the most appropriate method for computing weights (Roszkowska, 2013). In general, this method involves two steps: i) ranking the criteria according to their importance; and ii) weighting the criteria from their ranks using one of the rank order approaches.

(6) Compute the optimal decision

Finally, in the seventh step, the optimal decision is computed given the modelling assumptions. The computation and analysis of the results depend on how we have structured the decision problem. The basic computational task is to find the alternative which maximizes the overall alternative values, previously quantified according to the selected aggregation method (i.e. linear additive model). After analysing the results, it is important to examine the sensitivity of the decision to different value structures and uncertainties related to alternatives’ consequences (Eisenfuhr, Weber, & Langer, 2010; Ralph L. Keeney, 1982).

2.2.2 Portfolio decision analysis

Salo, Keisler, & Morton (2011) defined PDA as ”a body of theory, methods, and practice which seeks to help decision makers make informed multiple selections from a discrete set of alternatives through mathematical modelling that accounts for relevant constraints, preferences, and uncertainties”.

Contrary to other optimization models that identify a single alternative from a set, PDA generates and selects a subset of portfolios from a large set of alternatives given pre-defined constraints such as maximum budget (Salo et al., 2011). The aim is then to generate all portfolios that fulfil the constraints and to identify those that achieve the highest (intrinsic) value (Figure 3). An important advantage of a portfolio framing is that it provides a more realistic problem representation if the performance of different alternatives is affected by the selected set of alternatives, as interconnection among them occurs (see Salo, Keisler, & Morton, 2011).

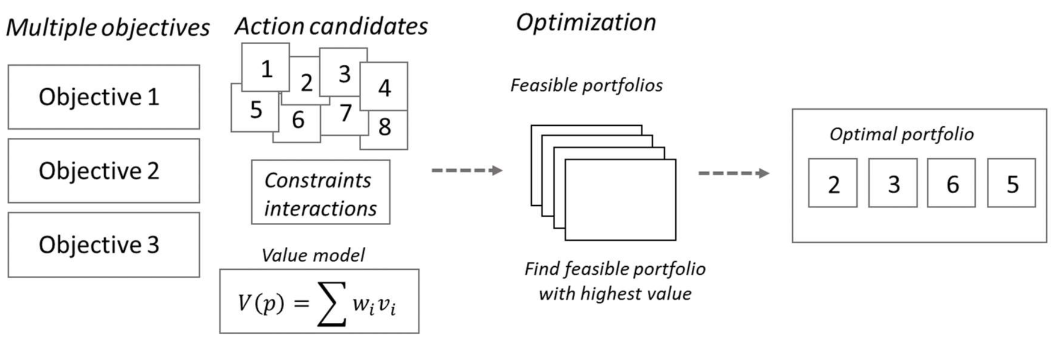

Figure 3. Portfolio decision analysis approach (Lahtinen, Hamalainen, & Liesio, 2017)

PDA approaches are suitable for dealing with a broader class of real-world problems because resource allocation and infrastructure decisions are often portfolio decisions (Ollila, 2013). Also environmental decision processes have recently been framed in PDA models (Huang, Keisler, & Linkov, 2011). However, examples of the use of portfolio analyses in a humanitarian context were not found in the literature review for this research. Nonetheless, looking at the case study, the allocation of refugees can be considered as resource allocation problem (e.g., Davis & Lambert, 2002), which is well framed in a portfolio decision analysis as demonstrated in numerous applications (Salo, Keisler, & Morton, 2011). Specifically, refugees need to be allocated to a discrete set of alternatives, i.e. current refugee hosting sites or new locations.

Applying portfolio decision analysis

When implementing a PDA model, some steps of the rational decision-making process need to be adapted, as outlined by Lahtinen et al. (2017). Comparing the steps of the PDA framework (Table 3) with the standard MCDA, an additional step can be identified in “Interaction and overall consequences”, where synergies and constraints among the alternatives are studied (Lahtinen et al., 2017). These interactions can be analysed according to the effect of the selection of certain alternatives and the way they use the available resources. The analysis also allows for the identification of possible constraints on the alternatives that are in the same portfolio. Two interactions can be identified: mutual exclusivity constraints and follow-up actions. Alternatives are mutually exclusive if only one of them can be selected into the portfolio. In contrast, follow-up alternatives can be only selected together with their prerequisite alternative. Morton, Keisler, & Salo (2016) introduced an additional interaction named technical interaction. In this case, an alternative or action cannot be included without first considering another action. This describes alternatives that form sequencing processes.

The fifth and the sixth steps of the rational decision making process framework differ as well. The value model needs to capture the preferences of decision-makers for the combination of alternatives (portfolio). Consequently, the value model is combined with the portfolio model to provide decision recommendations based on the portfolios' analysis. A common analysis is the identification of the optimum portfolio which maximizes the overall portfolio values.

Table 3. Portfolio decision analysis framework for environmental decision making (Lahtinen, Hamalainen, & Liesio, 2017)

Steps	Tasks
1. Problem framing	Determine context and scope Specify initial resources constraints and performance targets Identify stakeholders Design the participation and analysis process
2. Objectives and actions	Generate the initial set of objectives and actions Use objectives to generate additional actions Use actions to identify missing objectives Screen and specify the objectives, constraints and actions Specify attributes and measurement scales
3. Interactions and overall consequences	Identify interactions between actions Specify constraints related to the interactions Specify models for calculating the overall consequences Collect data and estimate the consequences of actions
4. Value model	Determine the forms of the value functions on the attributes Elicit weights for the attributes
5. Computation and analysis of results	Find optimal or non-dominated portfolios of actions Perform what-if analyses Communicate and visualize results Compare results between stakeholder groups

2.3 Water security

Multiple definitions of water security exist in the literature, each reflecting the goal of their different applications (Cook & Bakker, 2012; Dickson, Schuster-Wallace, & Newton, 2016). The UN-Water institution proposes the following definition of water security: "The capacity of a population to safeguard sustainable access to adequate quantities of and acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability". Interrelated themes among different water security frameworks (ADB, 2013; Dickson et al., 2016; UN-Water, 2013; WaterAid, 2012) can be recognised and sorted into four main topics: (1) water availability; (2) human resilience to water-related hazards; (3) human needs (e.g. water access, food security and, human development-related concerns); and (4) sustainability (e.g. acceptable quality of water for both humans and the environment).

2.4 Stakeholder Analysis

For the purpose of this research, the term stakeholder is used to indicate any group or individual who can affect or is affected by a certain decision (Freeman, 1984; Laplume, Sonpar, & Litz, 2008; Ollila, 2013; R. A. Phillips, 1997). Accordingly, stakeholders can be distinguished among decision-makers and interest groups. Decision-makers are the persons and/or organizations with the power and responsibility to make the decision. Interest groups are all others with an interest in the outcome (Ollila, 2013).

A systematic process for stakeholder identification and categorization is given by the Stakeholder Analysis (SA). This analysis aims to identify the key actors in the policy process, assessing and categorizing their levels of interest and power (Brugha & Varvasovszky, 2000). Reed et al. (2009) structure the SA in three phases: (1) identifying individuals, groups and organisations who are affected by or can affect those parts of the phenomenon; (2) differentiating between and categorising stakeholders; (3) prioritising stakeholders for involvement in the decision-making process.

A well-known stakeholder classification is proposed by Grimble & Wellard (1997) with the Interest/Power Grid. The term *interest* refers to those whose needs are the priorities, while *power* referred to as the influence that certain stakeholders have over the success of a project. These characteristics allow us to distinguish four type of stakeholders: key players (to engage closely), context setters (to consult), crowd (to inform) and subjects (to involve).

Mitchell, Wood, & Agle (1997) add two other stakeholder characteristics to the above stakeholders' categorization: legitimacy and urgency. The term *legitimacy* indicates a "generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions" (Suchman, 1995). The attribute *urgency* was included in order to capture the dynamics of the stakeholder-manager interactions. Urgency is based on (1) time sensitivity and (2) criticality. The former is meant as the degree to which the delay in providing a response to the claims is unacceptable to the stakeholder, while the latter is the importance of the claim to the stakeholder. Therefore, the degree to which stakeholders claim for immediate attention is defined. These stakeholder characteristics, together with the definition of *power*, are used to capture the dynamic nature of stakeholders relations.

Given the emergency context in this research, characteristics as *urgency* and *legitimacy* are significant to the distinction between Demanding Stakeholders and Dependent Stakeholders. Demanding stakeholders are involved in the decision problem only because of the urgency, however they have neither power nor legitimacy. In contrast, dependent stakeholders lack in power but have urgent legitimate claims. Dependent stakeholders depend on others to obtain the required power needed to carry out their will (Mitchell et al., 1997). The addition of the urgency and legitimacy to the common stakeholder characteristics (power and interest) helps to define the roles and position of the refugee and host community more accurately.

2.5 Needs Assessment

Needs Assessment (NA) is a performance analysis for identifying and addressing gaps or needs between the current conditions and the desired conditions or "wants" (Kaufman, Oakley-Browne, H., Watkins, & Leigh, 2003;
Figure 4). The needs can be a desire to improve current performance or to correct a deficiency. They can be prioritized on the basis of the cost of ignoring the gaps and the benefits of closing them (Pershing, 2006).

Figure 4. Needs Assessment Definition

In the need assessment, the evaluation of the current situation requires a substantial amount of data collection especially if no prior needs assessments were carried out (Pershing, 2006). The review of annual reports, documentation from previous projects and program evaluations can be a first support for the assessment process. If this information is not available from existing sources, methods for collecting new or supplemental data should be applied. Pershing (2006) suggested some methodologies as direct observation, individual interviews, group interviews or focus groups, document searches, questionnaires or surveys, examination of public data, and review of existing research.

3. Structured decision making in the SNARA application for water security conditions

The research presented in this chapter focused on developing a generalizable procedural tool for Sustainable Newly-Arrived Allocation (SNARA) decision problem. This tool is intended to support WASH officers by providing them a comprehensive overview of relevant water security criteria for increasing water security conditions of newly-arrived refugees and host community. The clarification of the decisional context and the generation of relevant criteria provide the basis for a rational structuring of the refugee allocation problem, enhancing the identification of rigorous, defensible, inclusive and transparent solutions based on available data. The research contributes to literature by using and discussing the step of the SDM-approach for the decision context of refugee allocation.

3.1 Materials and Methods

This chapter describes the applied methodology for structuring the generic decision problem of refugee allocation in new or existing hosting sites (SNARA). For the research scope, the first three steps of the rational decision process were adopted. These are: (I) define the decision context, (II) generate objectives and (III) identify attributes. The methods selected for each step are presented in the following homonymous sections.

3.1.1 Decision context

The first step of the Structured Decision-Making process consists of framing, structuring and learning the decision problem. This was accomplished together with the decision-makers during the fieldwork in Geneva. The main goals were: (1) the clarification of the generic SNARA decision problem and (2) the identification of the key decision makers. In this research, the first objective was achieved through the need assessment while the second by using a stakeholder analysis.

1. **Defining the decision problem to be addressed – Needs assessment**

Needs assessments (NA) are triggered by a need to better understand a particular situation, identifying gaps between a current state and agreed standards, as further presented in Section 2.5. In this study, the NA analysis was applied to get a better understanding of the decision context, structure the decision problem and investigate the methods, tools, and criteria that are currently used to support the decision-making.

The review of UNHCR's policies and guidelines was the first phase of the assessment process. This helped to gain a general idea of the decision problem. In a second phase, information gathered from direct observation during field work, individual semi-structured interviews and questionnaires were integrated to the analysis. These activities were conducted during 2-week stay at UNHCR headquarter in Geneva. Based on this information, the general decision context was framed.

2. **Identification of decision-makers – Stakeholder analysis**

In this research, a Stakeholder Analysis (Section 2.4) was carried out to identify who are either likely to play a major role in the identification of suitable refugee hosting sites, or are affected by such decision. The SA framework proposed by Reed et al. (2009) was used as guideline for structuring the process because of its schematic approach. This framework provides different models and tools for each SA phase, useful for identifying stakeholder typologies in different natural resource management contexts. According to the refugee context in analysis, we selected suitable methods for each SA phase (Figure 5). The identification and categorization of stakeholders was finally shown through a *Power/Interest Grid*.

Stakeholders may have different interests, and engagement should be adjusted to contexts. When considering which stakeholders engage in the SNARA SDM-process, it was important to distinguish them in four different groups: decision makers, affected people, advisors and executors. *Decision makers* are institution groups or individuals who make the decision; *affected people* are institution, groups or individuals who are affected by the decision; *advisors* are institutions, groups or individuals who are likely to influence the decision; and, finally, *executors* are institutions, groups or individuals who implement the decision. To distinguish stakeholders' categories, the interest/power grid was subdivided in four sections representing the four identified groups.

In our application, given the emergency and humanitarian context, the stakeholder characteristics: *urgency* and *legitimacy* were used to capture the dynamic nature of stakeholders relations and in particular, to distinguish between demanding and dependent stakeholders (e.g. Mitchell et al., 1997).

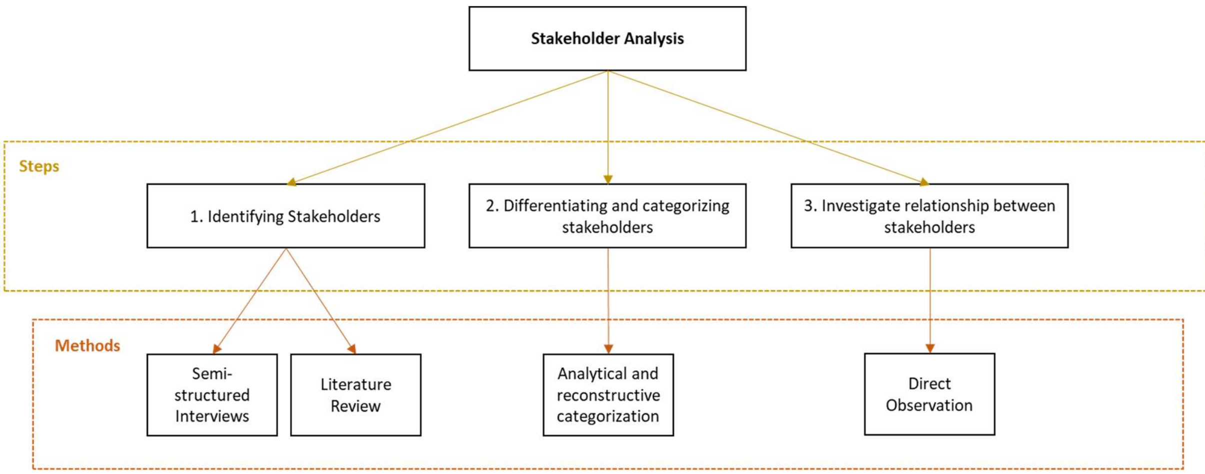

Figure 5. Stakeholder Analysis Methodology adapted from (Reed et al., 2009)

3.1.2 Generation of objectives

Following the value-focus thinking of (Ralph L. Keeney, 1996), objectives were clarified first and then alternatives were generated. This helped in identifying desirable decision opportunities and thinking broadly on possible alternatives. For the development of the first hierarchy objectives, a bottom-up approach was carried out through analyses of literature and relevant documents, and consultations with experts and stakeholders. This approach was selected because the investigated objectives are not explicitly expressed in current policies. However, indicators and good practice are often cited in guidelines to support the stakeholders in the decision process. Hence, a clarification on the objectives was relevant for comprehensively analyse the problem in the water security prospective.

Based on the bottom-up procedure described in Eisenfuhr et al., 2010 and the approach suggested in Gregory et al., 2012 (Chap.4), four steps were selected and carried out: (1) identification of criteria from the literature; (2) distinction among ends and means objectives; (3) hierarchy structure; (4) test. According to the first two steps, relevant UN guidelines and researches on the refugee allocation problem were analysed to create a preliminary objectives hierarchy. Subsequently, the hierarchy structure was reviewed through semi-structured interviews and survey (step 4). The applied process aimed to generate a generic hierarchy applicable to various refugees' allocation problems. This multi-iterative approach has resulted in a final generation of a system of objectives which are comprehensive, non-redundant, measurable, independent, concise and specific. Each step is described in detail in the following sub-sections.

(1) Identification of criteria from the literature

According to the bottom-up procedure, criteria, indicators and preference statements of the main stakeholders were collected from the literature. Papers on site locations for temporary shelter in disaster management and spatial analysis for identifying suitable refugee hosting sites were reviewed. Only the papers relevant for the decision problem in analysis were used for a first identification of the objectives related to the water security conditions (Table 4). Indicators and criteria mentioned in the UNHCR guidelines and Sphere Project were also analysed. Finally, water security frameworks were analysed in order to verify if important aspects were missing from the identified list of objectives. To this end, the water security indicators were extracted and related to the identified fundamental objectives. When no correlation was found, the objectives behind the indicators were identified and added to the list only if relevant for the decision problem.

Table 4. Literature sources used for the initial identification of the objectives.

Category	Sources	Data Extracted
Site locations for temporary shelter in disaster management	(Nappi & Souza, 2014)	Objectives
	(Trivedi & Singh, 2017)	
	(Celik, 2017)	
MCDAs for refugee site selection	(Beaudou, Cambrézy, & Zaiss, 2003)	Objectives and criteria
	(Çetinkaya, Özceylan, Erbaş, & Kabak, 2016)	
	(Mong, Nelson, & Oni, 2014)	
	(Spink, 2015)	
UNHCR and Sphere project	(UNHCR, 2007) (Site selection, planning and shelter)	Criteria and indicators
	(UNHCR, 2007) (Water)	
	(The Sphere Project, 2011)	
Water security framework	(Dickson, Schuster-Wallace, & Newton, 2016)	Indicators
	(ADB, 2013)	
	(WaterAid, 2012)	

(2) Distinction among ends and means objectives

The criteria, previously identified from the literature review, were organised and structured in a means-ends network (*Generate Objectives*, Section 0), enabling a comprehensive and structured visualization of the objectives. According to Bond, Carlson, & Keeney (2008), we distinguished among means and ends objectives using the question "Why is that objective important?". The approach helped in identifying fundamental objectives while avoiding redundancy.

(3) Objectives Hierarchy

Objectives were organised into a hierarchical structure to facilitate the validation of the completeness and to avoid redundancies in the system of objectives (Gregory et al., 2012). Breaking them down into lower-level objectives also allowed the description of the original objectives more concretely, enhancing their measurability. According to Gregory et al. (2012), the distinction between higher-level objectives and lower-level objectives was made clear by the question: "What exactly makes it important to me?".

(4) Test: Semi-structured interviews to key stakeholders

Participant observations of the analysed decision context and semi-structured interviews were used to review the system of objectives. The process aimed to revise the preliminary objectives' hierarchy by verifying whether the identified objectives comprehensively cover the decision.

A framework of subjects to explore was prepared in advance, with a clear interview schedule tailored to the interview context/situation (refers to Section 2.2 in Appendix). One of the aims of the interview guides was to ensure that some questions were asked exactly in the same way to each respondent. Variations in the ways a question is asked is indeed a potential source of error in the research (Bryman, 2012). For a similar reason, all interviewees were recorded if they authorized so. This reduced error caused by a distorting transcription of the respondents' answers.

Whenever possible, single interviews were preferred to group interviews. In framing the series of questions, open-ended questions were preferred to closed-ended questions. The latter were used only a few times to better define the subsequent set of questions. Projective question (such as: "what if something will happen?") were used to allow participants to 'project' their own thoughts onto a context different from the current one.

The following steps were adopted in each interview:

1- Personal introduction for establishing an initial relationship with the respondent;
2- Brief clarification on the confidentiality policy adopted for the information collected along the interview;
3- Request of the consent for recording the interview by clarifying that the material recorded will be used only for research scope;
4- Introduction to the research for providing a credible rational to the respondent which makes valuable the time spent during the interview. Besides, this provides to the interviewee an understanding of the topic while building up confidence and trust;
5- Follow up of the interviewee in case no answers were given to certain questions.

Each interview was transcribed and summarized. From these summaries, the goals, needs, alternatives, preferences, concerns/issues were extracted and used for the development of the framework.

(5) Test: Questionnaire survey

With the same purpose of verifying the preliminary objectives' hierarchy and identifying overlooked criteria, a questionnaire survey was prepared for UNHCR officers (Survey Form in Appendix C). This was distributed to 20 officers from UNHCR-HQ in Geneva and it was sent by e-mail to 41 UNHCR WASH officers in the field and 27 WASH partners from the global cluster. In the e-mail, the purpose of the research was explicitly mentioned with the aim of providing a valid motivation in filling out the survey. However, no reminder was sent and no deadline was provided. With the exception of few individuals, the selected participants in UNHCR-HQ comprised a group of professionals presenting a long field experience and having broad knowledge on the decision context.

The survey was structured in three main parts: (i) respondent information; (ii) generation of goals; (iii) other opinions (Figure 6). In order to support the respondents in the generation of decision objectives (part ii), the survey was developed according to a logical and systematic approach suggested by Bond, Carlson, & Keeney (2010), (Table 5).

The adopted elicitation approach comprises five steps. In the **first step**, participants were asked to individually list the objectives that are personally significant to the problem (self-generation of objectives). In support of this procedure, a brief introduction describing the decision context was provided previously. In this stage, decision-makers or individuals have to specify the objectives thinking broadly about consequences of interest. To help the participants to adopt a broader construal and approach the task from multiple perspective, when possible, the questionnaire was filled out by them after the semi-structured interviews.

In the **second step**, participants were asked to rethink about the self-generated list of objectives by providing categories under which list any additional objectives. The main goal of this step was to evoke a variety of uncued (not-perceived) objectives, overlooked in the previous step due to an incomplete representation of the decision problem. To motivate and encourage the participants, it was important to inform them about the successful application of reviewing and supplementing the original list for the generation of additional relevant objectives. The adoption of this procedure showed, indeed, a notable improvement in the elicitation of the objectives by previous researches (e.g. Bond, Carlson, & Keeney, 2010).

In the **third step**, participants needed to tick the relevant objectives from a **master list** (list of objectives identified by us through the literature review). This included 13 fundamental objectives elaborated from the literature. This master list aimed to help the participants in identifying additional objectives while guiding them in their formulation. By presenting potential fundamental objectives, participants become more aware about the difference between fundamental and mean objectives.

In the **fourth step**, participants were asked to map the objectives from the self-generated list and the cue-list to the master list. Matching self-generated objectives to those deemed relevant from the master list helped in providing a gateway to interpret the participant goals. Finally, in the **fifth step**, the relevant objectives from the master list were ranked according to their importance. A summary of the steps in the selected approach is provided in Table 5.

Table 5. Survey steps to support stakeholders in generating objectives

Steps	***Processes***	***Detailed Actions***
1	Self-generated list	• Participants read a brief introduction describing the decision context; • Generate and list all objectives that were personally relevant.
2	Extension of the initial list	• Second chance to think about the generated objectives; • Category Cues; • Motivation.
3	Master List	• A master list containing a variety of potential objectives is shown to the participants; • Participants check all objective that they think relevant for the decision problem in analysis.
4	Map checked objectives	• Participants map objectives from their first list to the master list.
5	Rate objectives	• Participants rank the objectives in the new master list.

In the last part of the survey (part iii; Figure 6), we investigated which individuals or groups influence the decision problem. This aims to verify the results obtained previously from the stakeholder analysis.

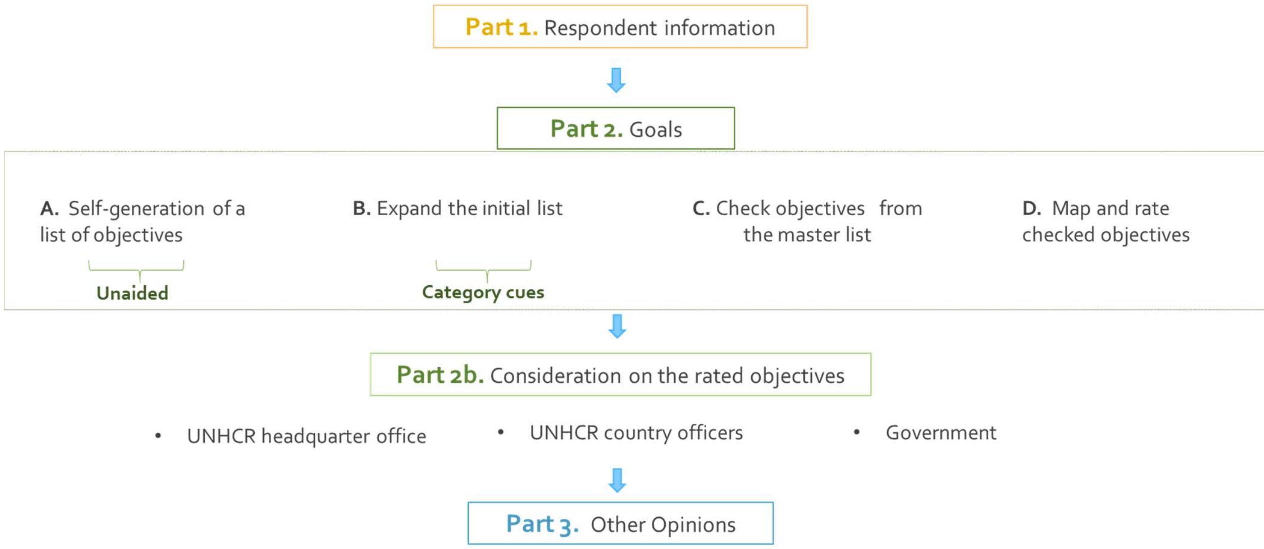

Figure 6. Survey questionnaire's structure

3.1.3 Defining attributes

Attributes are needed to quantify the performance of the alternatives in achieving each objective (Eisenfuhr, Weber, & Langer, 2010; Gregory et al., 2012; Ralph L. Keeney & Gregory, 2005). A general idea of potential attributes for the generic SNARA objectives' hierarchy was acquired through a review of indicators used in: (I) the current UNHCR guidelines (Division of Operational Services UNHCR Geneva, 2006; The Sphere Project, 2011; UNHCR, 2007), (II) in proposed water security assessments/frameworks (ADB, 2013; Dickson, Schuster-Wallace, & Newton, 2016), (III) developed MCDA for the decision problem in analysis (Çetinkaya, Özceylan, Erbaş, & Kabak, 2016; Mong, Nelson, & Oni, 2014) and (IV) global water assessment studies by international organizations (Gassert, Landis, Luck, Reig, & Shiao, 2013). Attributes were constructed to be applicable to different cases while global databases and open data sources were explored to support both their identification and assessment.

3.2 Results

Below we present the results of the initial SDM structuring steps as carried out in the general SNARA application for water security conditions. Results obtained from each problem-structuring phase, up to the objectives' hierarchy generation and attributes identification, are described under the respective homonymous sub-paragraphs. In addition, global data sources and models are explored here to enable the use of the SNARA objectives hierarchy in specific applications, guiding the selection of suitable attributes.

Objectives and attributes are further outlined in Appendix F, where we tried to answer the following two questions: "Why this objective?"; "What does it aim to encompass?".

3.2.1 Decision context

Several assessment templates and guidelines attempt to support different actors in the refugee site selection process. An example is the *Master Plan Assessment Template* recently developed by the shelter and settlement unit at the UNHCR-HQ with the scope to encourage shelter and settlements actors in including environmental considerations in the decision-making process of refugee allocation. These environmental considerations require the analysis of available natural resources, potential conflicts on shared resources and the risk of natural disasters. In addition, the template stresses the concept of sustainable site carrying capacity in the selected refugee hosting site. For sustainable site carrying capacity is meant the number of people, animals or crops which a given territory can support. This reduces the pressure on the natural resources over the settlement life span and enhances livelihood opportunities.

In this settlement analysis tool, the section dedicated to WASH officers comprises a set of decision objectives, which need to be made explicit and structured to support an effective decision process. With this aim, we explore the decision context further by answering the following questions: “What is the problem or the set of problems that should be addressed?”, “Who is involved?”,” What concerns are included?”,” What options are possible?”, “What are goals of decision makers?”.

1. **“What is the problem or the set of problems that should be addressed?”**

A wrong selection of the refugee hosting site can trigger different issues, especially related to water security conditions. Poor water quantity and quality, flooding and landslides events are only some of the water/environmental issues that many refugee settlements currently face. Re-accommodation of the refugees cannot be seen as a viable solution due to high economic and human effort involved on that. The same applies for water trucking interventions, which should only be used in short-time periods of necessity.

At the outset of an emergency, the technical valuation carried out by WASH, site planners and shelter officers assess the suitability of the hosting site. They provide suggestion to the hosting government on number of people that could be accommodated and infrastructures/services needed to cope with the increasing number of population. The assessment is only based on local available information and from field visits, since deeper studies cannot be carried out at the outset of an emergency due to time and resource limitations. However, this information is not enough to comprehensively evaluate the suitability of the site. Therefore, uncertainties need to be accounted for when little is known. Limited resources and time allow to carry out only a specific assessment on one water source (e.g. available water quantity or water quality conditions in one water source). A better understanding of the decision objectives and priorities can support the process, effectively considering multiple criteria and identifying area of analysis in which more capital resources need to be invested to improve the reliability of the assessment.

In an emergency situation, the driving process is to save lives, while other considerations (such as environmental protection) come second. The current decision objectives are therefore defined by the time available to effectively cope with the emergency without worsening it. However, through the implementation of the preparedness actions (PPRE), the decision process can start before an emergency happens. This allows for considering a set of objectives related to long term planning previously neglected due to time constraints and limited discussion with the government. Examples of such objectives are water use of the host community, national and local development plans and the needed water for supporting refugee livelihood.

2. **“Who is involved?”**

According to UNHCR (2007), host governments are ultimately responsible for allocating land for camps and settlements. UNHCR Country and Sub-Country offices have the task of supporting the government if it does not have enough resources to effectively respond to the refugee influx. In this context, a state of emergency is declared. According to the declared level of emergency and the capacity of the local sub-office, different units at the HQ are activated. The Division of Emergency, Security and Supply (DESS) is the first to be activated in the HQ. Usually, an officer from this division is sent to the field in order to initiate the collaboration with the government and the coordination with the different partners. Consequently, the WASH Unit and Shelter & Settlement Section at the HQ are involved only if requested by the country office. WASH, site planners and shelter officers support the decision process by a joint-assessment mission on the sites identified by the government. If the local staff is sufficient for such operation, the HQ units will be not directly involved in the process.

The involvement of other operational UNHCR unit such as environment, livelihood and protection units happens only when the site is already selected. This is mainly due to an insufficient staff number for the environment and livelihood units both at the HQ and sub-country offices. Once involved, the environment unit looks at the refugee impact and potential mitigation measures within the site. The public health unit is responsible for the identification of potential diseases outbreaks and the actuation of preventive and mitigation measures. The education unit defines the requirements for the educational institutions within the site. The livelihood unit looks at the agriculture development for subsistence farming, livestock and commercial activities for the refugees.

Local authorities as well as host and refugee communities should also be involved at the early stage of the decision process (Corsellis, 2001; UNHCR, 2007). However, this rarely happens with the exception of the selection of private sites. In this case, hosting communities become key decision-makers.

The identified stakeholders were classified according to the Interest/Power Grid (Figure 7). The introduction of legitimacy and urgency as stakeholder features better clarifies the relationships among host community, refugees, national and international humanitarian organization. Demanding stakeholders are the refugee population that do not have any legitimacy in the host country and, therefore, no power for decisions. Dependent stakeholders are local population, presenting legitimacy and urgency but not power. NGOs and international organizations have the legitimacy but not the influence. Finally, the host government has the highest influence in the decision process but, usually, a low interest in identifying suitable refugee hosting site.

Even if the key decision maker of the selection process is the government, the developed decision structure seeks to support UNHCR WASH officers. This is because government decisions are often based on political interests rather than technical analyses, which can be hardly structured in a general decision context as highly dependent on the specific case.

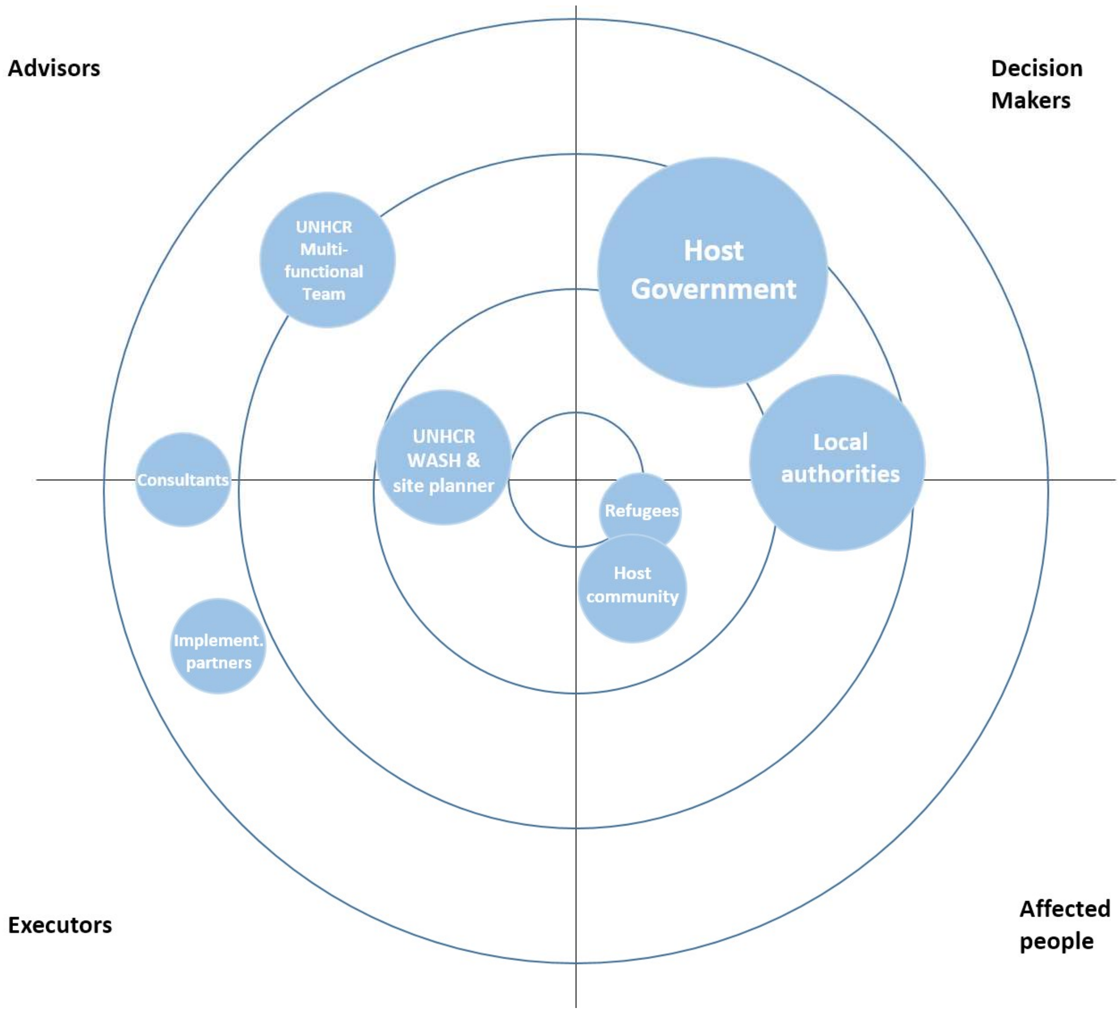

Figure 7. Interest/Power Grid for the general SNARA decision problem. The level of power is presented by the dots' size, while the level of interest by the proximity to the axis origin. The grid is partitioned in four sections, representing the following stakeholder groups: decision-makers, affected people, executors and, advisors.

" What options are possible?"

Usually, only one site is proposed by the government and there is no possibility for discussions. Therefore, even if previous analysis on the site forecasts possible hazards, rarely there is a possibility to reconsider the decision of the government until a disaster happens. Furthermore, the number of people to be accommodated in the site can be directly decided by the government, without the engagement of other important stakeholders (e.g. UNHCR, NGOs, and other experts). In case the site is unsuitable, UNHCR can appeal to the refugee convention of the 1951, if the host State has signed it as well. In the convention, legal obligations of hosting States to protect refugees are defined. However, discussions with the government cannot take too long in order to avoid an escalation of the emergency situation.

" What concerns are included?"

- *Time pressure in emergency situation*

If long-term accommodation is not selected quickly, the situation can worsen in the transit centre as the population build up due to continuous flows. Therefore, the discussion with the government on which site is available/suitable should be done before an emergency occurs.

- *The site assessment should comply with the Master Plan Approach*

The framework proposed in this research needs to fit into the principles of the Master Plan Approach. As introduced at the beginning of this chapter, the approach guides main actors in the suitability assessment of potential refugee hosting sites. The key principles of the approach are summarised, as follows:

1. Integrate national development plans and priorities in the refugee settlement design, creating a linkage between humanitarian settlement and local development;
2. Guarantee equitable and improved access to social services and economic opportunities for supporting the integration of the displaced population within the hosting communities;
3. Reduce conflict related to the use of natural resource and environmental degradation promoting a peaceful coexistence of communities.

- *Primary focus on WASH mandate*

In the context of the master plan, the proposed framework needs to focus on the WASH mandate (Table 6). For this reason, water-related hazards will not be explored in detail in this research as they are under the environment & energy and shelter & settlement units' mandates. The framework needs hence to provide information on the site carrying capacity according to water security and primarily on the water availability.

Table 6. An excerpt of the Master Plan assessment template which refers to the WASH mandate

9. TOPOGRAPHY AND DRAINAGE

9.1 What is the slope percentage?	Flat 0%-2%	Steep 6%-10%	Severe >10%	Ideal 2% - 4%	Moderate 4% - 6%
9.2 What is the soil condition?	Sand ( )	Rock ( )	Clay ( )	Silt ( )	Gravel ( )
9.3 Is the soil type "black cotton soil"?	Yes ( )	No ( )		Any other type:	
9.4 Are soils permeable?	Yes ( )	No ( )		Explain:	
9.5 Are soils collapsible?	Yes ( )	No ( )		Explain:	

11. WATER SOURCE AND ENVIRONMENTAL SANITATION

11.1 Is access to sustainable and sufficient water source(s) compromised? Pleas expand in the remarks section	Yes ( ) Explain:	No ( ) Explain:
11.2 Is there an existing water provision system? (Boreholes, Open stream, Protected stream, River, other)	Surface water: River ( ) Lake ( ) National pipeline ( )	Groundwater: Borehole ( ) Spring ( )
11.3 Is water available year round?	Yes ( ) No ( )	Indicate the source of information:
11.4 What is the distance to nearest water source? (if boreholes indicated the depth)		Indicate the source of information:
11.5 What is the water depth?	Less than 3 m below the ground level ( ) Indicate depth:	More than 3 m below the ground level ( )

"What are goals of decision makers?"

- *Increase the application of the preparedness actions*

An initial discussion with the government and an assessment of the site should be pursued before the emergency. For this reason, UNHCR is encouraging the implementation of the Preparedness Package for

Refugee Emergency's (PPRE's) methods and components. These aim to speed up the process of response, agree on the different partners' engagement and getting already an understanding on the capacity of the country to act in case of emergency. In case a risk of refugee influx is assessed, the site selection process needs to be preventively carried out. Currently, the preparedness actions are not well implemented and rarely an agreement with the partners on the actions to take in case of emergency is in place. This is mainly due to: (1) recent accomplishment of the policy for preparedness actions which it is still not yet applied in many areas; (2) partner agencies and government counterparts do not have any obligation in following the protocol. Therefore, the site selection process usually takes places at the outset of an emergency, when a large number of people cross the border. Taking these decisions before the emergency is essential to be able to quickly develop and implement a sustainable response strategy. Delay in the decision process aggravates the situation. The application of the preparedness action will improve also the coordination between partners in the planning and implementation of interventions at the outset of an emergency. (*"In general, there is not enough time to do a proper aquifer study before other partners have put in place their own boreholes"* Dekrout, A. (2018, August 8), Personal interview)

- *Encourage a participatory process*

Sites should be selected in consultation with a range of sectors including environment, livelihood and protection units, as well as with local expertise and technical specialists such as hydrologists, surveyors, planners, engineers, and environmental engineers (Rooij, Wascher, & Paulissen, 2016; UNHCR, 2007). This will reduce the risk of failure in developing a site to the required standards, avoiding further displacement and causing economic losses, distress to persons of concerns and putting some groups at further risks (Master Plan, UNHCR 2018). Additionally, it is important to build up a relation with local governments to aligning the settlement process with the national and local development plans. This favours the developments of sustainable communities able to integrate into the hosting environment.

- *Increase independence of the refugee camps*

Efforts to link humanitarian responses with long-term development plans are needed to increase the independency of the refugees and decrease the needed of external support. According to the Master Plan, the average life of a refugee camp is 17 years. This leads to the transition of the camp into a town or even a large city. It is, therefore, important to assess the opportunities that the site can offer to the refugees for the development of a livelihood from the beginning of the plan.

3.2.2 Generation of objectives

Results obtained for each of the four adopted steps of the iterative bottom-up approach are shortly presented in the sub-sections below. The tables summarizing the results obtained in each step are shown in Appendix E: "Additional information for: Step (2) Generate Objectives". The final objectives' hierarchy of support for the refugee allocations' problems in different host countries is then presented in Section (5).

(1) Identification of criteria from the literature and means-ends network

According to a first scan of the available UN guidelines and scientific literature (Table 4, in paragraph 3.1.2), we identified 11 fundamental objectives at the highest hierarchical level (Table 30 in Appendix E links each identified objective with the related literature). Among them, only four are specifically related to the allocation phase while the others (such as equitable access to essential services, privacy and dignity, and cultural adequacy) are mainly related to the planning phase.

Referring to the allocation phase, all the studies and guidelines explored mention the importance of selecting hosting sites with minimal risk of water-related disasters and with a high reliability of water quantity. According to the literature, water quantity needs to be sufficient for satisfying primary needs and only few studies (e.g. Corsellis, 2001) mention the importance of satisfying the water needs of income-generating activities (e.g. agriculture, livestock). While the importance of water availability is well recognized in literature, we cannot state the same for the water quality, cited as a relevant factor only by Corsellis (2001) and UNHCR (2007).

Furthermore, previous studies on the refugee site selection (Çetinkaya, Özceylan, Erbaş, & Kabak, 2016; Mong, Nelson, & Oni, 2014; Spink, 2015) and UNHCR guidelines stress the relevance of locating refugees close to water sources. However, the reason behind this "good practice" is not explicitly clarified. From an analysis of UNHCR refugee operational update reports in different host countries (UNHCR, 2015; UNHCR (Technical Suport Section), 2005), it emerged that large distances of settlements to the water points are one of the main causes of sexual violence against women and children. This could be avoided by bringing the water access points closer to the settlement, resulting in high installation cost of the water infrastructure if the water source is located far from the camp. Minimize the distance of the site to the water source is relevant both for reducing violence on women and children and for reducing investment costs.

In all guidelines and studies analysed, low cost for the installation and operation & maintenance of the water system is not explicitly indicated as a relevant criterion in the site selection. However, proper soil condition and topography are frequently cited factors in UNHCR guidelines and the Sphere Project, when referring to suitable refugee hosting sites.

Finally, the interaction between refugees and host community is analysed only in terms of competition on the shared water resources and environment damages (Çetinkaya et al., 2016; UNHCR, 2007). Benefits for the host community from the refugee allocation are not identified as objectives. Instead, improved water services and growth of the local economy are reported only as possible consequences of refugee allocation (Corsellis, 2001; UNHCR, 2007). Alternatively, the positive impact of humanitarian aid on the host community development can be included as stand-alone objective.

Through the means-ends network (Figure 26 in Appendix E), we were able to identify fundamental objectives from "best practices" and factors. For example, UNHCR suggests that groundwater table in the refugee site should be at least 3m. We linked this standard to the second-level objective: "minimize contamination of the water sources", whose fundamental objective is "high safety for the refugees".

(2) Preliminary objectives hierarchy

By deleting redundant objectives and rephrasing others from the means-ends network, a preliminary objectives hierarchy was developed as shown in Table 7. These preliminary objectives were then used to develop the **master list** that we used in section 3 of the survey (see sub-paragraph (4) for results on the master list).

Table 7. Preliminary objectives' hierarchy (master list used in the survey)

Fundamental Objectives	*Second-level objectives*
High Safety for the community	Minimize the exposure of people to water related hazards (floods, droughts,..)
	Minimize exposure to violence (e.g. woman and children)
	Minimize exposure to water-related diseases (e.g. water-borne diseases)
High adequacy of the water sources	High reliability of raw water quantity for immediate needs
	High reliability of the raw water quality
	Guarantee water for future needs (e.g. flexible host capacity, support income-generating activities)

Promote advantages for the host community	Improve current water services and/ infrastructure for the host communities and for the settled refugees. If missing, provide new ones.
	Improve economy of the host community (e.g. local scale)
	Avoid water competition between host and refugee communities
	Ensure a high protection of the water sources and the natural protected areas
Low Costs	Minimize operational and maintenance costs
	Minimize investment costs
	Minimize the needs for difficult corrective measures(at the planning/designing phase and after)

(3) Review objectives: Semi-structured interviews

The decision context and objectives were investigated through eight semi-structured interviews with key stakeholders from the Division of Programme Support and Management (DPSM) and from the Division of Emergency, Security and Supply (DESS) in the UNHCR HQ of Geneva (UNHCR-HQ organigram in Appendix A and interviewees in Appendix B). Three objectives were mainly stressed by stakeholders during the interviews: (I) 'high reliability of water quantity', (II) 'low cost' and, (III) 'high environmental protection' (Figure 8). Some of these objectives have not been mentioned directly, but related standards have been cited instead. The logic workflow, used to derive from interviewee statements the objective, is shown both in bullet points and a means-ends network in Section (2) of Appendix E. According to these analyses, the objective "high reliability of water quantity" was upgraded to a fundamental objective in the hierarchy. Additionally, the interviews revealed the importance to take into account the potential downstream impacts of the refugees on the host community. Therefore, we added the objective "high protection of the downstream areas" in the hierarchy. Finally, the interviewees showed a high concern for the response time to the refugee needs. A longer time to complete the water system results in higher cost of water trucking. This was considered in our objectives hierarchy by including the objective: "low water trucking cost". From the interviews, we were also able to identify preferences, alternatives and constraints perceived by the stakeholders. These are presented in the text boxes below as the bases for structuring the PDA model.

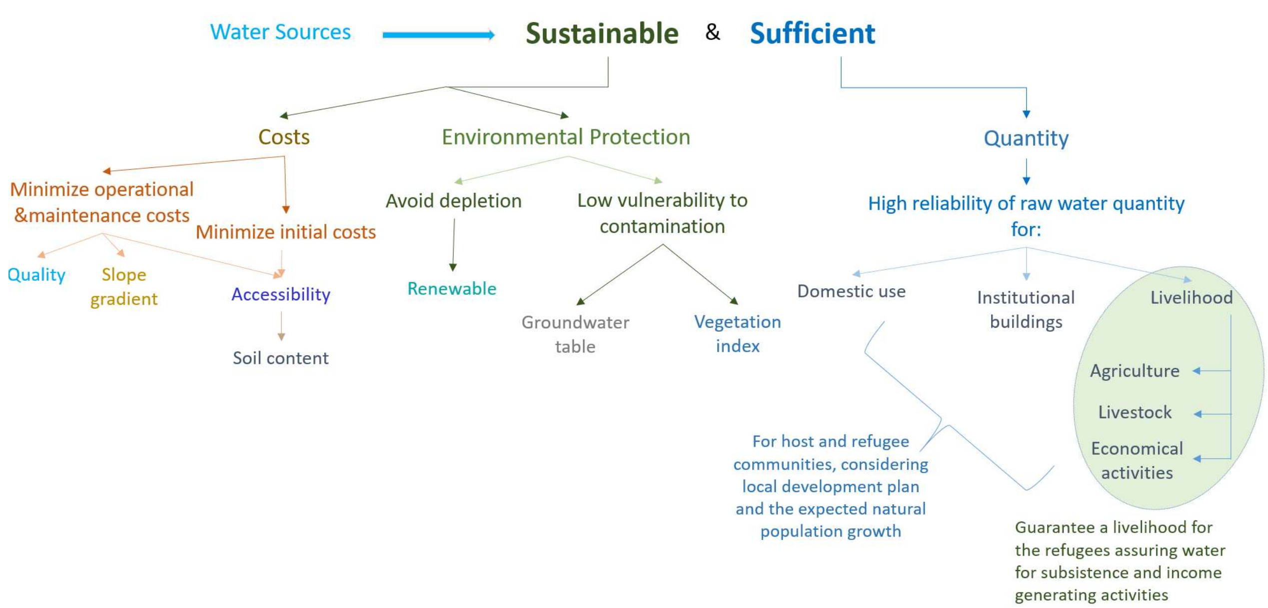

Figure 8. Cognitive map elaborated from the interviews

Text Box 1: Preferences on the objectives

- The objective "high reliability of water quantity" is prioritised on "high reliability of water quality" and "high environmental protection". (*Water quantity is more important than water quality as it is always possible to use an appropriate treatment technology in order to meet the standards. However, if no water is available, the only option is water trucking*; *In an emergency phase, the driving process is to save lives and the environmental consideration comes secondly*);

- The objective" minimize O&M costs" is preferred over "minimize investment costs" (*One of the main objectives is to reduce operational and maintenance costs. Therefore, technologies with higher capital cost but lower operational costs are usually preferred)*. This is because the financial support is higher at the beginning of the emergency, tending to decrease along the lifetime of the camp (*The money are more at the beginning and we should be quick enough to plan smartly with a long term vision; The lowest long-term cost option is preferred).*

Text Box 2: Preference on the alternatives

- **Preference to scatter newly arrived refugees in different existing urban and rural areas** was stated by many interviewees. The development of settlements does not encourage the integration of refugees with the host community, especially if they escalate in high-density communities. This complicates the response strategy as usually infrastructures and services are missing. ("*UNHCR prefers to accommodate refugees in existing urban areas or rural communities than in new settlements. This option is preferred for several reasons: first, the refugees can have an easy access to the services and to the market, the integration of the refugees in the host community is facilitated assuring a better livelihood and food security for the refugees and finally, infrastructures and services are already in place accelerating the refugee response and reducing the required investment cost"*).
- In order to support the refugee livelihood and their integrations in the host community, **area-based approach in the refugee response is preferred over settlement based-approach**. The former aims to engage a participatory process able to provide multi-sectorial support in specific geographic areas (Archer, 2017). This allows getting away from processes focused on individuals or households, approaching intervention at larger scale able to support the government development plans and to have a long-term vision. An excerpt of the means-ends network is shown in (Figure A) to underline this preference, overlooked from the previous literature review.

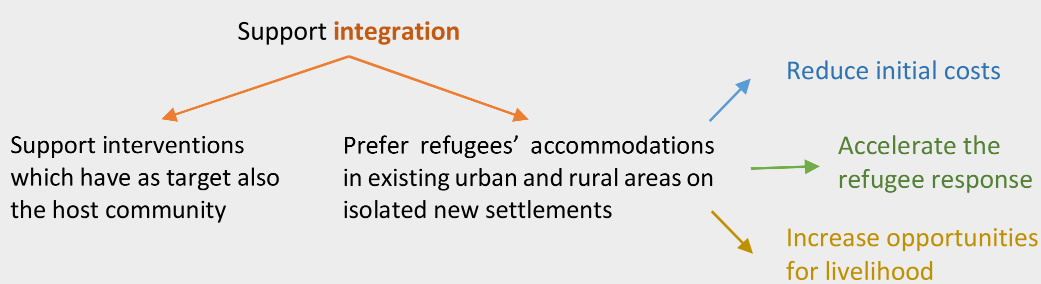

Figure A. An excerpt of the Means-Ends network elaborated from the interviews. The end objectives are coloured.

Text Box 3: Potential constraints

- It is preferable to not accommodate more than 20,000 people in a site. (*Ideally, newly arrived refugees should be scattered in more than one urban area, in order to encourage integration. Additionally, this option can accelerate the refugee response).*

(4) Review objectives: Questionnaire survey

Only 12 out of 20 UNHCR-HQ Geneva officers filled out the survey, in particular from the DPSM and DESS division. While only three UNHCR WASH officers in the field and two WASH partners from the global cluster among the 68 stakeholders contacted by e-mail returned the completed questionnaire. The total number of surveys analysed was, hence, 17.

The respondents were all from UNHCR with the exception of two respondents respectively from UN-Habitat and the Norwegian Refugee Council. Seven of the 17 participants belong to the UNHCR WASH unit, while the others were mainly from DESS division and, Energy and Environment unit (see Appendix E, Figure 27). Below, we present a part of the results, relevant to the revision of the objectives' hierarchy. A detailed analysis of the results is shown in Sub-paragraph (3) of Appendix E.

Part 2a- Goal

In the second part of the survey, we helped the respondents to generate objectives through five steps explained in the methodology (sub-paragraph (5)). In the last step of the section, not all the respondents have clearly followed the instructions concerning the ranking of the objectives with the highest properties according to their personal view. Four respondents out of 17 have ranked objectives not considered previously relevant. However, the objectives used for the ranking should have been coherently taken from the list of the relevant objectives that the respondent has previously generated. In order to correct this inconsistency, objectives included in the top-5 list were also manually added among the relevant objectives. The achieved results are shown in Figure 9 under the label: "Attempt 2".

In the second step of the section, the self-generated objectives by the respondents were already covered under different titles in the master list or were means objectives. In the following step, the respondents did not add any self-generated objectives into the master list. However, they mapped the self-generated objectives to the master list, with the exception of few respondents. In that case, we manually mapped them. The final results are shown in Table 31, Appendix E. In general, we can infer from them that the respondents had quite well understood the objectives in the master list as we meant them.

In the third step where the participants were asked to tick the relevant objectives from the master list, 11 of 13 objectives were perceived as relevant by nearly all respondents (Figure 9). The two objectives more often discarded were: (1) "improve economy of the host community" and, (2) "minimize investment cost". Looking at the background and current tasks of the respondents, we could not identify any distinguishing group from the respondents that considered important the improvement of the host community economy. For this reason, the objective was removed from the final objectives' hierarchy. Conversely, we noticed that mainly energy officers from the HQ and WASH officers currently in the field regarded the low investment cost in the analysed refugee hosting sites as important criteria. For this reason, we decided to keep this objective in the final objectives hierarchy.

In addition, the objective "high reliability of raw water quantity for immediate needs" was perceived by most of the respondents as the one with the highest priority, followed by "minimize exposure to water related diseases" and "minimize exposure to violence" (Figure 10). According with these results, these objectives were kept as phrased in the final objectives hierarchy with the exception of "minimize exposure to violence". This is because through interviewee with SGBV officer, we found out that exposure to violence can mainly be connected to factors related on the design of the camps, such as the location and layout of the latrines and the illumination system. While the only factor related to the site identification is the distance of the water source, which also affect the cost. Therefore, we decided to consider the latter factor only under the objective "low cost" in order to avoid redundancy.

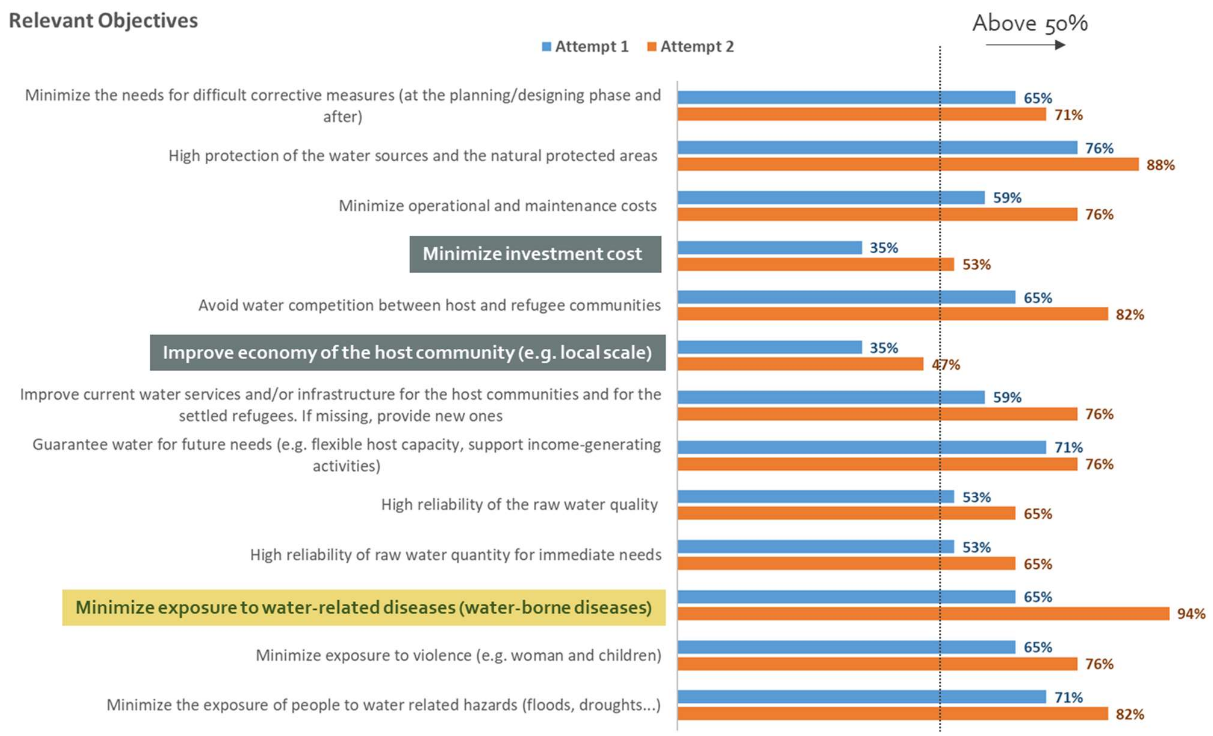

Figure 9. Percentage of the frequency with which the objectives in the master list are considered relevant by the respondents in their first and second attempts. The objective with the highest percentage is highlighted in yellow. The objectives highlighted in grey have the lowest percentage.

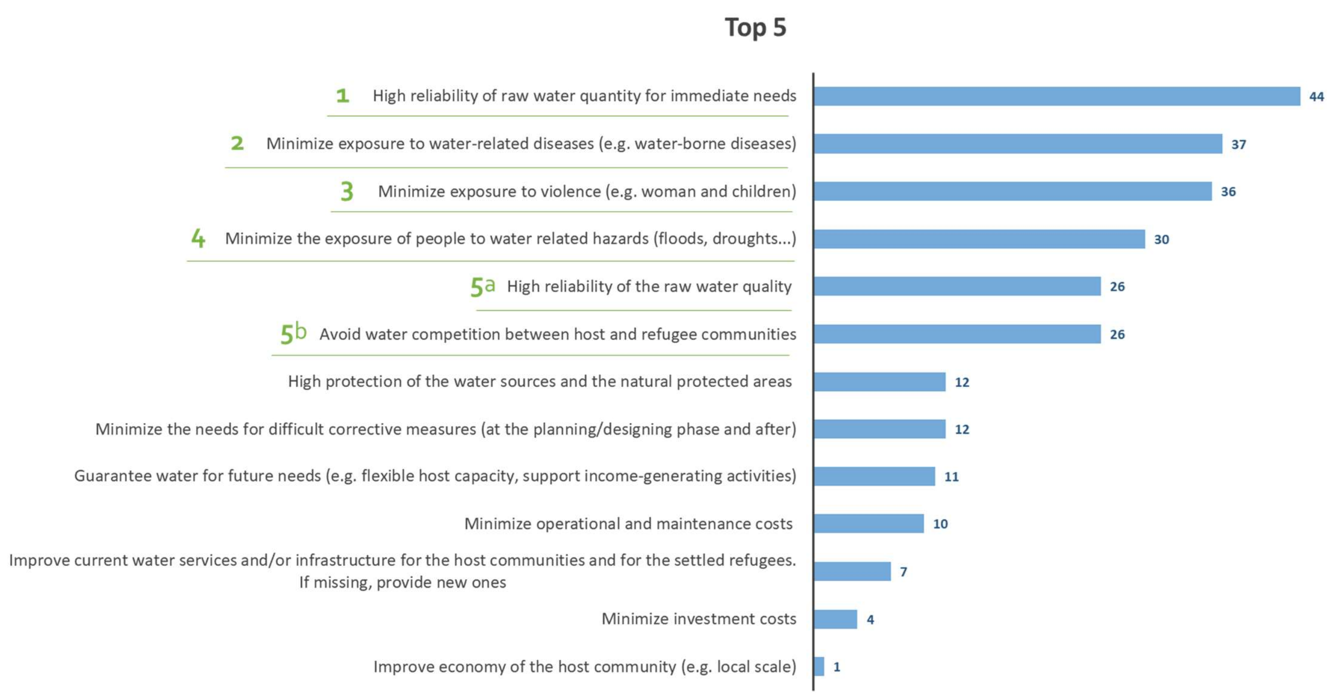

Figure 10. Frequency of the objectives considered to have a high priority (where the highest score corresponds with the highest priorities and conversely). The average top-5 objectives are underlined.

Part 2b - Opinion of other stakeholders

According to the respondents, UNHCR-HQ considers relevant almost all the objectives listed in the master list during the site selection and planning phase, with a particular attention for the goal: “guarantee high reliability of raw water quantity”. The same is valid for the sub-country UNHCR offices. The respondents instead perceive that the government does not consider important the goal: “minimize the exposure of people to water related hazards (floods, droughts...)”. On the other hand, according to them, the government strongly agrees on improving current water services and infrastructures and on improving economy of the host community. The government also agrees on selecting a site with high reliability of raw water quantity and quality and, with a low risk of water-related diseases.

In line with these results, we decided to consider both the positive and negative impacts of refugees on the host community, when generating goals. A reformulation of the decision-making process as opportunity for the host community rather than only a humanitarian effort, can promote an active engagement of the government and local authorities in the search for sustainable allocation solutions. Therefore, we added to the final hierarchy the objectives: "improve current water services and/or infrastructures" and "reduce the environment impact of refugees on the hosting site", looking also at the impact on downstream areas as suggested from the interviews. Both goals aim at increasing the acceptance and integration of refugees in the hosting site, thereby improving livelihood opportunities and long-term planning.

Part 3 - Individuals and groups with high influence

According to the respondents, the stakeholders that have a high influence in the site selection and planning process are listed in Table 8. The hosting government was always the first mentioned in all questionnaires. The results in the survey validate the stakeholder analysis carried out during the definition of the decision context by literature review.

Table 8. Individuals or groups with a high influence in the site selection and planning process

n.	Stakeholders
1.	Hosting Government
2.	Expert from organizations/government (UNHCR/NGO/local experts)
3.	Host Community
4.	Local Authority
5.	Refugee leaders

(5) Final objectives hierarchy

The stakeholder interviews and the survey supported the development of a final decision structure which can be now considered comprehensive in relation to the stakeholders' goals. The fundamental objectives of the final objectives' hierarchy are given in Figure 11 (for details including narrative descriptions of the objectives, see Appendix F). The objectives' hierarchy was constructed in order to minimize dependency among different objectives' levels. Table 9 clarifies which of the items identified during the interviews relate to which objective while summarizing the main findings from both interviews and questionnaire.

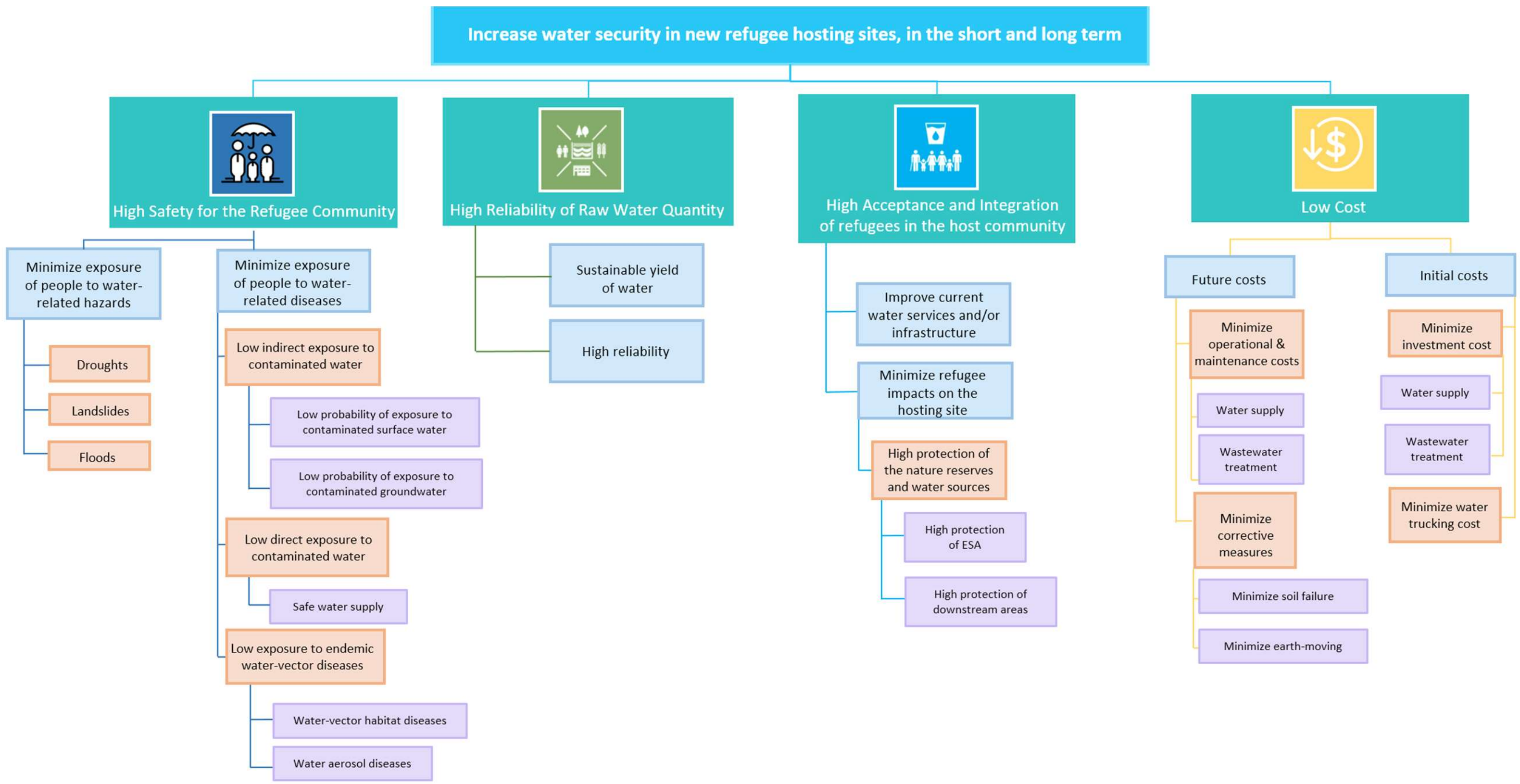

Figure 11. Final objectives hierarchy

Revision based on input from interviews and outcome from survey. The highest-level (1) objectives are coloured in blue-green, the second-level (2) are blue, the third-level (3) are orange and the lowest-level objectives (4) are purple.

Table 9. Final objectives and related findings from interviews and questionnaire

Object. (level 1)	Object. (level 2)	Object. (level 3)	Notes from interviews and survey
1.High safety for the refugee community			
Minimize exposure of people to water-related hazards	Minimize risk of: Flooding; Landslides; Droughts.		The importance to assess the risk of flooding and landslide was stated by five interviewees. (*Presence of flooding events can lead to problematic accommodation of refugees*). This objective was considered relevant by 14 people out of the 17 respondent and ranked at the fourth position
Minimize exposure to water-related diseases	Low indirect exposure to contaminated water	Low probability of exposure to contaminated surface water	The objective was not explicitly stated by the interviewees. However, four of them claimed the importance to assess groundwater table level for assessing the suitability of a site. Deep groundwater level reduces, indeed, the risk of contamination of the aquifer by faecal sludge in case latrines are used as disposal system. The indicator was also self-generated in one questionnaire (*Water table).* The objective was considered relevant by 16 people out of 17 respondents and it was ranked at the second position.
		Low probability of exposure to contaminated groundwater	
	Low direct exposure to contaminated water	Safe water supply for: Domestic use; Irrigation use; Livestock use; Production use;	Water-related diseases measured by UNHCR are: Watery diarrhoea; Bloody diarrhoea; Intestinal worms; Eye Disease; Skin disease;
	Low exposure to endemic water-vector diseases	Water-vector habitat diseases	These are used as indicator to assess water issues (such as poor water quality and quantity) in the monitored refugee settlement.
		Water aerosol diseases	The objective "low direct exposure to contaminated water" was self-generated in five questionnaires under the statement: *good quality at the taps, good water quality, safe water supply.*
2. High reliability of raw water quantity			This objective was frequently mentioned in the interviews as necessary condition for the suitability of the hosting site. It was considered relevant by 11 respondents and it was ranked at the first position. The objective was self-generated by nine respondents under the statement: *Water availability*.
Sustainable yield of water	Surface water		

	Groundwater		The statement: "avoid depletion of the sources" was repeated thrice during the interviewees and it was self-generated in the survey by five respondents (*Avoid depletion of the water sources; Consider groundwater recharge; Water use(demand) does not exceed the sustainable volume of water available; Sustainable use of the water sources; Regulation in the water abstraction)*.
High reliability	Surface water sourcing Groundwater sourcing Rainwater sourcing		Stated by two interviewees and self-generated by one respondent (*Reliable water quantity*).
3.High acceptance and integration of refugees in the host community			
Minimize refugee impact on the hosting site	High protection of the nature reserves and water sources		The objective was mentioned both in two questionnaires and one interview under the statements: *Downstream water protection*, *protection of riparian areas* and *protection of the surface water.* It was considered relevant by 15 respondents out of 17 and it was ranked at the sixth position on 13 objectives.
Improve current water services and/or infrastructures			The objective was self-generated by two respondents (*Opportunity for improved access to water supply for domestic /commercial/agriculture and livestock; Consider local water development plan).* It was considered relevant by 13 respondents out of 17 and it was ranked at the tenth position.
4.Low cost			
Minimize initial costs	Minimize investment costs	Groundwater supply Surface water supply Rainwater supply Wastewater treatment;	The objective was mentioned in one interview and self-generated by two respondents (*Reasonable cost for the access to the water sources; Minimal infrastructure capital expense (CAPEX)).* It was considered relevant by 9 respondents out of 17 and it was ranked at the second to last position.
	Minimize water trucking cost		The objective was stressed in two interviews. Water trucking is highly expensive and not a sustainable solution in a long-term. This objective was not self-generated or investigated in the questionnaire.
Minimize future costs		Groundwater supply	The objective was mentioned in two interviews and self-generated by 8 respondents out of 17. (Cost of treating water supply is reasonable and benefit outweigh costs;

	Minimize operational & maintenance costs	Surface water supply Rainwater harvesting Wastewater management	Minimize operational expense; The water supply system is low cost to maintain). From interviews and questionnaire, this objective resulted more important than investment cost because: (1) the available budget decreases with the time and (2) refugees can contribute directly to the cost of water supply and sanitation services if this is sustainable. The objective was considered relevant by 13 respondents out of 17 and it was ranked at the ninth position.
	Minimize corrective measures		This objective was not self-generated in any questionnaire and it was not explicitly mentioned by the interviewees. However, the mean objective "*High suitability of the site enhancing rapid WASH interventions*" and the elicited preference for alternatives "*with no rocky soil*" to cut installation cost of latrines (both mentioned in two interviews) are explicitly correlated to the objective in analysis. The objective was considered relevant by 12 respondents and it was ranked at the seventh position.

3.2.3 Defining attributes

The generation of attributes was based on the review of current guidelines and face-to-face interviews with experts (e.g. hydrologists, WASH implementing partners, WASH officers). The process seeks to identify "natural attributes" applicable to different cases. When this was not possible, "proxy attributes" were proposed and suggestions for future improvement where provided by reference to methods/approaches that could be further explored. Identified attributes are shown in Table 10 and are explored further in Appendix F. Potential data sources for the SNARA objectives hierarchy are provided in Table 12. These give a glimpse on the water security condition while guiding the decision-makers in the selection of the indicators.

Table 10. Attribute description to measure how well an objective is achieved. A further description of the attributes is presented in Appendix F, whose section number is listed for each criteria under the column "Detail"

Natural Attribute	Proxy Attribute	Unit measures	Description	Detail
Minimize exposure of people to water-related hazards				
Out of the scope of this research				
Low probability of exposure to contaminated SW				

Water quality parameters (TSS, TDS, Faecal Coliform, NO3, PO4)	Flow distance to main pollution sources	[meter]	Water quality parameters are natural indicators of quality status in water bodies. However, related data are not easily available in many geographic areas due to the presence of few monitoring stations and the challenge of measuring water-quality from satellite data and global models. The proxy attribute can, then, be used to evaluate the probability of contamination of water bodies. Flow distance, produced contaminants and slope are just some of the indicators that can be used to understand the potential hazard of contamination.	Section 1
	Total amount of pollution load (BOD, COD, TN, TP, Faecal Coliform) produced in the sub-catchment	[kg/day, CFU]		
	Slope	[%]		
Low probability of exposure to contaminated GW				
Water quality parameters (TSS, TDS, Faecal Coliform, NO3, PO4)	Total amount of pollution load (BOD, COD, TN, TP) produced in the intersection between river basin and aquifer boundary	[kg/day]	The total amount of pollution load produced on the overlying land-surface of the aquifer constitute a hazard for its water quality. However, the effect of this potential hazards depends also by the aquifer vulnerability to contamination. This, for example, decreases with low groundwater table depth.	Section 2
	Groundwater table	[meter below surface]		
Safe water supply				
SW sourcing: Standard deviation of the water quality parameters in a year	Range size (Max-Min)	-	In drinking water treatment process, chemical substances (such as chlorine or ammonium) are dosed according to a simple manual water quality tests at the outflow made by water quality operators. Surface water quality at the source is, rarely measured. Hence, no monitoring systems exist to inform variations in the quality. If water quality at the outflow is not constantly measured, there is the risk that the pre-calculated dose is inadequate. Usually, only one water quality operator is in charge of the whole water system in one or more refugee settlements, with the risk that strong variation of water quality at the source cannot be captured in time.	Paragraph (2)
Deep and shallow GW sourcing: - Microbiological; - Chemical; - Physical parameters.		[CFU/100ml mg/l NTU]	No treatments are guarantee for water extracted from aquifer, so that, the *microbiological, chemical* and *physical water quality parameters* at the source can be compared with the inter/national agencies standards for agriculture, livestock, domestic and industrial use (Figure 32 and Figure 33).	
Rainwater harvesting:	Topographic distance to industries and cities	[meter]	It is not predictable that a treatment system will be adopted for rainwater harvesting system. Therefore, the quality of the rainwater should be compared with inter/national agencies standards. However, this information can be hardly available.	

			Therefore, a proxy indicator is the *topographic distance* of the site to potential air pollution sources. These can be towns/cities (traffic pollution) and industries.	
Low exposure to endemic water-vector habitat diseases				
	n. people affected by Malaria,..	[people]	According to WHO, common water-vector habitat diseases and aerosol diseases are Malaria and Legionellosis *(Stanwell Smith, 2003)* (Table 32). However, it strongly depends by the geographic region in analysis.	Paragraph (3)
Low exposure to endemic water aerosol diseases				
	n. people affected by Legionellosis	[people]		
Sustainable yield of water				
Ratio of residual surface flow (after extractions) to environmental flow	Ratio of annual water demand to renewable surface and groundwater flow.	[-]	The ecological status of the water bodies can be seriously damaged if over-abstractions take place. Environmental flow and minimum ecological lake level refers to the water considered sufficient for protecting the structure and function of an ecosystem and its dependent species.	Paragraph 6.1.1.3
Ratio of annual water extraction (from GW) to renewable groundwater flow (=30% groundwater recharge)		[-]	GW is one of the main source used for supplying water in refugee hosting sites. If the GW abstraction exceeds the recharge, seasonal or permanent drawdown of the GW table is possible. This is a threat for the reliability of the water at the long term both for host and refugee's community. Additionally, environmental issues can rise.	
High reliability of water quantity				
Ratio of volume of shortage in a year to the volume of water extracted, respectively for SW, GW and, RW sourcing		[-]	The volume of shortage is in itself an indicator for assessing the reliability of the water supply according to the volume available in the water source. Dividing it by the total amount of water extracted, we provide an additional information to the decision makers, which could result useful if decision needs to be taken among few alternatives.	Paragraph 6.1.1.4
High protection of downstream areas				
	Sufficient vegetation index or NDVI	[-]	Areas having a low vegetation index are more susceptible to soil erosion due to increased runoff. Moreover, adequate riparian vegetation traps sediment and pollutants, increasing water quality condition and reducing refugee impact on downstream areas.	Paragraph 6.1.1.5

High protection of ESA				
Topographic distance to ESA		[meter]	Sites located close to ESA could worsen the impacts of refugees on the environment.	
Improve current water services				
Budget intended for the host community (30% of the total investment divided by the host community population)	Reciprocal of percentage of access to safe water [-]	Currency/person	According to the CRRF, 30% of the local investment cost need to be allocated for improving local services. Hence, the proposed attribute estimates the benefit on the local water services by computing the budget that each person in the host community will virtually receive if refugees is settled nearby their villages. If no information of the total investment is available, the proxy of the marginal return of the investment intended for the refugees can be consider as an attribute.	Paragraph 6.1.1.6
Minimize investment cost				
GW supply: $\text{Cost}_{\text{drill/well}} + \text{Cost}_{\text{power supply}} + \text{Cost}_{\text{chlorination syst.}} + \text{Cost}_{\text{reservoir}} + \text{Cost}_{\text{distribution}}$ f (water demand $_{\text{GW}}$, GW table, altimetry area, soil type, potential yield, slope)		[currency]	Capital costs of the water supply system vary according to the water body used as source.	Paragraph 6.1.1.7
SW supply: $\text{Cost}_{\text{intake, DWTP, sludge treatment}} + \text{Cost}_{\text{power supply}} + \text{Cost}_{\text{transmission}} + \text{Cost}_{\text{distribution}}$ f (water demand $_{\text{SW}}$, water level, altimetry area, soil type, distance, slope)				
RW supply: $\text{Cost}_{\text{gutters, tank, tank base}}$ f (water demand $_{\text{RW}}$, population composition)				
Wastewater treatment: $\text{Cost}_{\text{treatment disposal/ technology}}$			For the sanitation cost, common adopted faecal disposal systems are the latrines, which cost is composed of the materials need for their construction. The typology of latrines depends by the soil type (e.g. raised latrines in rocky soil).	
Minimize water trucking cost				
	Cost to track water	[currency]	Cost of water trucking depends by many factors such as the period needed to complete or upgrade the water supply system, the amount of water to transport and the travelled kilometres.	Paragraph 6.1.1.8
Minimize O&M costs				

Groundwater supply	Cost $_{\text{power supply}}$ + Cost $_{\text{chlorine}}$ + Cost $_{\text{manpower}}$ + Cost $_{\text{maintenance}}$	[currency]	Running cost depends by the type of water source used to supply the water system. A present value of these costs should be consequently computed, considering 15/20 years as life span of water infrastructures.	Paragraph 6.1.1.9
Surface water supply	Cost $_{\text{power supply}}$ + Cost $_{\text{chemicals}}$ + Cost $_{\text{manpower}}$ + Cost $_{\text{maintenance}}$			
Rainwater harvesting	Cost $_{\text{maintenance}}$			
Wastewater management	Cost $_{\text{maintenance \& operation}}$		The maintenance costs of the wastewater management in refugee camps can be the running cost of the WWTP or the collection and, transportation of faecal sludge from common latrines.	
Minimize corrective measures				
Slope		[%]	An adequate slope can reduce the risk of soil erosion and enhance a good drainage. According to (UNHCR, 2007) a site should have a slope between 2%–4% for good drainage.	Paragraph 6.1.1.10
Soil type (% black cotton soil, % peat)		[%]	Vertisol (or black cotton soil) is a highly expansive soil which may cause deterioration of the pipes by the movements related to their expansion, contraction and flood issues. Also the peat soil can be problematic for soil stability.	

The computation of the attributes related to water system costs and the reliability of the raw water quantity depends on the refugee water demand. Standards to meet the basic water needs are set by UNHCR and the Sphere project. However, the reviewed guidelines do not propose standards or methods for computing the amount of water needed to support refugee's livelihood (e.g. water for enhancing agriculture practices or livestock). This is because long-term considerations are not included in the current decision-making process. In order to compute the total water requirements, standards and computational methods are proposed in Appendix G, which refer both to the basic water needs in emergency and post-emergency and to the water needs for refugee activities (Table 11). The analysis presented in the appendix aims to support the estimation of refugee water requirements in the short and long term.

Table 11. Fixed variables in the decision problem structure

Total water demand (to guarantee sufficient water quantity):
• Standard for domestic supply • Standard for institutional building supply • Standard for agriculture supply • Standard for livestock supply • Standard for production supply *(Consider the natural population growth and production /commercial growth in the computation)*

To support the identification of suitable attributes for a specific application, global databases and open data sources were analysed. The limited availability of data is indeed a shared reality in humanitarian contexts and one of the main causes of uncertainty. The results of the analysis are summarized in (Table 12), where for each fundamental objective we have identified potential data sources that can (i) provide a general understanding of local water security conditions, (ii) support the process of identifying attributes and, (iii) support their calculation.

Table 12. Global data and common open sources for the SNARA objectives' hierarchy

IGRAC- GW quality

The IGRAC centre collected groundwater quality data over the world in a web-portal. https://apps.geodan.nl/igrac/ggis-viewer/viewer/gwquality/public/default

World Pop

High spatial resolution, contemporary data on human population distributions. http://www.worldpop.org.uk/

National Bureau of statistics

The bureau of statistics is an important source of information. Generally, it is possible to gather data such as percentage of access to water supply or poverty index.

GEMStat - water quality

Water quality database which account for four million entries for rivers, lakes, reservoirs, wetlands and groundwater systems from 75 countries and approximately 4000 stations. http://portal.gemstat.org/

FAO Soil portal

The portal provides harmonized World Soil Database at a resolution of 30-arc second. This can be downloaded in the section: "Survey" under the link Maps and Database
http://www.fao.org/soils-portal

WHO-Map

It provides access to over 1000 indicators on priority health topics with a country scale resolution.
http://apps.who.int/gho/data/node.home

https://www.who.int/gho/map_gallery/en/

Health-Map

Data for a comprehensive view of the current global state of infectious diseases and their effect on human and animal health.
https://www.healthmap.org/en/

Aqueduct - WRI

Aqueduct is a global water risk mapping tool which provides global maps for seven indicators on physical risk quantity.
https://www.wri.org/our-work/project/aqueduct/

MODIS - NASA

MODIS project provides vegetation index products (NDVI and EVI) at multiple-spatial resolution.
https://lpdaacsvc.cr.usgs.gov/appeears/task/area

EarthExplorer

It is a web-portal to download satellite data from the Landsat missions and NASA Terra and Aqua missions. E.g. DEM data can be downloaded from there to then, generate the slope map.
https://www.usgs.gov/earthexplorer-0

3.3 Discussion

In this part of the research, we developed a generalizable objectives hierarchy to provide a procedural tool to WASH officers for “Sustainable Allocation of Newly-Arrived Refugees” (SNARA), according to water security conditions. Based on literature review, semi-structured interviews and, survey, we carried out the initial steps of the SDM-approach, showing their application to a new topic not yet covered in the literature. Below, we discuss the applied methodology together with the obtained results. Finally, we discuss the final objectives hierarchy.

Step (1) – Decision Context

In the proposed SDM application, we found face-to-face interviews highly beneficial in the process of understanding and clarifying the decision context (as emphasized also by Gregory et al., 2012). Interviewees were able to support their claims with more examples of real cases in the world, make connections with current guidelines and provide useful documentation. Face-to-face interviews also allowed the engagement of stakeholders in the subsequent phases of the analysis.

By selecting UNHCR-HQ officials from different units for semi-structured interviews, we were able to understand the overall decision-making context by minimizing the biases that may result from the analysis of a specific case study. The HQ officials’ experiences in different emergency contexts all over the world have enriched the analysis of the decision process with different perspectives. However, selecting stakeholders is tricky (Eisenfuhr, Weber, & Langer, 2010; Gregory et al., 2012), especially if the analysis purpose is the development of a generalizable objectives’ hierarchy. Due to time constraints, a simplistic stakeholder selection has been adopted in this research. In future studies elaborating on the proposed methodology, we advise the use of a more systematic approach such as the social network analysis (e.g. Lienert, Scholten, Egger, & Maurer, 2014), which enables a better identification and visualization of stakeholders in complex multi-actor decision-making settings.

Step (2) – Generation of objectives

The generation of objectives in the SNARA application was quite time-intensive. This was mainly the result of an extensive review of reports and guidelines aiming a comprehensive view of the decision problem and water security issues. Furthermore, the generation of objectives was an iterative approach (as recommended by Gregory et al., 2012) and more than once it was necessary to go back to this step to ensure the development of a comprehensive hierarchy with minimum independence among the objectives.

In our SNARA-application, we preferred individual interviewees to group discussions, as the hierarchical relations among UNHCR members were unclear at that point in the research. It is indeed important to understand the power relations among participants to effectively structure group interviews, as outlined by Bryman, 2012; Kitzinger, 1995. However, it was not always possible to meet stakeholders individually and improvised group meetings took place in more than one occasion. No feedback on the decision-making process structure were provided by the interviewees in these meetings, except for a better understanding of the relationships among different key stakeholders in the organization. The poor results can be explained by the improvised nature of the group interview.

Only few interviewees did not give their consent for recording the interview. This could be explained with the lack of clarity about the scope of the interview, mainly caused by time pressure. At the beginning of each interview, it was not explicitly stated that their answers should reflect their personal opinions. However, along the interview, it was asked to the respondents to answer according to their personal opinions. Furthermore, it happened in few cases that the interviewee itself agreed on being interviewed only if (s)he could answer according to her/his personal experience and not on the behalf of the unit to which he or she belongs. However, this situation did not affect the results as we did not address the decisional context and goals in the unrecorded interviews.

The questionnaire prepared for UNHCR officers allowed us to investigate both the decision context and objectives (using the approach suggested in Bond et al., 2010), ensuring a fair representation of different perspectives. Furthermore, it was helpful in reviewing and validating the preliminary objectives hierarchy. However, the low number of returned surveys could have negatively affected the proposed analysis. We believe that this effect was limited or negligible, as the few respondents constituted a diverse sample, comprising different sectors involved in the decision problem.

To improve stakeholder engagement, we suggest conducting face-to-face interviews before asking interested parties to complete the survey. According to the results showed in paragraph (4), eleven out of 12 respondents completed the survey provided at the end of the interviews. In contrast, four out of 100 WASH experts actually completed the survey which was shared via e-mail without the establishment of previous personal communication with the experts. Therefore, we can deduce that the interview helped provide the right motivation to complete the survey, while stimulating a broader thinking about the problem under analysis.

An inconsistency was found in the analysed surveys, concerning the selection of the five highest priority objectives from the provided master list. Six out of 17 respondents selected objectives, which were considered not relevant in the previous question even if was explicitly requested to answer to both questions according to their personal opinions. Two different assumptions could be made to explain the phenomenon. The respondent selected only the objectives relevant to the organization's policies, while (s)he ranked the objectives based on his personal opinion. This could have happened the other way around as well. Another possibility is that the respondents developed a deeper thinking, going further in the questions, which led the respondent to include objectives previously not considered relevant (a process well described by Bond, Carlson, & Keeney, 2008). However, this inconsistency did not significantly affect the results. Including the objectives selected in the ranking list into the group of relevant objectives (second attempt), there was a homogeneous growth (5-10%) of the frequency in which each objective was considered relevant, with the exception of the objective: “minimize exposure to water-related diseases”. This objective has a frequency increase of 30%.

Final objectives hierarchy

The selection of actors from different sectors both in the survey and in the interviews aimed to ensure a fair representation of different perspectives for the purpose of building a comprehensive, generalizable objectives hierarchy. However, we think that the SDM application would have highly benefited from a better inclusion of the stakeholders aiming to reach a general consensus on the final objectives hierarchy and encourage a participatory decision-making process. In fact, the actors involved mainly belong to UNHCR, while it would have been useful to involve government actors and other NGOs in generating and discussing the objectives.

In face-to-face interviewees, participants often stressed the importance of guaranteeing a refugees’ livelihood in the hosting community and to fit in the national and local development plans. However, they did not evaluate these objectives as priority criteria of the site selection process in the survey. This can be explained by the urgency context in which the decision-making process is carried out. The objectives mentioned above can again assume relevance only in a state of non-emergency (preparedness actions), where the life of the refugees is not yet in danger.

The provision of an adequate amount of water can prevent the spread of diseases caused by poor hygiene. Nevertheless, the objective “high reliability of raw water quantity” was not defined under the highest-level objectives: “high safety”. The objective was considered, indeed, a fundamental objective in the presented hierarchy given its self-related importance found both in the interviews and survey. Clear decision-makers' preferences can, indeed, be elicited for this objective while the same is not true for other sub-level objectives. However, dependency among different objectives' levels is preferably avoided (Eisenfuhr, Weber, & Langer, 2010).

To support the application of the SNARA objectives hierarchy to specific case-studies, global and common local data sources were cited in this research. These can guide decision-makers in a preliminary review of the relevant objectives and the subsequent selection of the attributes.

4. SNARA decision support in Rwizi catchment, south-western Uganda

The SNARA objectives' hierarchy was applied to the refugee allocation decision process in south-western of Uganda. In this area, refugee influxes are expected from the Democratic Republic of Congo. Newly-arrived refugees are currently accommodated in existing refugee settlements located near the western border. However, the land available in these settlements is reducing rapidly and soon they will be full. As a response to the problem, the government has decided to direct the new refugee influxes to the Nakivale refugee settlement, located in the Rwizi basin, south-west of Uganda. This site currently hosts about 90,872 people on a land of 184.6 km2 where 21.01% is used for residential use, the 63.1% for farming use and the remaining is wetlands areas (REACH, 2018b). The host community comprise 30% of the total population (Personal communication with the commander of the settlement, 2018).

The decision of the government to increase the population in Nakivale raises some concerns of the local authorities and of the UNHCR. First, because the basic refugee water needs are not yet satisfied in the settlement with an average of per capita water that varies between 16 and 18 l/day (Nsamizi, 2018). Second, severe water shortages have been reported in the whole Rwizi basin. Lake Nakivale, the main water source for the Nakivale refugee settlement, is shrinking in size while the river Rwizi is drying out in the dry seasons (District Planning Unit, 2011).

This research develops a framework to identify efficient allocation solutions according to portfolio modelling by exploring three potential refugee hosting sites in the Rwizi catchment. This study shows how the refugee allocation decision problem can benefit from the portfolio decision analysis (PDA). In addition, the research aims to test the applicability of the SNARA objectives' hierarchy to a specific case study and to concretely use global database and open sources for attributes' computation.

This study contributes to the literature by providing an example of portfolio approach to the refugee allocation problem.

4.1 Materials and Methods

In developing the framework, we implemented all steps of the portfolio decision analysis process (see section 0 in literature), with a restriction related to step 4 (consequences and interactions). In this step, we have not particularly examined the interactions between alternatives. In the specific application of the refugee allocation process, a detailed analysis of the interactions would have strongly influenced the elaboration and calculation time, developing an ineffective framework for the time available in case of emergency. The implemented steps and related tasks are summarised in Table 13 and they are further presented in the following paragraphs.

Table 13. Implemented steps in the portfolio decision analysis framework for the refugee allocation decision-making

Steps	Tasks
1. Problem framing	Determine context and scope Identify stakeholders
2. Objectives and attributes	Screen and specify the objectives from the SNARA hierarchy Specify attributes and measurement scales
3. Portfolio Alternatives	Specify alternatives Specify constraints related to the interactions
4. Consequence vector	Compute alternatives' consequences with regard to the attributes
5. Preference elicitation (or value model)	Determine the forms of the value functions on the attributes Elicit weights for the attributes
6. Overall Consequences	Specify models for calculating the overall consequences Collect data and estimate the consequences of alternatives
7. Analysing portfolio	Find feasible portfolios Find optimal or non-dominated portfolios of alternatives

4.1.1 Step (1) Local decision context

A 5-week field work in Uganda was carried out to gain a better understanding and to assess local perspectives on the decision-making process related to the allocation of refugees. Face-to-face interviews were conducted with key stakeholders in the UNHCR office (Kampala), as well as in the UNHCR office (Mbarara) and in the campaign office located in the Nakivale refugee settlement. These, integrated with informal discussions with WASH implementing partners and with the members of the Victoria Water Management Zone, allowed an overview both of the allocation of newly-arrived refugees and of the current water security conditions in the Rwizi basin.

4.1.2 Step (2) Defining objectives and attributes

According to the acquired knowledge, objectives in the SNARA structure were reviewed, in order to find the ones relevant to the analysed problem. Consequently, the attributes were identified by first analysing information available from global sources. In case global information was too generic, i.e. presenting poor/coarse spatial resolution, governmental data and other secondary sources were integrated, when possible, for improving the accuracy of the used information. Constrained by data availability, "proxy attributes" were then selected rather than the "natural attributes" suggested in SNARA SDM-process. Feedback on the considered objectives and selected attributes were collected during a monthly group meeting of the technical unit in the UNHCR country-office of Kampala, Uganda.

4.1.3 Step (3) Defining portfolio alternatives

The set of alternatives generated was value-focused, addressing the objectives previously identified. This allowed to recognise three different decision variables that influence the achievement of the objectives: (i) the potential refugee hosting sites, (ii) water sources' usages and, (iii) the number of newly-arrived refugees to allocate in each set site. The investigated refugee hosting sites were defined by the government which explicitly asked to identify possible allocation solutions within the Rwizi Basin. Consequently, a decision matrix was derived through the different combinations of the decision variables. This combination process was carried out automatically by an algorithm. Then, decision alternatives were grouped in portfolios according to global constraints for portfolio optimization.

4.1.4 Step (4) Consequence vector

In this step, we computed the attributes for each alternative, obtaining a consequence vector $x^j = (x_1^j, x_2^j, .. x_n^j)$ where $x^j{}_i$ is the consequence of alternative j with regard to the attribute i. In the attribute calculation, the data collected from local and global sources were further processed. To this end, python algorithms were developed: (i) to compute automatically the water demand of refugee and host communities (considering population projection in 15 years), (ii) to delineate the watersheds from pour points (representing the investigated sites) and, (iii) to delineate the buffer area of the potential refugee settlement according to the number of refugees allocated in the site. In addition, a simple water balance model was developed to extract relevant hydrological information on the catchment. The data sources integrated into these algorithms were selected taking into account the time available for decision-makers to perform the analysis and the general lack of local data. For this reason, particular attention has been paid to global databases, remote sensing images and satellite data. The above algorithms were processed as functions in a final programming algorithm (PA) that calculates all attribute values for each alternative Figure 12. A summary of the relevant features of the PA is presented in Text Box 4.

Text Box 4: SNARA programming algorithm

To facilitate the computation of the attributes, a programming algorithm (PA) written in Python language was developed. Based mainly on spatial analysis functions, the algorithm is able to elaborate and analyse continuous and discrete data provided as input of the framework. The PA is partitioned into two main consecutive models (Figure 12). In the **first module**, input data are processed and converted respectively in different scales and formats (i.e. monthly time scale and spatial format). In the **second module,** four distinct sub-modules calculate the attribute values respectively for the fundamental criteria (Safety, Acceptance, Cost and, Quantity).
User inputs for the PA are the decision variables that characterise each alternative: the number of refugees (1) to allocate over a certain location (2) and the percentage of water extracted from groundwater, surface water and, rainwater sources (3). Inputs (1) and (3) are entered in the model with a numeric format while input (2) is entered as shapefile (GIS spatial data format).

First module of the PA

In the first module, the point shapefile of the location (input 2) is used for delineating the watershed with the PyGeoProcessing library. The number of refugees (input 1) is used for the creation of a buffer area that represents the extension of the potential refugee site. Its computation is based on the UNHCR standard of 45 m^2surface per person for building a shelter (UNHCR, 2007). We added to the residential plot size other 45 m^2, in order to consider the allocation of land for agriculture purpose.
Subsequently, the algorithm computes the water demand. This depends on: the refugee population allocated in the site and, the refugee and host population growth (for details concerning water demand computation, see Appendix H). Needs for irrigation are assessed to support future refugee agriculture activities. These are computed using the FAO guidelines (Section iii, Appendix G). In the computation, we used the global database 'MIRCA2000', which provides spatial information on crop types and local agriculture practices (e.g. use of irrigation system or rain fed practices).
Finally, the algorithm extracts the hydrological forcing data from EartH2Observer database as spatial data masked over the catchment in analysis. These are input of the water balance model, which is computed in the second module and, specifically, in the *Quantity* function.

Second module of the PA

In the second module, water security attributes are actually computed through spatial analyses (i.g. shapefiles intersection), in which spatially distributed data are "clipped" by the buffer area outline. These spatial data were elaborated from reports and datasets gather during the fieldwork. In the sub-models Safety and Acceptance (Figure 12), the algorithm mainly computes the spatial data average over the refugee camp's extension. The calculations instead become more complex for the other 2 sub-models, in which we integrated additional functions for the assessment of the suitability of rainwater harvesting and the calculation of the water balance in the delineated watershed (for details on the Water Balance Model, see Appendix I). As final results, the algorithm computes all 23 water security attributes for the alternatives in analysis.

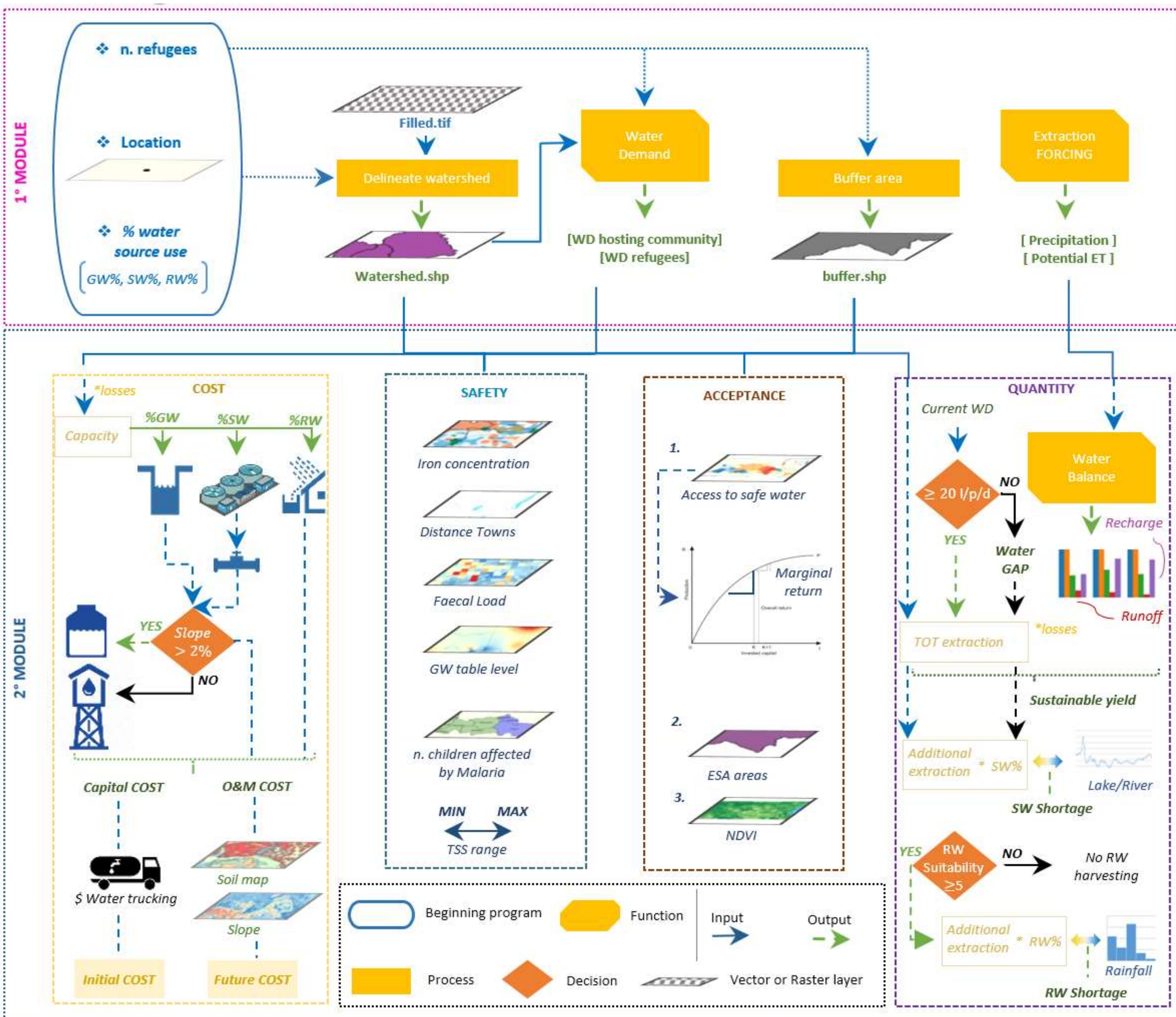

Figure 12. Programming Algorithm for criteria value assessment

4.1.5 Step (5) Preference elicitation

In this step, we determined the forms of the value functions on the attributes and elicited weights for the attributes. For the first task, linear scoring functions over attribute ranges were used when stakeholder preferences were not known. Whereas, the bisection method was used when preference of stakeholders could be explicitly extracted from guidelines, policies and statements. All derived value functions are monotonic with the exception of the value function for the slope.

For the second task, attribute weights were constructed according to a rank ordering weighting method. The use of ranked weights results from the incomplete and imprecise information on the decision makers' preferences. No preference elicitation model was actually used to capture decision makers' preferences due to limited research time. The rank-order centroid (ROC) method was selected among the various rank ordering weighting methods since its effectiveness is shown in several papers (Barron, 1992; Barron &

Barrett, 1996) and the error on the generated weight decrease for large set of criteria (Roszkowska, 2013). According to the ranking method, two steps were carried out: (i) ranking the criteria according to their importance and, (ii) weighting the criteria from their ranks using ROC approach according to *Equation 1*:

$$w_j = \frac{1}{n}\sum_{k=j}^{n} r_k \tag{1}$$

where r_k is the rank of the k^{th} criterion and n the number of criteria.

The adopted weight methods can strongly affects the identification of the efficient portfolios (e.g., (Mustajoki, 2012). Therefore, it is important to critically review the final results with the decision-makers to verify if the identified solutions reflect their preferences.

4.1.6 Step (6) Overall consequences

Adopting a linear-additive value model (*Equation* 2) attribute values were aggregated into an overall decision alternative value.

$$V(x^j) = \sum_{i=1}^{n} w_i\, v_i^j \tag{2}$$

According to the equation, the m alternatives ($x^1,\ x^2, .. x^j, .. x^m$) are evaluated with regard to the n criteria according to the score vector $v_i^j \in [0,1]$ of alternative x^j and to the weight w_i which measures the relative importance of the i_{th} criteria. The criteria weight $V(x^j)$ expresses the overall value of the alternative (Eisenfuhr, Weber, & Langer, 2010; Gan et al., 2017; Ralph L. Keeney & Raiffa, 1993; Liesiö, Mild, & Salo, 2007). In this linear-additive model, the portfolio value can be described, as follows:

$$V(p, w, v) = \sum_{x^j \in p} V(x^j) = \sum_{x^j \in p} \sum_{i=1}^{n} w_i v_i^j \tag{3}$$

Where p is the portfolio in analysis (or specifically, a subset of available alternatives), *i* represents the set of criteria and *j* the set of alternatives (Liesiö et al., 2007; Liesiö, Mild, & Salo, 2008; Ollila, 2013). The set of feasible portfolios was identified according to portfolio constraints. A global constraint for portfolio optimization was the number of newly-arrived refugees that needs to be allocated per scenario. A local constraint was the available space in each investigated location. However, this information was unknown and hence, the assumption that each investigated site has sufficient space to allocate a maximum of 30,000 people was made.

4.1.7 Step (7) Analysing Portfolio

We first solved the portfolio problem by assuming complete preference elicitation and after, by using the RPM-Decisions software. In the first approach, portfolio solution was acquired by maximizing portfolio value. In the second approach, we solved the set of efficient portfolios with RPM-Decisions software which supports elicitation of incomplete weight information. The software was used with the support of the department of Mathematics and Systems Analysis of Aalto University, Helsinki. Liesiö Juuso, associate professor from the department of Mathematics and Systems Analysis, ran the software for us using the attributes' values and the ranking information. After the execution of the software, he provided us with the alternative's core index value (Liesiö et al., 2007; Ollila, 2013). This index allowed us to identify the alternatives present more often in the set of efficient portfolios. An alternative which is present in all efficient portfolio has the core index equal to 1 and is called core alternative. Contrarily, the alternative which is present in no efficient portfolio has the core index 0 and is called exterior alternative. Alternatives with core index in the range (0,1) are called borderline alternatives (Liesiö et al., 2007).

4.2 Results

In the below paragraphs, the results of the application of the portfolio decision analysis (PDA) to the refugee allocation problem in south-western Uganda are shown. Results obtained from each step of the adopted PDA framework are presented under the homonymous paragraphs.

4.2.1 Step (1) Local decision context

1. **"What is the problem or the set of problems that should be addressed?"**

The site selection process of refugee hosting sites in Uganda is mainly driven by the availability of the land. Public area with sufficient space to enhance cultivation practice is seen by the government as the most suitable for hosting refugees. However, no criteria concerning water security are currently taken into consideration for the site selection. This has led to severe problems in the north of Uganda, where refugees have been allocated with the assumption that water could be found merely by drilling, digging or trucking.

In south-western Uganda, the Nakivale refugee settlement (Figure 13) was selected by the Office of the Prime Minister (OPM) and UNHCR as a potential location for the accommodation of around 10,000 newly arrived refugees in response to a potential influx from the Democratic Republic of Congo (DRC). However, an increase in settlement population can exacerbate the current water scarcity condition. Water is a topic of extreme concern in the Nakivale settlement, since it is essential for refugees to support primary needs and to guarantee livelihood through agricultural and livestock practices. Water standards have not yet been met in some part of the settlement, which has led to the need to transport water by truck over the past 5 years.

Previously, OPM would select sites only once a refugee influx would start to happen. Currently, the process is slowly changing. According to the preparedness actions (PPRE's), the government is identifying suitable land when a medium or high risk of influx is assessed in the contingency plan. Aware of the high water trucking cost, the government is also becoming more willing in including water security criteria in the refugee hosting site selection process.

2. **"Who is involved?"**

OPM is the decision maker who has the overall responsibility for the selection of the refugee hosting site. UNHCR WASH officers together with a multi sectorial team (usually site planners and settlement officers) advise OPM on the suitability of the site by providing information on the number of people that could be accommodated. The assessment carried out by UNHCR officers is mainly based on a technical visit in which the WASH officers investigate the current water and sanitation infrastructure/services and available water sources. During this visit, the local population are interviewed, to understand possible risks related to the site (e.g. risk of flooding, drought). As presented in Figure 14, OPM has the highest power in the refugee site selection, while host community and refugees have the lowest power in the decision. The power relation reverses when the only available land is community-owned. In this case, the key decision-maker is the host community and the government has a limited influence on the final decision.

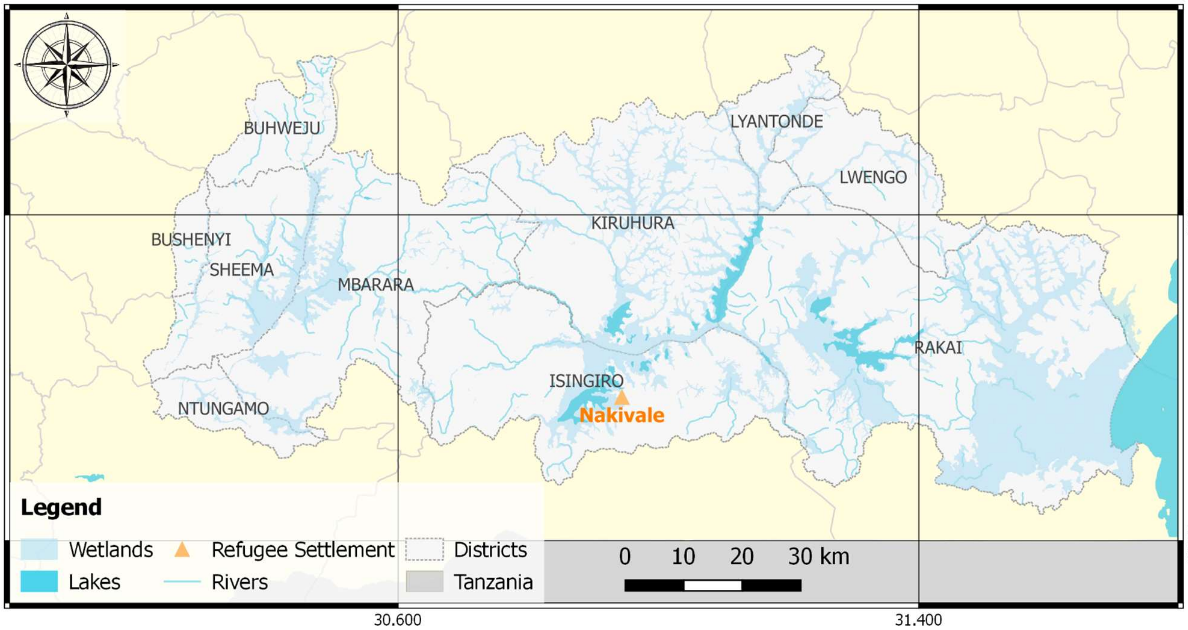

Figure 13. Political map of Rwizi catchment (2016)

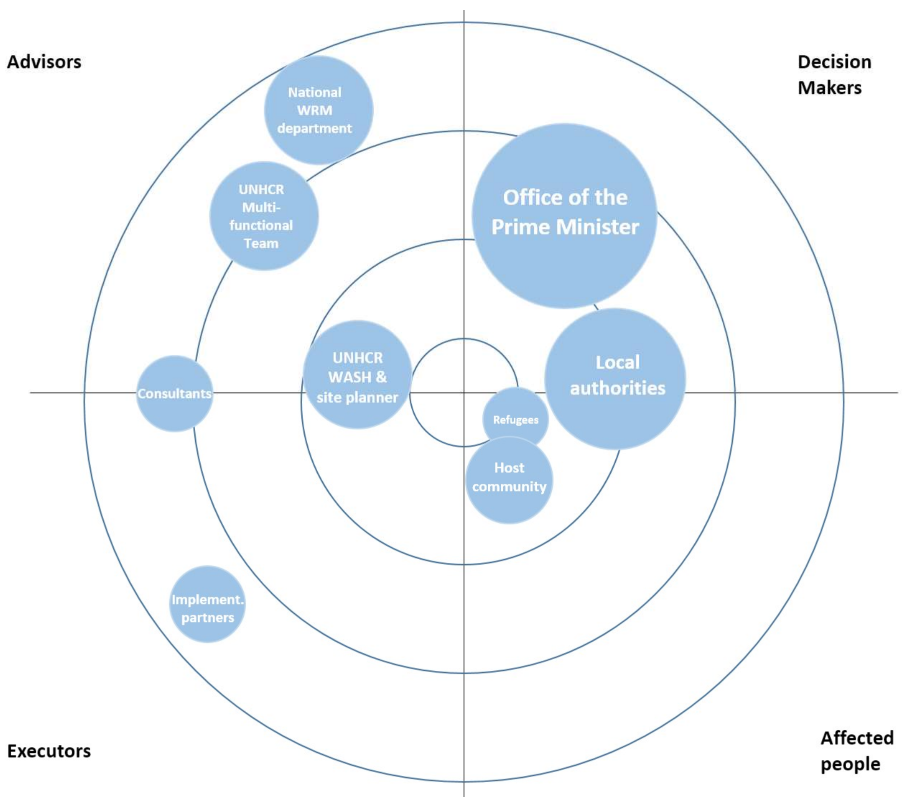

Figure 14. Interest/Power Grid for the general SNARA decision problem in south-western Uganda. The level of power is presented by the dots' size, while the level of interest by the proximity to the axis origin. The grid is partitioned in four sections, representing the following stakeholder groups: decision-makers, affected people, executors and, advisors.

3. ” What options are possible?”

In structuring the decision problem, the Ugandan government and the UNHCR office have requested support in identifying suitable refugee hosting sites within the Rwizi basin. Therefore, we selected three locations as potential refugee hosting sites to investigate (Figure 15): (A) Mbarara town (town in the upstream part of the catchment), (B) Nakivale refugee settlement, (C) site close to lake Kijanebalola in Rakai district (downstream catchment area). The selection of these locations gave the opportunity to explore three different refugee allocation options:

> **A**. Establish an urban refugee settlement (option preferred in general by UNHCR-HQ Geneva);
> **B**. Expand Nakivale settlement (current preference of the government);
> **C**. Create a new refugee settlement (in Rakai district);

The surface water sources for water supply are respectively: river Rwizi for location A, Lake Nakivale for location B and Lake Kijanebalola for location C.

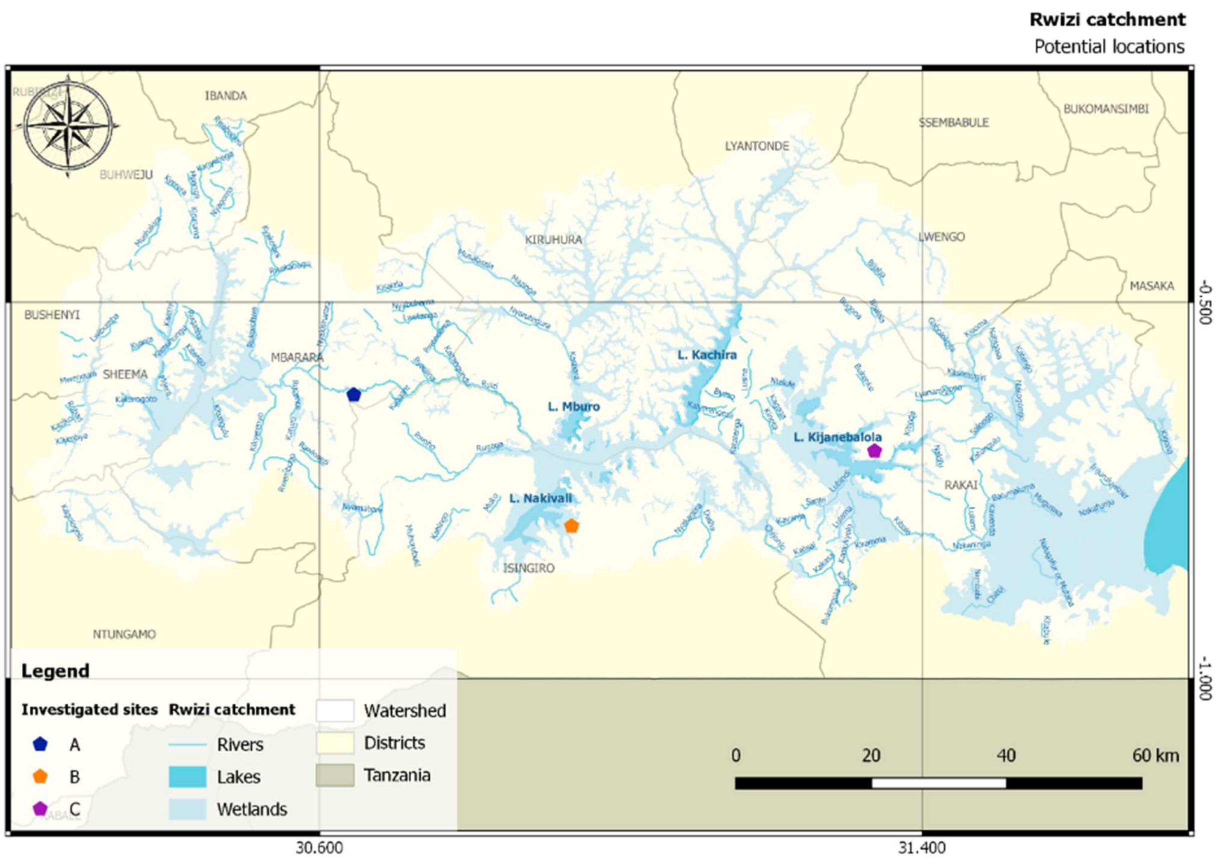

Figure 15. Locations investigated in the PDA framework

4. “What are goals of decision makers?”

The purpose of the analysis is to identify those locations that are the best candidate for accommodating newly-arrived refugees in the Rwizi catchment in terms of water security conditions. Additionally, the decision makers are interested in understanding what the hosting capacity of the investigated sites is and how the use of the available water resource can be optimized.

4.2.2 Step (2) Objectives, attributes and data

The general SNARA decision structure was applied to the specific context of the Uganda case study. All objectives were considered relevant to the analysed problem after being reviewed together with the UNHCR operational unit in Kampala. The final objectives hierarchy for the Uganda case was actually presented during one of the monthly meetings. The participants did not make particular comments on the selected objectives and attributes, with the exception of asking for a better alignment of the framework with the PPREs. This has been addressed by reviewing the basic principles of PPREs and linking them to the identified objectives. Attribute selection was primarily driven by existing data without performing direct field measurements, preferring proxy attributes on natural attributes when data was poor. In Figure 16, the final objectives' hierarchy and attributes for the specific decision context in analysis are shown. The reviewed fundamental objectives were structured in four main groups under four highest-level objectives: "high safety for the refugee community" (Objective 1), "high reliability of the raw water quantity" (Objective 2), "high acceptance and integration of refugees in the host community" (Objective 3) and "low cost" (Objective 4). The data sources used for computing the attributes are listed in

Table 14. These sources were mainly satellite imageries, data from the Uganda Bureau of Statistics and local data collected through reports provided by the Victoria Water Management Zone. Attributes related to Objective 1 and 3 were manly computed by using global and open data while attributes related to Objective 2 and 4 required the use of local data.

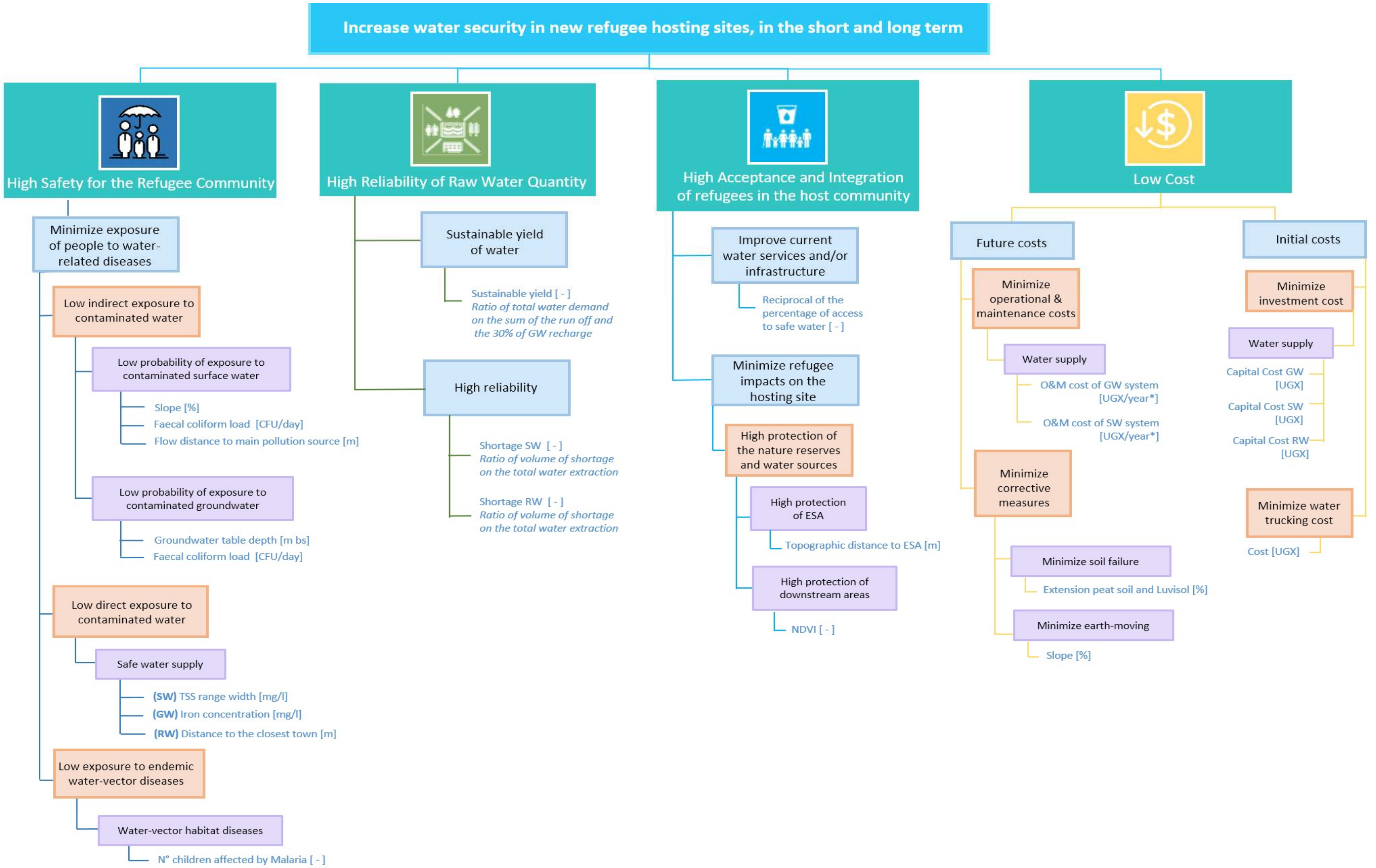

Figure 16. Objectives' hierarchy for the Ugandan decision problem in analysis

Table 14. Attributes and data sources for the Ugandan decision-making process

	Object.	ID	Attributes	Unit measure	Data	Source
High safety for the refugees community	1. Low probability of exposure to contaminated *surface water*	**1**	Slope	%	Slope map Shapefile elaborated from: Global Multi-resolution Terrain Elevation Data 2010 (GMTED2010) (15 arc-sec resolution)	(Danielson & Gesch, 2011) Downloaded from: https://earthexplorer.usgs.gov/
		2	Total faecal coliform produced in the area that drain toward the investigated location	Kg/day	• Population (spatial distribution); • Livestock (spatial distribution); • Human and animal fecal emission per day [CFU/day];	• (WorldPop, 2010) • (FAO, 2010) • (UNEP, 2016) and (FAO, 2003a)
		3	Topographic distance to the highest pollution source (the pixel with the highest fecal coliform load in the drainage area)	Meter	Spatial distribution of the fecal coliform produced by human and livestock emission (cattle, pig, chicken, goat and sheep). The shapefile was created using the data listed in the above attribute.	
	2. Low probability of exposure to contaminated *groundwater*	**4**	Total fecal coliform produced in the area given by the intersection between river basin and aquifer boundary	Kg/day	• Spatial distribution of the fecal coliform produced by human and livestock emission (cattle, pig, chicken, goat and sheep); • Global aquifer boundaries;	(WHYMAP, 2006) Downloaded from: https://produktcenter.bgr.de/terraCatalog/OpenSearch.do?search=whymap+shape&type=/Query/OpenSearch.do
		5	Groundwater table	Meter below surface	Static groundwater table depth (spatial distribution). The shapefile was elaborated from water level measures in different locations of the catchment.	• VWMZ (2016) • UNHCR (2018) for Nakivale settlement
	3. Safe water supply from *surface water* sourcing	**6**	Range size (Max-Min) of the TSS	mg/l	Max and min TSS values over a year in Rwizi river, lake Nakivale and lake Kijanebalola (discrete data)	• NWSC (2018) for Rwizi river • Nsamizi (2018) for lake Nakivale • (Ministry of Water and Environment (MWE), 2013) for lake Kijanebalola
	4. Safe water supply from *shallow groundwater* sourcing	**7**	Iron concentration	mg/l	Iron concentration shapefile (spatial distribution)	(Arup, 2014)

	5. Safe water supply from *rain water* sourcing	**8**	Topographic distance to towns	Meter	Point shapefile of the towns	Uganda Bureau of Statistics (2016)
	6. Low exposure to water-vector habitat diseases	**9**	n. people affected by Malaria	Number	Number of children affected by Malaria per region	(Uganda Bureau of Statistics, 2016)
High reliability of water quantity	7. Sustainable yield of water	**10**	Ratio of total water demand in the area that drain toward the investigated location to the sum of the catchment yield (CY) and 30% of the groundwater recharge (GW_R) $\frac{Water\ demand}{CY + 0.3 * GW_R}$	-	• Water demand (spatial distribution); • Catchment yield; • Groundwater recharge;	• Water Demand comp. (Appendix (2)) • Water Balance Model (Appendix 0)
	8. High reliability of *surface water* source	**11**	Ratio of the volume of shortage to the water extraction from surface water $\frac{(Volume\ of\ shortage)_{SW}}{(Water\ extraction)_{SW}}$	-	1. Daily discharge time series data of the river Rwizi; 2. Projected water demand (WD of newly arrived refugees + future WD of host community + water gap); 3. Percentage of extraction from surface water;	1. VWMZ (2016) 2. Water Demand comp. (Appendix (2)) 3. User variable
	9. High reliability of *rainwater* source	**12**	Ratio of the volume of shortage to the harvested rainwater $\frac{(Volume\ of\ shortage)_{RW}}{Harvested\ RW}$	-	1. Precipitation time series from 1979 to 2009 (spatial distribution); 2. Projected water demand (WD of newly arrived refugees + future WD of host community + water gap); 3. Percentage of water collected from RW;	1. (Beck, Van Dijk, Levizzani, Vincenzo Schellekens, Jaap Miralles, Diego G. Martens, & De Roo, 2017) 2. Water Demand comp. (Appendix (2)) 3. User variable
High acceptance and integration of	10. High protection of the natural reserve and water sources	**13**	Average value of the Normalized difference Vegetation Index (NDVI) in a buffer area	-	1. NDVI raster data; 2. Buffer area.	1. (Didan, 2015) downloaded from: https://lpdaacsvc.cr.usgs.gov/appeears/task/area 2. User variable
		14	Topographic distance to protected areas	Meter	Protected areas in RWIZI catchment	VWMZ (2018)

	11. Improve current water services and/or infrastructures	**15**	Reciprocal of the percentage of access to safe water $\frac{1}{access\ to\ safe\ water}$	-	Access to safe water per villages	(Ministry of Water and Environment, 2017)
Low Cost	12. Minimize investment cost of the groundwater supply	**16**	Inv. Cost GW = Solar power supply system cost+ Borehole construction cost + Distribution system cost	USh UGX	1. Projected water demand (WD of newly arrived refugees + future WD of host community + water gap); 2. Percentage of extraction from groundwater; 3. Static water table depth (spatial distribution); 4. Inventory cost;	1. Water Demand comp. (Appendix (2)) 2. User variable 3. VWMZ (2016) and UNHCR (2018) for Nakivale settlement 4. UNHCR 2016, 2018
	13. Minimize investment cost for the surface water supply	**17**	Inv. Cost SW = DWTP cost + Transmission line cost + Distribution line cost	USh UGX	1. Projected water demand (WD of newly arrived refugees + future WD of host community + water gap); 2. Percentage of extraction from surface water; 3. Water bodies map; 4. BOQs	1. Water Demand comp. (Appendix (2)) 2. User variable 3. (WRMD Ugandan government, 2017) 4. (IOM, 2016) and UNHCR 2016, 2018
	14. Minimize investment cost of the rainwater supply	**18**	Inv. Cost RW harvesting system	USh UGX	1. Projected water demand (WD of newly arrived refugees + future WD of host community + water gap); 2. Percentage of water collected from RW; 3. BOQs	1. Water Demand comp. (Appendix (2)) 2. User variable 3. UNHCR 2016, 2018
	15. Minimize water trucking cost	**19**	Cost Water Trucking	USh UGX	1. Projected water demand (WD of newly arrived refugees + water gap); 2. Water bodies map; 3. Inventory cost;	1. Water Demand comp. (Appendix (2)) 2. User variable 3. UNHCR 2016, 2018
	16. Minimize O&M cost of groundwater supply[2]	**20**	Maintenance cost of the solar panels system	USh UGX	1. Projected water demand (WD of newly arrived refugees + future WD of host community + water gap); 2. Percentage of extraction from surface water; 3. Inventory cost;	1. Water Demand comp. (Appendix (2)) 2. User variable 3. UNHCR 2016, 2018
	17. Minimize O&M cost of surface water supply[1]	**21**	Energy cost of the DWTP	USh UGX	1. Projected water demand (WD of newly arrived refugees + future WD of host community + water gap);	1. Water Demand comp. (Appendix (2)) 2. User variable

[2] The estimation cost refers to the PV

				2. Percentage of extraction from surface water; 3. Inventory cost;	3. (IOM, 2016)
	22	Slope	%	Slope Map (spatial distribution)	(Danielson & Gesch, 2011)
18. Minimize corrective measures	**23**	% peat soils + % luvisol in the buffer area	%	Soil Map	(FAO, 2009) Downloaded from: http://www.fao.org/soils-portal/soil-survey/soil-maps-and-databases/harmonized-world-soil-database-v12/en/

4.2.3 Step (3) Generating Alternatives and defining portfolios

The alternatives were identified according to different combinations of three decision variables (Table 15), which are: (i) refugee hosting site, (ii) number of refugees to allocate in each site, and (iii) percentage of water extracted from surface water (SW), groundwater (GW) and rain water (RW). These decisional variables were selected to investigate in the PDA model both the optimal number of refugees to allocate in each explored location and the efficient use of available water resources to meet the water demand of the newly arrived refugees and projected local population.

According to the request of the government to explore refugee allocation solutions into the Rwizi basin, we selected three locations, presented in Table 15 and already discussed in the definition of the decision-making context (paragraph 4.2.1).

The number of newly arrived refugees to allocate in each investigated site was calculated as a percentage of the total refugee influx (% *refugees*). This means, for example, that if a total refugee influx of 10,000 people is expected, a '% *refugees'* of 50 in location A corresponds to the accommodation of 5000 refugees in that particular site (Table 15). This framework setting allows decision-makers to analyse different scenarios by modifying only the total influx of refugees.

The additional amount of water extracted from each water source in the site depends on the number of refugees that will be there allocated. Therefore, we distributed the amount of water extracted over the different water sources through a percentage (GW%, SW% and RW%). Due to the high variability of rainwater during the seasons, we set the upper limit of the rainwater percentage interval to 20 (Table 15).

Each alternative was made by: location (*A*, *B* or *C*) + percentage of newly arrived refugees to allocate in that location (*% refugees* (0, 25, 50, 75, 100) of the total refugee influx) + percentage of water sources' usages (*GW% +SW% + RW%).* In the generation of the alternatives, we also considered the case in which no refugee is allocated in the investigated locations (% *no. refugees* equal to 0). In this case, we assessed the identified criteria only looking at the water gap in the host community and the projected domestic water demand in the next 15 years.

Table 15. Decision variables used to identify alternatives

Decision variables	
Location	A: Mbarara town B: Nakivale Settlement C: Lake Kijanebalola in Rakai district
% refugees	0, 25, 50, 75, 100 (%)
% water sources' usages	Groundwater :0,10,20,30,40,50,60,70,80,90,100 (%) Surface water :0,10,20,30,40,50,60,70,80,90,100 (%) Rainwater :0,10,20 (%)

An algorithm was written to automatize the generation of the alternatives. This algorithm creates all possible combinations of the decision variables generating 450 decision alternatives. To help the reader in understanding how decisional variables were combined to generate alternatives, we provide two examples from the decision matrix in Table 16:

Example 1. In alternative 'A1', no refugees are accommodated in location A and the expected water demand (which refers only to the projected local population) is entirely extracted from the groundwater source.

Example 2. In alternative 'B24', 25% of the total influx of refugees is allocated to site B and the new and projected water demand (both of new refugees and host community) is met by withdrawing 90% of the total water extracted from surface water bodies and collecting 10% from rainwater harvesting.

Table 16. Excerpt of the decision matrix

Water Sources' usages			% new refugees/location														
SW	GW	RW	0			25			50			75			100		
			A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
0	100	0	A1	B1	C1	A13	B13	C13	A25	B25	C25	A37	B37	C37	A49	B49	C49
10	90	0	A2	B2	C2	A14	B14	C14	A26	B26	C26	A38	B38	C38	A50	B50	C50
20	80	0	A3	B3	C3	A15	B15	C15	A27	B27	C27	A39	B39	C39	A51	B51	C51
30	70	0	A4	B4	C4	A16	B16	C16	A28	B28	C28	A40	B40	C40	A52	B52	C52
40	60	0	A5	B5	C5	A17	B17	C17	A29	B29	C29	A41	B41	C41	A53	B53	C53
50	50	0	A6	B6	C6	A18	B18	C18	A30	B30	C30	A42	B42	C42	A54	B54	C54
60	40	0	A7	B7	C7	A19	B19	C19	A31	B31	C31	A43	B43	C43	A55	B55	C55
70	30	0	A8	B8	C8	A20	B20	C20	A32	B32	C32	A44	B44	C44	A56	B56	C56
80	20	0	A9	B9	C9	A21	B21	C21	A33	B33	C33	A45	B45	C45	A57	B57	C57
90	10	0	A10	B10	C10	A22	B22	C22	A34	B34	C34	A46	B46	C46	A58	B58	C58
100	0	0	A11	B11	C11	A23	B23	C23	A35	B35	C35	A47	B47	C47	A59	B59	C59
0	90	10	A12	B12	C12	A24	B24	C24	A36	B36	C36	A48	B48	C48	A60	B60	C60
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

The alternatives were identified for two different scenarios: expected and extreme situation (Table 17). The expected scenario was elaborated from the risk analysis carried out by UNHCR, which predicted the arrival of 10,000 refugees from the DRC in the upcoming months. An extreme scenario was generated by tripling the expected refugee influx number. According to the two scenarios, the decision variable relating to the number of refugees per location is shown in Table 18.

Table 17. Scenario analysed in the portfolio framework

Current scenario	Only one refugee settlement (Nakivale) is present in the catchment Rwizi. There, water demand is not yet met and water trucking is in place to meet the gaps; Considering the current population and projection over 15 years, the current and future water security in the analysed hosting sites is estimated;
Expected situation	10,000 refugees coming from the DRC;
Extreme situation	30,000 refugees.

Table 18. Decision variable: no. of refugees per location

	Scenario 1 (refugee influx: 10,000)	Scenario 2 (refugee influx: 30,000)
no. of refugees	0, 2500, 5000, 7500, 10000	0, 7500, 15000, 22500, 30000

Then, decision alternatives were grouped. The portfolio selection (p) was based on two constraints:

1. Each portfolio includes three alternatives each with a different refugee-hosting site (i.e. alternative 1 is made by location A, alternative 2 by location B and alternative 3 by location C)
2. The sum of the newly arrived refugees in the three alternatives of each portfolio is equal to the total refugee influx (%refugees A + %refugees B + %refugees C= 100%);

Constraint 1 is related to the specific construction of the set of decision alternatives. This includes also alternatives in which no refugees are allocated in the investigated locations and hence, water security criteria are assessed based on the current situation. Constraint 2 is applied to allocate exactly the total amount of newly arrived refugees, in line with the UNHCR humanitarian imperative to provide shelters to all persons of concern. According to these constraints, 405,000 feasible portfolios were identified for each scenario.

This particular frame of the problem helps us to explore different refugee allocation solutions. Specifically, we create portfolios in which refugees are all allocated to one site or are distributed on different sites.

4.2.4 Step (4) Consequence vector

Subsequently, according to step 4 the attributes' values for each alternative were computed through the SNARA - Programming Algorithm. This lead to the computation of 18 attributes for all 450 alternatives, considering respectively the expected and the extreme scenario (for details related to attribute computation, see Appendix J). In some cases, it was not possible to aggregate attribute values until the second-level objectives. This happened for some of the proxy attributes which have different unit measures per different sub-level objectives. For example, the second-level objective "low future cost" was broken down into four sub-level objectives: (1) 'minimize the O&M cost of the GW system', (2) 'minimize the O&M cost of the SW system', (3) 'minimize soil failure' and (4) 'minimize earth moving'. For the first two sub-objectives we selected Cost as natural attribute. This allowed us to aggregate the attributes by summing them and, hence, obtaining an attribute value for the second-level objective: 'minimize O&M cost of the water system'. However, we could not make the same for criteria 3 and 4 as the related attributes are %peat soil and %slope, which values cannot be aggregated. Therefore, we had to elicit incomplete preference also for some third-level objectives.

4.2.5 Step (5) Preference elicitation

In this step, the value functions and weights for each criterion were defined. The results from both processes are shown in the sections below.

(1) Value functions

Linear scoring functions over attribute range were used when decision-makers' preferences were unknown. Bounded scales on the attribute values were adopted when it was possible to extract particular preferences from UNHCR-guidelines (Table 19). The linear scoring functions were computed over full ranges of the measurement scales consisting of values from the expected and extreme scenarios. These functions transformed attribute levels to a neutral scale between 0 and 1. A higher bound of 0.95 was set for all scoring function to ensure that all attributes' values fit in this range. An example of linear scoring function is shown in Figure 17. All the value functions are presented in Appendix K.

Table 19. Preferences on attribute values

ID	Attribute	Preference on the attribute values	Source
5	Groundwater table (m bs)	*The groundwater table should be a minimum of 3 m below the surface of the site*	(UNHCR, 2007)
7	Iron concentration (mg/l)	*The drinking water standard for iron is 0.3 (mg/l)*	(WHO, 1996)
22	Slope (%)	*The whole site should be located above flood prone areas, preferably on gentle (2 to 4%) slopes. Sites on slopes steeper than 10% gradient are difficult to use and usually require complex and costly site preparations. Flat sites present serious problems for the drainage of waste and storm water.*	(UNHCR, 2007)

For attribute 5 and 7, the value functions over the continuous measurement scale were linear and decreasing up to a lower bound which the value function was constantly 0. This means that beyond the bound, every value was considered inacceptable for the decision-makers (Figure 18). For criteria 22 the scoring values were equal to 0.95 for a certain range, after which the value function decreases linearly. The non-monotonic trend of the functions could be avoided by splitting the value function into monotonic lower level of objectives (Eisenfuhr, Weber, & Langer, 2010; R.L. Keeney, 1981) (e.g. the objective could be split in "high drainage in the site" resulting in an increasing value function with the slope and "reduce soil erosion" resulting in a decreasing value function).

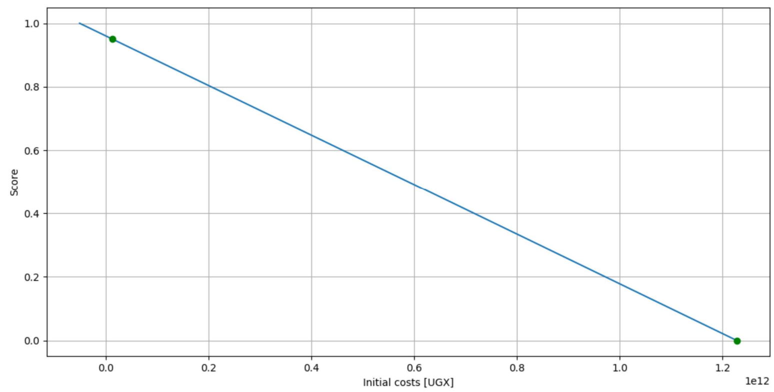

Figure 17. Function for scoring initial costs (the green dots represent the range of the measurements)

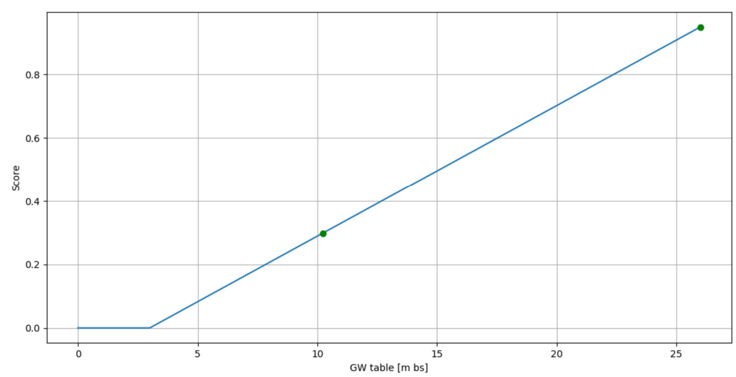

Figure 18. Function for scoring GW table (the green dots represent the range of the measurements)

(2) Weights

In this step, we elicited incomplete information about the criterion weights. Based on the information acquired through face-to-face interviews and surveys, a rank order of second-level objectives was constructed (Table 20). The questionnaire and the interviews showed that the *reliability of raw water quantity* was the most important criteria. In the questionnaire, its priority score in the overall value was higher than the score of any other criterion (Figure 10, Chapter 3.2). The next two in the survey were *sustainable yield of water* and *low future cost*. *Low direct* and *indirect exposure to contaminated water* and *low exposure to endemic water-related diseases* were included in the top-5 of the highest priority objectives list by almost all respondents at the UNHCR-HQ. No stance was taken on their mutual ordering. Therefore, they were arbitrarily ranked. *Low initial cost* was considered relevant by few at the UNHCR-HQ. However, the implementation of the refugee response is strongly limited by the initial budget, which is perceived insufficient by many UNHCR members working in the fields. *Minimize refugee impact on the hosting site* and *improve current water services and/or infrastructures* were the two least important criteria.

Incomplete preferences were elicited from the survey only for second-level objectives. We found indeed difficult to elicit preferences regarding higher or lower level objectives, because they are respectively too generic and too specific. However, we had to construct weights of third-level objectives due to the selection of proxy attributes (see sub-paragraph 'Step (4)', in Results). No stance was taken according the ordering of these third-level objectives, but the sum of their weights cannot be higher than the weight applied to the related second-level objective. Therefore, we applied weight constraints to the sum of their weights (Table 21).

Table 20. Rank ordering

Rank order	Objectives
1.	High reliability of the raw water quantity
2.	Sustainable yield of water
3.	Low future cost
4.	Low direct exposure to contaminated water
5.	Low indirect exposure to contaminated water
6.	Low exposure to endemic water-related diseases
7.	Low initial cost
8.	Minimizing refugee impacts on the hosting site
9.	Improve current water services and/or infrastructures

Table 21. Weight constraints of lowest level objectives

Objectives	4th /5th level objectives	Weight constraints
3) Low future cost	3a. O&M cost	$w_3 \geq w_{3a} + w_{3b} + w_{3c}$
	3b. Minimize earth moving	
	3c. Minimize soil failure	
5) Low indirect exposure to contaminated water	4a. Low raw SW quality variability over a year	$w_4 \geq w_{4a} + w_{4b} + w_{4c}$
	4b. High raw GW quality	
	4c. High raw RW quality	
5) Low indirect exposure to contaminated water	5a. Low SW vulnerability to contamination	$w_5 \geq w_{5a} + w_{5b} + w_{5c} + w_{5d} + w_{5e}$
	5b. High SW drainage	
	5c. Maximize distance to pollution source	
	5d. Low GW vulnerability to contamination	
	5e. Low hazards of GW contamination	
8) Minimizing refugee impacts on the hosting site	8a. High protection of ESA areas	$w_8 \geq w_{8a} + w_{8b}$
	8b. High protection of downstream areas	

The feasible weight set was defined as follows:

$$S_w = \{ w_1 \geq w_2 \geq w_n, \forall n = 1, \ldots, 9;\ w_3 = w_{3a} + w_{3b} + w_{3c} \geq w_k, \forall k = 4, \ldots, 9;\ w_4 = w_{4a} + w_{4b} + w_{4c}, \forall k = 5, \ldots, 9;\ w_5 = w_{5a} + w_{5b} + w_{5c} + w_{5d} + w_{5e} \geq w_k, \forall k = 6, \ldots, 9;\ w_8 = w_{8a} + w_{8b} \geq w_9 \} \quad (4)$$

Rank ordering weighting (ROC) method was used to identify criteria weight vector. More specifically, a feasible weight set (w) was constructed from the incomplete rank order of the criteria (Table 20), from which approximations for criteria weights were calculated by using Equation 1 (Table 22). Weight for sub-level objectives were identified applying the constraints showed in Equation 4 and considering equal preferences among sub-level objectives (column 3 of Table 22).

Table 22. Weight vector using ROC method

ID	Weight	Weight for sub-level objectives	
$\boldsymbol{w_1}$	0.314		0.314
$\boldsymbol{w_2}$	0.203		0.203
$\boldsymbol{w_3}$	0.148	w_{3a}	0.0493
		w_{3b}	0.0493
		w_{3c}	0.0493
$\boldsymbol{w_4}$	0.111	w_{4a}	0.037
		w_{4b}	0.037
		w_{4c}	0.037
$\boldsymbol{w_5}$	0.083	w_{5a}	0.0166
		w_{5b}	0.0166
		w_{5c}	0.0166
		w_{5d}	0.0166
		w_{5e}	0.0166
$\boldsymbol{w_6}$	0.061		0.061
$\boldsymbol{w_7}$	0.042		0.042
$\boldsymbol{w_8}$	0.026	w_{5d}	0.013
		w_{5d}	0.013
$\boldsymbol{w_9}$	0.012		0.012

4.2.6 Step (7) Analysing portfolio

As a result of the large numbers of portfolio, an individual study on each possible portfolio was not feasible. Two different methods were applied. In the first one, we assumed complete preference elicitation and we adopted the linear-additive value model by using the ROC method for weights generation. In the second method, we used the robust portfolio modelling (RPM) methodology, which enables analysis of portfolios when there is incomplete information about stakeholder preferences. Both approaches are presented further in the following sections.

Approach 1 – Maximizing portfolio value

According to the first approach, we assumed that the weights computed with the ROC method are exact. Consequently, the solution of the portfolio model was acquired by maximizing portfolio value or, more specifically $\max V(p_z, w, v)$ where z represents the set of feasible portfolios. The results for scenario 1 and 2 are shown in Table 23 and in Table 24. In the latter table, it is possible to compare the criteria score against the target values (maximum criteria values on all portfolios' criteria scores).

Table 23. Maximum portfolio value on all feasible portfolios, with the assumption of complete preference elicitation

Locations	Scenario 1				Scenario 2			
	n. refugees	% water extracted/collected			n. refugees	% water extracted/collected		
		GW	SW	RW		GW	SW	RW
A	5000	100	0	0	30000	90	10	0
B	5000	70	30	0	0	70	30	0
C	0	60	40	0	0	60	40	0

Table 24. Criteria' scores of the portfolio that maximize all feasible portfolios. The targets are the maximum criteria scores on all portfolios.

	Reliable raw water quantity 1	Sustainable Yield 2	Low Future Costs 3	Low direct exposure 4	Low indirect exposure 5	Low exp. to water-vector diseases 6	Low Initial Costs 7	Minimize refugees' impact 8	Improve local water services 9
Scenario 1	0.8958	0.2324	0.3122	0.1222	0.1147	0.1151	0.0827	0.0374	0.0140
Target 1	0.8958	0.2345	0.3414	0.1239	0.1206	0.1151	0.1194	0.0410	0.0140
Scenario 2	0.8958	0.2254	0.3112	0.1265	0.1218	0.1151	0.0835	0.0425	0.0141
Target 2	0.8958	0.2284	0.3473	0.1282	0.1271	0.1151	0.1194	0.0452	0.0144

However, one could argue that identifying the portfolio solution on all feasible portfolios is misleading. This is because also a portfolio that underperforms on some attributes could be selected as a viable portfolio solution if only one of the criteria scores high enough to compensate the low performance of the others.

To avoid this mistake, dominated alternatives need to be excluded from the analysis. An alternative A dominates another alternative B, if A outperforms B on at least one attribute and performs equally on all others (Scholten, Maurer, & Lienert, 2017). A programming algorithm was created for solving all non-dominated portfolios at attribute level. With 405,000 portfolios and 9 attributes, the effort in performing pairwise comparisons on the attribute level is unsustainable at computation level. To simplify the problem, portfolios were sorted according to their performance on each criterion, obtaining a matrix with nine columns (number of attributes) and 405,000 rows (number of portfolios). Portfolios that outperform on a certain criterion were located in the last rows of a matrix. The range comprising non-dominated portfolios was set by an iterative process, in which the frequency of each portfolio in the range itself was computed. When this was equal to nine (number of attributes), the set range comprised portfolios which criteria scores were higher for at least one attribute and equally high for all others. In scenario 1, a frequency equal to nine was reached considering a range which goes from row 205,000 to 405,000, with a number of feasible portfolios equal to 617. In scenario 2, instead, it was needed to expand the range discarding only the first 135,000 rows identifying 923 non-dominated portfolios. Using again the assumption of complete preference elicitation, the portfolio that maximize the set of non-dominated portfolios is shown in Table 25 for scenario 1 and 2. The respective attribute scores are shown in Table 26.

For the sake of simplicity, we call the portfolios that maximize the set of feasible portfolios as Portfolio 1a and Portfolio 2a, respectively for the expected and extreme scenarios. While, portfolios that maximize the set of non-dominated portfolios is named Portfolio 1b and Portfolio 2b.

Comparing attribute scores from the two different approaches (Table 24 and Table 26), the attribute value for the criteria 'sustainable yield' scores higher in portfolio 1b. The same applies for 'low indirect exposure to contaminated water' and 'minimise refugee impacts'. However, Portfolio 1b underperforms compare to Portfolio1a for the attributes 3, 4, 7 and 9. For scenario 2, instead, Portfolio 2b outperform on Portfolio 2a for criteria 2, 4 and 8 and underperforms for the remaining with the exception of criteria 6. It is also important to highlight the occurrence of a water sources' usage for which water is extracted only from groundwater source (GW=100%) in both Portfolio 1a and Portfolio 1b.

Table 25. Maximum portfolio value on non-dominated portfolios, assuming complete preference elicitation

Locations	Scenario 1				Scenario 2			
	n. refugees	% water extracted/collected			n. refugees	% water extracted/collected		
		GW	SW	RW		GW	SW	RW
A	0	100	0	0	0	100	0	0
B	0	90	10	0	0	100	0	0
C	10,000	50	50	0	30,000	60	20	20

Table 26. Criteria' scores of the portfolio that maximize non-dominated portfolios. The targets are the maximum criteria scores on all portfolios.

	Reliable raw water quantity 1	*Sustainable Yield 2*	*Low Future Costs 3*	*Low direct exposure 4*	*Low indirect exposure 5*	*Low exp. to water-vector diseases 6*	*Low Initial Costs 7*	*Minimize refugees' impact 8*	*Improve local water services 9*
Scenario 1	0.8958	0.2339	0.3068	0.1218	0.1177	0.1151	0.0789	0.0410	0.0139
Target 1	0.8958	0.2345	0.3414	0.1239	0.1206	0.1151	0.1194	0.0410	0.0140
Scenario 2	0.7667	0.2278	0.3069	0.1282	0.1189	0.1151	0.0692	0.0446	0.0080
Target 2	0.8958	0.2284	0.3473	0.1282	0.1271	0.1151	0.1194	0.0452	0.0144

Due to the large problem size, the performance of all feasible portfolios was investigated only under the four highest-level objectives: high safety for the refugee community (Criteria 1), high reliability of raw water quantity (Criteria 2), high acceptance and integration of refugees in the host community (Criteria 3) and, low costs (Criteria 4). Attribute scores of second-level objectives were hence, aggregated considering equal weights.

To analyse how results are affected by the set-up of the model, all feasible portfolios were plotted on different criteria space. A marked arrangement of the points on linear trends can be observed in all plots (Figure 19). This can be explained by the variability of the portfolio performance on each criterion. Portfolios that only vary by water sources' usages (or also called water-use mix; %GW, %SW and %RW) show different attribute values in Criteria 4 and 2 but equal values for Criteria 1 and 3. The attribute scores of the latter depend, indeed, only on number of refugees and location (for clarify look at Figure 12). Looking at Figure 19a, as Criteria 4 increases, Criteria 2 and 3 decreases. This means that Criteria 4 conflicts with the other two (the contraposition is more marked for Criteria 4 and 2 than Criteria 4 and 3). The conflict between Criteria 4 and 3 is related to the water gap (target water demand – current extraction), the increase of which results in an increase of the water trucking cost and of the marginal return of investments for improving current water services. On the same line, Criteria 2 increases because the current water extraction is low.

With an increase in the no. of refugees allocated in a site, attributes' scores for both Criteria 2 and 4 underperform. However, if only the water use mix changes and, particularly water is extracted only from SW and RW harvesting, the attributes' values decrease for Criteria 2 while are equal or higher for Criteria 4 due to the low cost of RW collection systems. More clearly, this can be seen in Figure 20b, where the non-dominated portfolio scores of high reliability were plotted against initial and future cost scores. The portfolio criteria scores are shown only referring to scenario 1 as scores from scenario 2 showed similar results with slight change at the range.

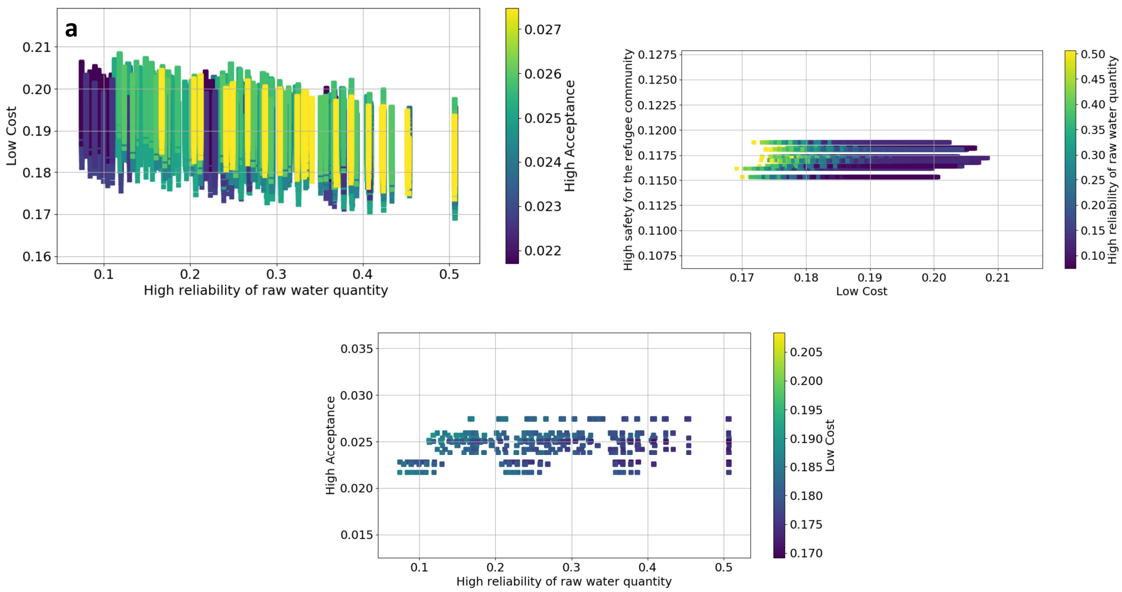

Figure 19. Plots of feasible portfolios on different criteria dimensions

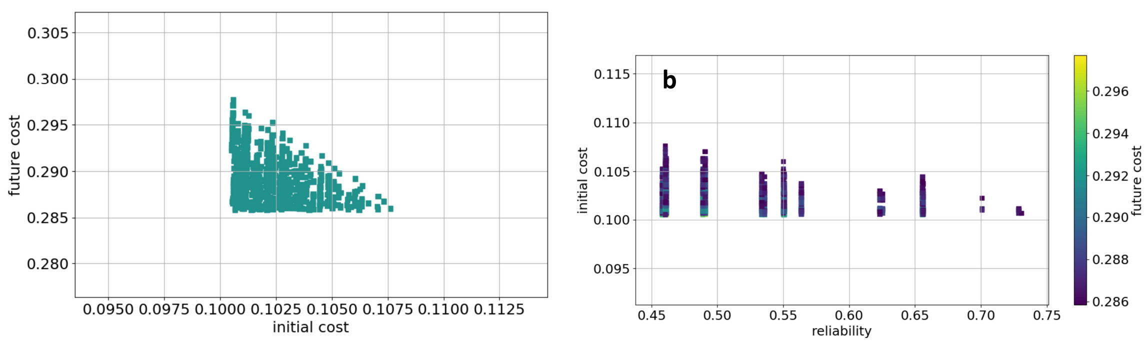

Figure 20. Plots of non-dominated portfolios on different sub-criteria dimensions

Approach 2 – Robust Portfolio Modelling

In the second approach, we identified the set of efficient portfolios through the use of RPM-Decisions software in collaboration with the department of Mathematics and Systems Analysis of Aalto University, Helsinki. The robust portfolio modelling (RPM) methodology enabled the analysis of portfolios considering incomplete information about stakeholder preferences. The Core Index values computed by the software allowed us to identify the alternatives present more often in the set of efficient portfolios. An alternative which is present in all efficient portfolio has the core index equal to 1 (core alternative). Contrarily, the alternative which is present in no efficient portfolio has the core index 0 (exterior alternative). Alternatives with core index in the range (0,1) are called borderline alternatives. According to Ollila, 2013, the core indices provide a clear decision recommendation: "select core actions, discard exterior actions and analyse the borderline actions further".

In the analysis, the number of alternatives was reduced from 450 to 150 considering a less dense discretization of the water-use mix (GW and SW% = [0,10,20,50,70,100]) to reduce problem size. Furthermore, preference information was added to the analysis (Equation 4, Section 4.2.5) to restrict the values of possible attribute weights.

The RPM-Decisions application shows quite conclusive results (Figure 21). For location A only eight alternatives present a core index greater than 0 and among them six present a value greater than the average. The same apply for location B and C. These results are more evident in Scenario 2 where the number of exterior alternatives reduce. In specific, the option of allocating part of the refugee influx to site A has the highest core index values and only two water-use mixes dominate in the borderline alternatives (10% SW - 70% GW - 20% RW and 70% SW - 10% GW – 20% RW).

With a closer glance at Figure 21, we can see that:

- The core index value for scenario 2 varies on a larger range. Even so, no core alternatives can be identified from the analysis. Alternatives that are comprised in the efficient portfolios in scenario 1 are also contained in the efficient portfolios set of Scenario 2. Alternatives in which water is extracted only from one or two sources are considered exterior alternatives by the software, with the exception of the alternative in which 30,000 refugees are allocated in C;

- Alternatives in which 2,500 refugees are allocated in A using 70% SW, 10% GW and 20% RW has the highest score index in Scenario 1. While for scenario 2, the allocation of no refugees in location A scores highest with a discretization of the water extraction over the water sources equal to 70% SW, 10% GW and 20% RW (the same for Scenario 1);

- Alternatives in which all refugees are allocated in one location are exterior alternatives. This excludes from the set of efficient portfolios also the alternatives in which no refugees are allocated in the other two remaining locations. Therefore, in efficient portfolios, the total number of refugees per scenario need to be partitioned among two or three locations;

- Alternatives that include the current government allocation strategy (B10,000) are mainly exterior alternatives. The only borderline alternative is the one that consider a water use mix equal to (10% SW - 70% GW - 20% RW). However, its core index is quite low compared to the average.

Figure 21. Core index values for Scenario 1 (on the left) and Scenario 2 (on the right). Each alternative is label as the combination of the decision variables: (location) + (n. refugees) + (SW%-GW%-RW%)

4.3 Discussion

In this second part of the research, we applied the SNARA objectives hierarchy to the decision problem of allocating newly-arrived refugees in south-western of Uganda. The structuring process was then followed by a PDA model, whereby we analysed possible combination alternatives. Below, we discuss some steps of the adopted PDA framework.

Define objectives and attributes

Objectives from the SNARA hierarchy were reviewed according to direct observations of the decision context and water security issues, semi-structured interviews and, a formal presentation of the final hierarchy in one of the monthly meeting of the UNHCR operational team in Kampala. However, there were no much interaction and engagement of the stakeholders in reviewing the hierarchy. We hence think that a workshop could have been more effective in getting feedback.

The selection of attributes was driven by the decision context and the available data. Given the lack of hydrological data, proxy attributes were adopted rather than natural attributes. However, proxy attributes do not directly describe consequences, complicating the preference elicitation of the decision-makers (Eisenfuhr, Weber, & Langer, 2010; Ralph L. Keeney & Gregory, 2005). Therefore, we think that direct measurements could have improved both the selection of the attributes and the reliability of their values.

Poor data on groundwater did not allow us to estimate the reliability of this water source in supplying water to new refugee sites. Simulation of groundwater volumes could have been useful to assess consequences and trade-off. However, we decided to omit this objective from the study due to the time constraints in this research and hence, we explicated value-based choices, related only on the available information.

Global and open data sources were used to assess some of the selected attributes. Once these data were identified the computation of the attributes took a short time, with the exception of the assessment of the catchment yield and the groundwater recharge. These required a high computational effort through the development of a semi-distributed hydrological model based only on global data.

According to Gregory et al., 2012, people cannot keep track of more than 10 objectives. If more objectives are necessary, they can be grouped in sub-objectives. Following this concept, the reviewed objectives hierarchy for the specific case study presents four highest-level objectives and seven second-level objectives. In order to better elicit stakeholders' preferences, the portfolio analysis was based on second-level objectives. However, due to the selection of proxy attributes, it was not always possible to aggregate attribute values at second-level objectives, which resulted in comparing portfolios' performances according to 18 objectives. This is against the condition of conciseness (Eisenfuhr, Weber, & Langer, 2010; Gregory et al., 2012; Ralph L. Keeney & Raiffa, 1993), complicating the analysis of the results. Better results could be achieved by selecting natural attributes and, hence, by improving the used data sources with direct measurements.

Preference elicitation

In this PDA application, value functions and weights were determined according to incomplete preference elicitation (short explanation in Eisenfuhr, Weber, & Langer, 2010). Imprecisions on preferences arise uncertainties on both shapes of values and weights. Methods to elicit value functions such as difference standard sequence technique and the bisection method can help in reducing this uncertainty (Eisenfuhr et al., 2010; Gregory et al., 2012). The same applied for the determinations of weights, where systematic methods such as the trade-off method and the SWING method (Eisenfuhr et al., 2010; Gregory et al., 2012) can better help in defining stakeholder preferences by comparing alternatives. If complete preferences cannot be captured, a sensitivity analysis can be applied to understand how changes in the value functions affect the results (Gregory et al., 2012).

The selected aggregation method and preference elicitation techniques can all affect the final result of the model (Gregory et al., 2012; Langhans, Reichert, & Schuwirth, 2014; Mustajoki, 2012; Scholten, Schuwirth, Reichert, & Lienert, 2014). To understand how robust are the obtained results a sensitivity analysis is necessary. This gives a feeling on how the models react on certain approximations.

Analysing portfolio

Using the assumption of complete preference elicitation, solutions in which water is extracted mainly from a GW source are strongly suggested by the model in both scenario 1 and 2, especially for location A. Partition of the total water extraction among water sources prevails in the alternative in which refugees are settled in location C. Portfolios that include alternatives in which RW is collected do no not score high. Different results are instead obtained by the use of RPM-Decisions software, where portfolios with the highest percentage of collected RW are part of the borderline alternatives. The different results obtained in the two analyses can be explained by the different approaches used for structuring the value models. RPM-Decisions software does not use a single weight vector for the computation of the criteria scores but preference ranking information. This allows to identify the set of efficient portfolios for all feasible weights reducing dependency (or bias) of the results on the weight method adopted.

Results dependency from the weight method selection is, hence, clearly noticeable from the comparison of the initial solutions with the RPM ones. This dependency especially affects alternatives in which RW collection is selected. Despite the high savings in total investment and operating costs, a greater dependence on rainwater collection for water supply results in an increase in water scarcity. This results in a poor performance of the analysed alternatives on the criteria: "high reliability of water quantity". This is also the criterion ranked at the first position in the computation of the weight, increasing the sensitivity of the results on the selected weight.

As we are dealing with incomplete information about model parameters, the RPM-Decisions results are more robust than the ones obtained from the simplistic analyses initially showed. The RPM methodology seeks, indeed, to identify robust solutions that in our case perform reasonable well across the full range of feasible weights (Liesiö, Mild, & Salo, 2008). However, the initial results obtained with the assumption of complete preference elicitation allow us to capture model behaviours.

It is also important to highlight another inconsistency in the initial analyses. Changing in the range for the identification of the non-dominated portfolios through ranking method strongly affects the selection of the "optimum portfolio". To test the sensitivity of the result on the range, increasing interval values were used, and respective optimum solutions investigated. In the resulted set of portfolios, the water-use mix varies but the number of refugees for each location remains the same.

From the results of the RPM-software, we can see that the option of distributing refugees in more than one location resulted the one with the highest performance on the investigate water security criteria. Looking back at the set-up of the model, this refuge allocation solution, allows, indeed, to reduce the impact on the natural resources while increasing opportunity for refugee integration and livelihood. In addition, the solution of allocating refugees in an urban setting performs better than the options of increasing the Nakivale refugee settlement or creating a new refugee hosting site. This can mainly be explained by lower investment costs. Furthermore, the current allocation strategy to direct the new influx of refugees to the Nakivale refugee settlement underperforms compare to the other explored solutions. This can be explained by the increase in water extraction due to the current water gaps. This leads to an increase of costs and water shortages. Indeed, the allocation of all refugee influx on only one site increases the pressure on available resources. by However, many are the uncertainty in the model and approximations on data and preferences were made. By comparing the two approaches in the analysis of the portfolios, we can state that results are sensitive to the selected weight method.

Criteria computation and data availability

Looking at the Uganda application, global data were used to compute some of the selected attributes such as vegetation index, slope and peat soil percentages. However, attributes such as "water shortage from SW, GW and RW sources" specifically required the use of local data. These attributes refer to the objective "high reliability of water quantity", which is considered by the stakeholders the objective with the highest priority. Therefore, we can assert that, in this specific framework, it is not possible to provide significant information regarding water security conditions only on the bases of global data.

The solutions obtained from the first approach showed a preference for alternatives with a higher percentage of extraction from GW than from SW. This is because the investment and operational costs for a water supply system based on raw groundwater are less than the ones for SW due to the high treatment cost of the latter. Additionally, the percentage of groundwater use does not affect the performance of the alternatives on the criterion: "high reliability", as we had to discard the criterion of "low water shortage from groundwater source" from the analysis due to lack of data.

The attribute of low exposure to water vector diseases was computed using existing data on the number of children affected by malaria. Due to the low spatial distribution of the data (the highest detail level was the regional scale), the attribute score varies only with the location. Specifically, the attribute score defers with regard to the alternatives having different locations while it is equal with regard to the attribute score of the portfolios. This is because, feasible portfolios comprise all locations (A, B and, C) and hence, the aggregated attribute value is the same for each portfolio.

5. Conclusion and recommendations

5.1 Conclusion

In this study, we suggest a rational framework to support UNHCR WASH (Water, Sanitation and Hygiene) officers in identifying solutions to the refugee allocation problem in data-scarce environments. The presented procedure attempts to help stakeholders to consider different water security criteria simultaneously, while analysing solutions neglected in an initial analysis, mainly due to lack of time in emergency settings. This resulted in (1) the development of a generalizable objectives' hierarchy which comprehensively addresses water security criteria and decision makers' goals and (2) the application of this structure into the portfolio decision analysis (PDA) model to enhance a Sustainable Allocation of Newly Arrived Refugees (SNARA) in south-western Uganda. According to the discussions in paragraphs 3.3 and 4.3, we drew the following conclusions for each research question.

1. How can we develop a generic procedural tool for the SNARA decision problem?

A generic procedural tool for 'Sustainable Newly-Arrived Refugees Allocation' was developed by applying the initial three steps of the structured decision-making (SDM) approach. The approach aimed to clarify the decisional context (step 1), generate the objectives (step 2) and provide guidance on possible attributes and data source for the calculation (step 3).

In step 1, a clear decision-making context helped to think more broadly about the problem of allocating refugees, looking both at the perspective of refugees and host communities. A generic frame of the problem was possible through the engagement of stakeholders from different units of the UNHCR headquarter. The extensive stakeholders' experience on the decision problem in different (political and geographical) settings have, indeed, provided a general overview of the problem under investigations.

In step 2, 36 fundamental objectives were identified based on literature review, face-to-face interviews, and questionnaire survey. These objectives comprehensively address the water security conditions from a development perspective of both refugees and host communities, rather than focusing only on the humanitarian requirements.

In step 3, attributes for the SNARA objectives' hierarchy are suggested together with useful global and open data sources. These aim to help the decision-makers in the application of SNARA hierarchy to a specific case, providing a first insight into the water security conditions in the geographic regions under analysis.

In SNARA decision-making context, we encourage the use of the proposed objectives' hierarchy, but advise others to carefully discuss the relevance of objectives for their specific application. From the application of the SNARA hierarchy to the Ugandan decision-making process, we validated objectives and attributes while showing, in practice, the advantages of structuring the decision by using the SDM approach. The set-up of the SNARA decision problem along the initial SDM steps helps to consider comprehensively all relevant criteria, providing the bases for an open-up thinking that enhances the identification of better and defensible solutions.

2. How can the SNARA decision structure be implemented in the PDA model for a specific case, e.g. Uganda?

For the Ugandan application, we added a PDA model to the SDM structuring process. This was possible by reframing the SNARA problem as a resource allocation process rather than reducing it to a mere site selection process, as usually is done in literature. The refugee hosting site is just one of the variables effecting the water security conditions of newly-arrived refugees. Through the initial SDM steps, we identified the decision variables to which a sustainable allocation of refugees in terms of water security criteria mainly depend. These are: the location, the number of refugees that are settled in each location and the use of the water sources. Refugees can be seen as a resource whose allocation to different hosting sites aims to increase advantages for the host and refugee community (e.g. enhance refugee livelihood, host economy, water services), while reducing environment impacts. Framing the SNARA problem as a resource allocation process does not discard the option of allocating all refugees to a single site. This solution was, indeed, analysed by our PDA model considering the current water security condition. In particular, we generated also the alternatives of not allocating any refugees to the site and allocating the entire refugee influx to the site. By combining these alternatives together, we created one of the analysed portfolios. The PDA framing allowed us to analyse different solutions:

- Allocating refugees in urban areas, expanding an existing camps and creating a new refugee settlement;
- Allocating the newly arrived refugees to one or more sites;
- Holding capacity of the site in analysis;
- Optimal use of the water resources.

3. Which recommendation can we give on the base of the PDA approach in the specific case?

In the Uganda application, results showed that overlooked solutions outperforms over the current allocation strategy. In specific, the scatter of newly arrived refugees in multiple locations of the explored catchment showed the highest scores on availability of water, socio-economic costs and host communities' advantages. The framework provides also suggestion on the optimal repartition of the future water extraction among available water sources, aiming to avoid their depletion while preserving sustainable costs of the water services. However, the adopted aggregation method, the incomplete preference elicitation and the data approximation may have affected the identification of the efficient portfolios. Therefore, it is important to look critically at the final results. It is indeed relevant to review the results with the decision-makers, in order to assess their consistency respect to the preferences. In addition, we strongly advise to analyse the sensitivity of the results to the set-up of the model.

4. Which global data and open sources can support the framework, by providing the spatial information needed for the evaluation of the different criteria?

The application of the SNARA objectives hierarchy to a real case-study showed that availability of data strongly affects the selection of the attributes. When local data was missing, proxy attributes were selected rather than natural attributes. These proxy attributes were computed through the use of global and open data such as satellite imageries and regional statistics. However, we did not rely only on global data in the calculation of attributes, which would have added more uncertainties in the model. For the attributes related to the most relevant criteria for the stakeholders, we collected local data to improve the reliability of the results. According to the specific set-up of the framework, we can assert that the use of global data sources was essential to provide a glimpse of the local water security issues, while complementing the missing local data for a more reliable assessment. However, we also learned that global data cannot be used to compute the natural attributes identified in the SNARA framework due to the coarse spatial resolution.

5. How generalizable are the results and the method and what would need to be done when applying it to another case?

Although we addressed the refugee allocation decision problem broadly, the SNARA framework refers to a particular refugee response setting. The framework is based on a development approach that includes both refugee and host communities rather than only focusing on humanitarian requirements. This is relevant for host developing countries that need human and economic resources and that infrastructure development is strongly dependent on humanitarian aid. For different decision settings (e.g. refugee influx in Developed Countries), it is important, instead, to identify stakeholders again and review/generate relevant objectives. In this case, the SDM-approach can also be a valid support, while most likely global data will be not strictly necessary. Moreover, the time available for identifying suitable refugee allocation solution is also a relevant aspect to evaluate the applicability of the SNARA framework. This procedural tool is mainly addressed to regions prone to refugees, which hence are interested in identifying suitable solutions beforehand (preparedness actions).

The current research hopes to contribute to the literature by showing the application of the SDM-process and a PDA-model to a new case in literature: the refugee allocation decision problem. We also believe to have provided a valid tool which allows to analyse and identify solutions in a way that is rigorous, inclusive, defensible and transparent while tackling the problem with a new perspective.

5.2 Recommendations

Further analysis can help in improving the reliability of the results The following improvements are recommended as part of future studies:

- 'High reliability of raw water quantity' is the criterion with the highest priority for UNHCR WASH officers in the selection of a refugee hosting site. However, this criterion was assessed only referring to surface water and rainwater sources as aquifer data were missing. To improve, we suggest to simulate different groundwater volumes and to implement a sensitivity analysis in order to understand the relevance of GW data;

- Sensitivity of the results to data and value model needs to be tested through a systematic methodology. Such analysis can reveal, for example, which information can be prioritized and which one can instead be discarded as not affecting model results;

- Stakeholder selection and engagement can be improved by adopting a more systematic approach. The engagement of key actors in the decision process can be enhanced by the organization of workshops;

- In structuring the value model for PDA process, it is important to capture preferences among alternatives combination as outlined by (Lahtinen, Hamalainen, & Liesio, 2017; Ollila, 2013). The value model could be improved in this research by adopting systematic preference elicitation method such as the SWING method for defining weights and bisection method to elicit value functions;

- In the Ugandan case study, logical interdependencies among alternatives were not explored. The selection of certain alternatives can, indeed, influence the criteria values of others in the portfolio. This happens especially for the objectives: 'high reliability of raw water quantity' and 'low probability of contaminated surface water and groundwater'. The assessment of related attributes depends on the water balance in the delineated watershed. For e.g. the allocation of refugees in site A can affect the water availability and quality in site B and C (downstream areas). However, in our case-study, this interdependency becomes more evident with a large number of refugees to allocate as refugees' water demand is quite low;

- In the computation of the attribute for the criteria: 'sustainable yield', GW and SW sources should be considered separately. This is because low run off can be compensated by a higher groundwater recharge. The same applied for the opposite. Therefore, it is possible that the attribute has a high score even if more water than the renewable is extracted from the investigated source. In the application, it was not possible to compute the attribute separately, due to poor data;

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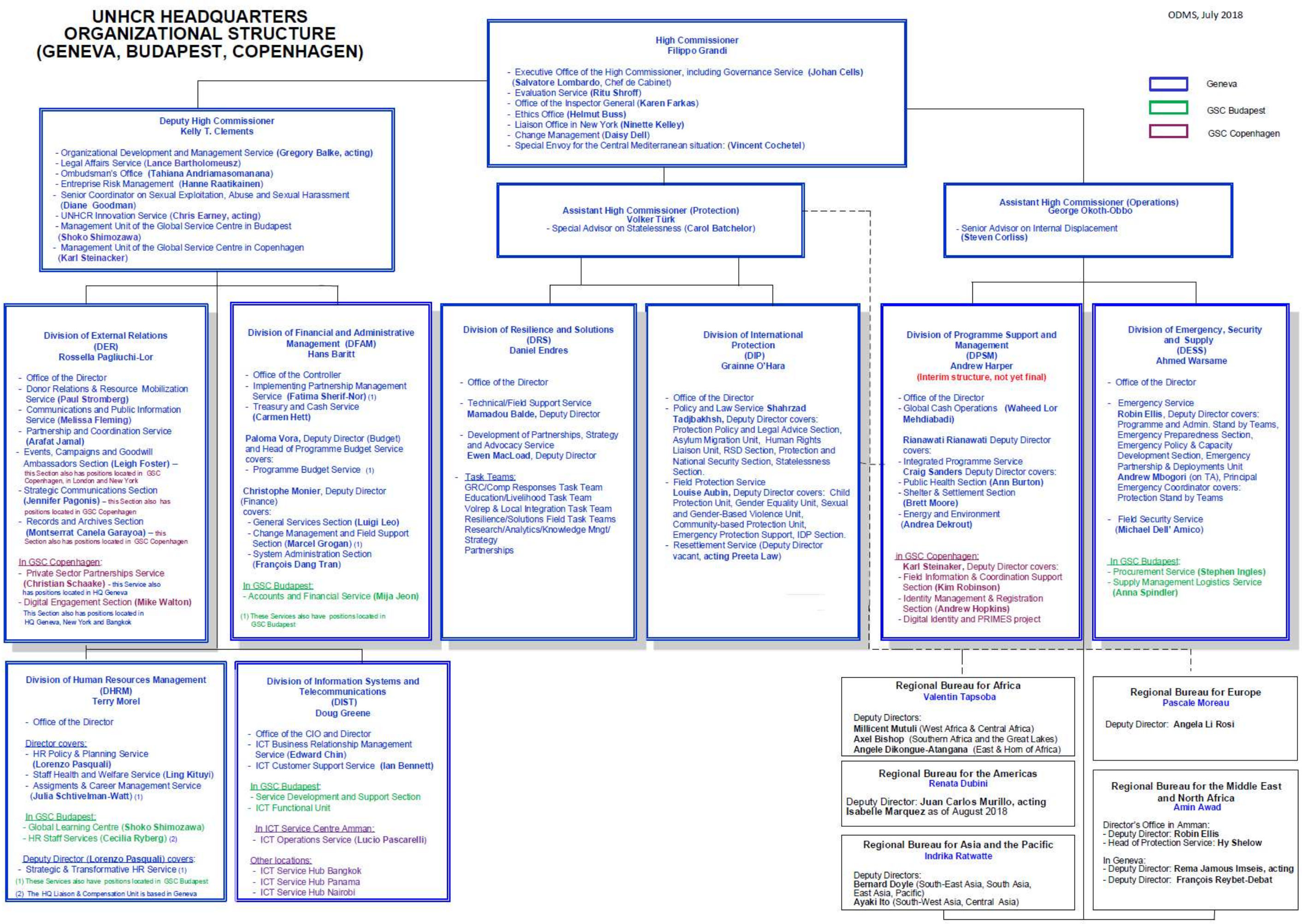
Appendix

A. UNHCR-HQ Organigram



B. Stakeholders' Interviews

2.1 Interviews' transcription

a) *Associated WASH officer: Franklin Golay (31/08/2018)*

The WASH office in Geneva provides technical emergency and strategy support to the WASH colleagues in the field and represents UNHCR in global events and conferences with agencies and donors.

The main role of UNHCR is to coordinate the different operations and programs that support the refugee response phases. On the other hand, the direct implementation is mostly carried out by Partners (as NGOs, local organizations, …) selected by UNHCR. The Headquarter (HQ) in Geneva aims to support the local offices by developing guidelines, providing technical and human support to the fields, and monitoring operations and programs in order to identify possible gaps and mismatch with the guidelines.

HQ's divisions involved at the outset of an emergency

At the outset of an emergency, the UNHCR divisions involved from the HQ are:

- DESS (Division of emergencies, security and supply)

In particular, the *Emergency administration and support* Unit

- DPSM: Division of programme support and management

In particular:

  - WASH Unit
  - Shelter & Settlement Section

Refugee response phases

The refugee response can be distinguished in different phases: (1) Emergency; (2) Transition; (3) Post Emergency.

A typical emergency situation is the sudden income of refugees in a host country. In this case the emergency happens when the number of refugees that crosses the border is larger than the historical influx, and the host country does not have the required resources to cope with the situation. The local UNHCR offices and the host country ask help to the HQ, which unlocks initial funds and sends officers to support the organization and coordination of the response activities. Usually, an emergency lasts for about 3 – 6 months and it ends when the influx stops. There are three levels of emergency (level 3 is the highest).

In level 1, the HQ's offices offer technical support. In level 2, an officer can be sent to the field if required. In level 3, there is full support from the HQ. In this situation, usually, a senior officer is sent to the field. The situation is reviewed after a certain period (usually 6 months). Consequently, the response is moved to the transition phase or stays into the emergency phase.

A generic definition of emergency is every situation in which certain indicators from the response programme are not met. In this case, the local office usually asks for the support of the HQ. According to the type of emergency, the HQ assesses if an officer needs to be sent to the field or if a person can be selected among the partners on the ground. The process of searching for partners on the ground and select a people among them frequently takes time and hence, most likely an officer from the internal cluster is sent to the field. As the emergency is evolving in time, more people are needed to be involved.

Protocol in the event of an influx of refugees

In case of refugee influx, an emergency happens when there is only a small operation at the local level which does not have the capacity to assist the incoming refugees. In this case, the local office requests the interventions of the HQ. According to the declared level of emergency, a different support is provided by the HQ and according to the needs on the ground, certain units are activated.

The first activated HQ division in case of an emergency is the DESS. Usually, an officer from this division is sent to the field in order to initiate the collaboration with the government (in particular with the migration office) and the coordination with the different partners. It might happen that the discussion with the government is already initiated by the local officers. In this case, by the time that the HQ's officers come to the field, the government has already proposed a site for the accommodation of the refugees. Therefore, the UNHCR officers directly visit the site for providing recommendation on its suitability. If the site is suitable, an estimate of the number of people that can be accommodated in the area is provided to the government. However, it might happen that the government decides to accommodate more people than the suggested number.

Sometimes the process of selecting a site is not straight forward and the officers needs to push the government for having an assigned site.

The newly arrived refugees are usually directed to a transit centre. If such centre doesn't exist, the refugees are settled in the first available area (self-settlement). If suitable, this area is used as transit centre. If the site is not suitable because, for example, it is too close to the border, another area is selected as a transit centre. In this case, UNHCR sends TRUCKS or boats to transport the refugees to the new area. Usually at this stage of emergency, there is a rough idea of the gender and age of the population and the number of people in needs. Only afterwards, a detailed profile is taken and the refugees are subjected to a health screening.

Information System

When an emergency takes place, the contingency plan is collected. It should contain all the actions needed to efficiently set up a first response, fronting needs and gaps. However, hardly a contingency plan is well made. The policies require UNHCR's offices to implement the PPRE's (Preparedness Package for Refugee Emergency) methods and components, but partner agencies and government counterparts are not under a similar obligation. Additionally, there is always a certain level of uncertainty in foreseeing an emergency.

In order to have a first understanding of the situation, the HQ's officers contact the colleagues on the ground. If refugee camps or UNHCR offices are already present in the area of emergency, the available data are collected for a first assessment. Otherwise, up-to-date satellite imagines provided by UNOSAT are requested. These images are analysed in order to extract information, such as presence of surface water sources and the land use of the area.

Financial support to the refugee response

In order to financially support the refugee response and the programs, a fundraising campaign is organised by UNHCR. Usually, the main donors are governments and more rarely, private donors.

If required by the host government, the initial expenses are covered by the internal UNHCR budget. Contemporarily, a more accurate estimation of the budget is made by local operators and, through the fundraising campaign, the money is collected. This is used to refill the internal budget of UNHCR. UNHCR informs the donors on the progress of the programs mainly through simple graphics and plots. Typically, when the situation is not in emergency, the donors come for a visit in the field.

Relevant information for assessing the suitability of a site

In the site selection process, the availability of water for a year-round basis is the first prerequisite for a suitable site. However, this information might ask more elaborated analysis and it is not obtained from the beginning. Therefore, the first information collected is the closeness to the surface water (through satellite imageries) and the presence of groundwater, if analyses on the groundwater are available.

Other specific information is collected instead by field visits. As soon as possible, a hydrological assessment is requested and it is usually carried out by local specialist agencies. Other additional information relevant for WASH operations are the type of soil and the groundwater table. These are essential for the installation of latrines. The slope of the land is considered in order to assure a gravity drainage network, and the risk of natural hazards is assessed especially though interviews with the host community and analysis of historical data. Usually, water quality is not a characteristic of the available sources to which much importance is given. This happens especially in the case that only one site is proposed by the government and, due to time pressure, research and further discussion on other sites are often not possible. In this case, the quantity of the available water is more important than the quality. The latter can always be improved by the use of certain technologies.

Under shelter and site planning prospective, relevant information is:

- available space; which should be sufficient also for institutional building (e.g. clinic, schools).
- Slope, in order to asses for possible landslides, erosion and floods.
- available materials on the site;
- access to the site.

Time frame in the site selection and planning process

An initial first assessment is carried out in 2 days, a second one in around 2-4 weeks with a first planning. In around 6 months, the final assessment, planning and implementation of the camps are accomplished.

Information system support for a first assessment

In order to develop a first assessment, the following information is used:

- remote sensing imagery: to have a first understanding of the presence of surface water (closeness to rivers);

- information on the ground: field visit and interview to the host population.

Contemporarily, UNHCR officers start to look for partners on the ground and collect data and information about previous assessments made in the area.

Currently, a boreholes database is under development (http://wash.unhcr.org/wash-gis-portal/). It aims to record any boreholes present in the current camps, providing technical and operational information. This information is essential in emergency for identifying possible close boreholes that can be reused for having a first water supply.

Another website under development is the so called iRHIS, which aims to collect information in the refugee camps to remotely and spatially assess their different needs. However, it is not yet ready and the previous version did not work so well.

https://uat.dewco.org/home (iRHIS)

https://his.unhcr.org/home

Issues in the site selection process

In the site selection process the government is usually the first issue. In few cases UNHCR has the opportunity to identify a site that would be accepted by the government. Generally, the site is identified by the government itself and there are no possibilities to discuss it. Therefore, unsuitable areas for locating camps are often used, leading to the issue of scarce water availability. The site selected by the government usually does not have sufficient water for the people that need to be accommodated there.

Budget

The budget is not a real constriction in the site selection since it will be allocated after the site is selected, according to a first estimation of the costs. If the allocated budget is not enough for the required situation, different measures are adopted in order to stay within the provided amount.

Missing stakeholder from UNHCR in the site selection process

Ideally, the organizations that should be involved in the site selection process are the site planner, the shelter, WASH, environment, livelihood and protection units. In reality, shelter and WASH units are involved from the beginning, while environment and sometimes livelihood and protection units are involved later on. This is mainly due to an insufficient staff in the other units both at the HQ and sub-office levels. Therefore, shelter, wash and emergency officers are involved in the discussion with the government for the selection of a site through a joint-assessment mission. Important external partner involved is, for example, UNICEF for the WASH sector.

Host community

In order to promote integration and avoid possible conflicts, the host community is increasingly taken into consideration. This happens through the increasing involvement of the community in the interventions. A first information that UNHCR tries to collect is the amount of inhabitants of the host communities.

b) *Associated Information Management officer for the emergency preparedness: Remo Fambri (02/08/2018)*

The Emergency Preparedness Section Partnership & Deployment Unit works in three major topics: preparedness, emergency partnership (stand-by partnership agreement) and deployment of the emergency staff through the internal UNHCR raster or stand-by-partners.

All key functional and response areas are coordinated by UNHCR or partner staff with the right profile, experience and authority across the entire spectrum of the response.

Definition of emergency

There are three elements that define an emergency:

- there is a threat to the life of the people of concern;
- there is an insufficient capacity to respond;
- there is an urgent need to act immediately with an exceptional response.

In case of influx of refugees, the situation is not an emergency if there is the capacity to response and the refugees are not at risk of life. This happens when, for example, the response is already on-going, many partners are already engaged, the money is available and refugees are already being assisted in the area.

An emergency gets declared once one of the three above elements occur. There are three levels of emergency. Level 3 of emergency is declared by the high commissioner. Level 2 and 1 of emergency is declared by the assistant high commissioner. Depending on the declared level of emergency, different mechanisms are established in the HQ. In case of level 3, a corporate whole-of UNHCR response is activated, which means that the entire organization is mobilized. In case of level 2, the Bureau may seek specific support from HQ divisions. For an emergency of level 1, preparedness actions are undertaken with the support of the

Regional Bureau, DESS and other support services as needed. This level of emergency is activated when an emergency situation is foreseen.

Table 27. Level of emergencies (UNHCR, 2017a)

Emergency level 1: Proactive preparedness	It is activated in order to trigger active preparations for a likely humanitarian emergency. Preparedness actions are undertaken in the operation(s) concerned, with the support of the relevant Regional Bureau, DESS and other support services as needed. These may include preparedness missions and human, financial and material support.
Emergency Level 2: Stepped-up Bureau support	It applies to a situation in which additional support and resources, mainly from the concerned Regional Bureau, are required for the operation to be able to respond in a timely and effective manner. Upon declaration of a Level 2 emergency, the Bureau is authorized to mobilize and/or re-allocate resources available under its auspices and may seek specific support from Headquarters Divisions.
Emergency Level 3: Whole-of-UNHCR Response	The activation of this level signifies an exceptionally serious situation in which the scale, pace, complexity or consequences of the crisis exceed the existing response capacities of the country operation and Regional Bureau(x) concerned, and call for a corporate, whole-of-UNHCR response. The declaration of this level of emergency automatically triggers the establishment of Headquarters coordination mechanisms, deployment of staff and supplies, access to additional financial resources, real-time reporting and follow-up mechanism.

Risks associated with a new refugee emergency or the deterioration of an existing situation need to be analysed at least once a year through an inclusive consultation with stakeholders (Figure 22). A systematic analysis of risks helps an operation to decide which preparedness actions are required in each context. The risk analysis comprises three steps: (1) Identification of one or more scenarios; (2) Risk ranking; (3) Risk monitoring and early warning.

Scenario identification begins by identifying the hazards in a neighbouring country that may cause forced cross-border displacement. In a detailed scenario, information as the entry points, geographical areas affected, and realistic population estimates is included.

According to the risk analysis, different preparedness actions are required. In general, it is important to carry out the following activities:

- Identify potential sites for the accommodation of future incoming people;
- Analyse the policy of the government;
- Initiate a strategic partnership engagement;
- Train the partners;

If a high risk is assessed, a contingency plan is required. The plan seeks to initiate agreement among partners (including government authorities, UN, NGO and civil society partners) for an effective response according to the context.

A complete contingency plan results in the following strategy (UNHCR, 2018a):

- A clear and practical context specific response strategy;

- An analysis of needed resources to adequately respond to the emergency scenario in the first 3 months from activation;
- Re-allocation of existing resources, or additional resources, when required and appropriate;
- An appropriate and timely response towards the protection of refugees, including the meeting of their basic needs.

Usually, levels 2 and 3 of emergency are directly declared, without passing through level 1. A failure in the Preparedness Actions plan can be determined by the level of uncertainty in foreseeing an emergency.

When an emergency is declared, an officer from the DESS department is in charge to start the discussion with the governments if the country level office required an intervention from the HQ.

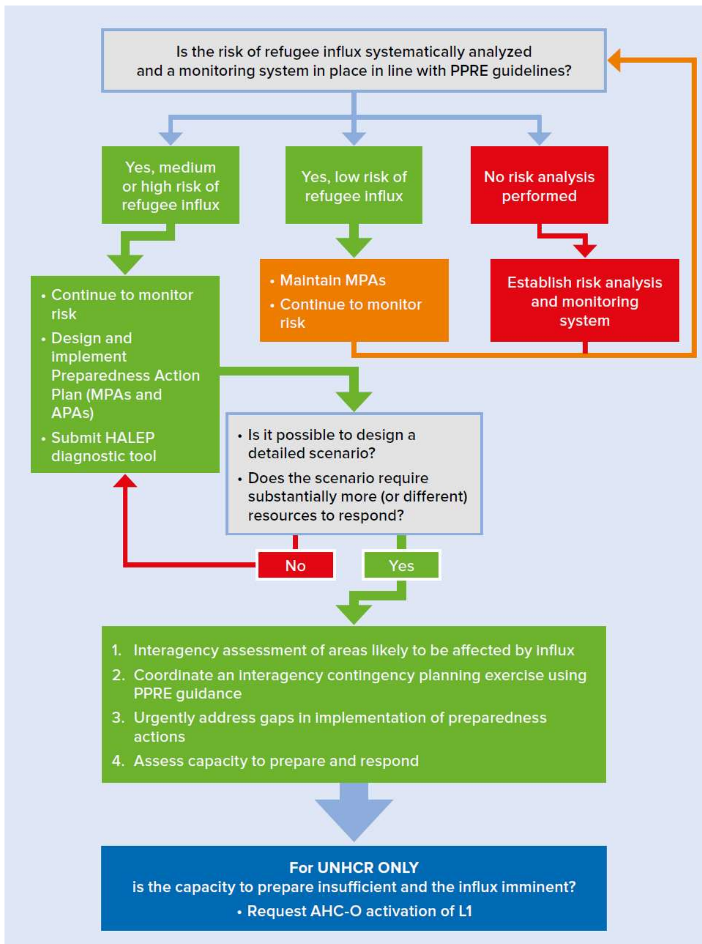


Figure 22. The PPRE workflow (Preparedness package for refugee emergency). (MPSAs= minimum preparedness actions; APAs= advanced preparedness actions)

Preparedness Actions

Through the preparedness plan, governments and partners try to agree on everything that can be agreed before an emergency. This aims in saving time and avoiding future discussions during the emergency. The preparedness actions aim to speed up the process of response, agree on the different partners' engagement and getting already an understanding on the capacity of the country to act in case of emergency. The risk of influx should be assessed and an agreement on the roles of the different local agencies during the response phase should be made. The preparedness actions look at a comprehensive strategy that includes different sectors together. The main goal is to already engage the partners and agree on bases for coordination, mechanism for response (actions) and first understanding on suitable sites to accommodate the people. The preparedness phase does not define specifically the actions to take in case of emergency as it is based on possible scenarios, which could be correct or not. Currently, the preparedness actions are not well made and there is no agreement with the partners on the actions to take in case of emergency. This is mainly due to recent accomplishment of the policy for preparedness actions which it is still not yet applied in many areas.

Settlement typologies

In order to encourage the integration of refugees with the host community, there is the preference to scatter them in different existing urban and rural areas. The development of settlements and the high concentration of refugees do not encourage their integration with the host community and complicate the response strategy as new infrastructures need to be built in order to provide the needed services. However, the governments often prefer to accommodate the refugees far from the cities.

Information system

The information is collected and analysed at country level as the Geneva HQ provides only technical advice and tools. If an emergency happens, the country can require the support of the HQ, which contacts specialists (as UNITAR for satellite maps) and partner staff with the right profile, according to the local office's request. If the country or local office does not have any expert able to analyse the information and support the response process, a WASH officer from the HQ or from the internal cluster is selected for a field mission. Contemporarily, an initial assessment on the available hydrological surveys is made.

Essential information for the site selection process is obtained in particular through interviews with the host community, who are better acquainted with the suitability of the area and the related risks. For example, in Uganda, some villages are located far from the cultivation areas. This is because the area between the cultivations and the villages is at risk of natural hazards.

c) *Head of the global WASH unit in UNHCR: Murray Burt (03/08/2018)*

The task of the head of the global WASH unit is to oversee all aspects of water, sanitation and hygiene globally, specifically for contingency planning, emergency response and long-term durable solutions.

Most of the time, the work focus on the emergency and post-emergency phases.

Response phases

An emergency situation is usually defined in the first 6 months from an influx. It is followed by a transition phase that usually lasts a maximum of 2 years since the start of the emergency. Finally, there is a post-emergency (or protracted phase) which is from 2 years onward. According to the WASH response program framework, the situation moves from an emergency phase to a transition phase according to certain indicators and standards contained in the UNHCR WASH manual (Figure 23). When the influx starts to stabilize, the WASH response aims to reach standards of the transition phase, as for example in water management, 15 l/day/person and 1 latrine for 50 people. In the protracted phase, different standards are met through WASH response.

UNHCR WASH Response Programme Framework

Time Period	Emergency Phase Short Term 0-6 months	Transition Phase Medium Term 6 months – 2 years	Post Emergency / Protracted Phase Long Term 2 - 20 years +
	Communal →		Household
Water Supply	**Target 7.5 – 15 l/p/d** • Water trucking • Emergency elevated tank (D306,D307,D308)* • Emergency tapstand (D300) • Bottled water • Aquatabs/PUR/HTH chlorine** • Jerrycan 10L collapsible (00096)** • Jerrycan 20L rigid** • Bucket with lid/tap (07071)**	**Target 15 – 20 l/p/d** • Emergency surface water treatment plant (EmWat). • Jetwells. • Temporary piped water network using Oxfam Tanks, PE pipes and tapstands • Extension of existing water network. • Cash/vouchers	**Target 20+ l/p/d** • Borehole source (D304, 305)* • Surface source and treatment • Elevated water tower (D309, D310)* • Pipe network • Tapstand (D301)* • Handpump (D302)* • Rainwater harvesting • Apartment plumbing upgrades • Cash/vouchers
Excreta Management	**Target 1:50 (communal)** • Trench toilets (D400,401)* • Chemical toilets • Elevated desludgeable toilets (D405)* • Daily cleaning/ maintenance • Plastic toilet slab** • Plastic sheeting (03153)** • Latrine digging kits**	**Target 1:20 (shared family)** • Increase toilet coverage by commencing household toilet programme, initially with one toilet shared between four families (1:20) and improving to one per household as resources permit.	**Target 1:5 or 1 per Household** • Basic pit toilet dome slab (D402, D403)* • UDD Toilet (D406)* • Pour flush toilet (D404)* • Apartment plumbing upgrades • Sewer network • Desludging • Septage treatment • Cash/vouchers
Hand Washing	**Target 1 hand wash device per toilet block** • Handwash container 50L with tap and stand** • Soap** • Daily refilling/ maintenance	• Increase handwashing promotion at household level and ensure each shared family toilet is equipped with appropriate handwashing device.	**Target 1 hand wash device per HH** • 2L container** • Washbasin/sink
Bath Shelters / Showers	**1:50 (communal)** • Bath / shower blocks (D700)* • Plastic sheeting (03153)** • Drainage **Soap 250 g/p/month** • personal hygiene only **Soap 250 g/p/month** • women and girls menstrual hygiene) (01511)**	**1:20 (shared family)** • Increase bath / shower coverage (1 per 4 families) • Encourage families to build their own facilities. **Soap 250 g/p/month** • personal hygiene only **Soap 250 g/p/month** • women and girls menstrual hygiene) (01511)**	**1:5 or 1 per Household** • HH bath/shower cubicle • Encourage families to build their own facilities. **Soap 250 g/p/month** • personal hygiene only **Soap 250 g/p/month** • women and girls menstrual hygiene) (01511)**
Hygiene Promotion	**1:500 Hygiene Promoters** • IEC materials** • Hygiene kit** • Baby kit**	**1:500 Hygiene Promoters** • IEC Materials**	**1:1000 Hygiene Promoters** • IEC Materials**
Solid Waste Management	• Rubbish bins (Stockpile) • Collection services/incentive workers • Rubbish pits	• Transition to long term cost effective community managed or individual household managed solutions.	• Transfer station / Landfill (D500)* • Household rubbish pits • Recycling, reuse • Clean-up campaigns
Vector Control	• Indoor residual spraying** • Treat pit toilets with chlorine or insecticide to kill fly larvae	• Transition to long term cost effective community managed solutions.	• Indoor residual spraying** • Rodent control
Laundry Facilities	**Soap 200 g/p/month** (01511)** • Laundry basin** • Drying lines 8mm (06644)**	**Soap 200 g/p/month** (01511)** • Transition to long term cost effective solutions.	**Soap 200 g/p/month** (01511)** • Laundry slabs (D701)* • Drying lines (D701)*
Schools / Health Clinics	• Trench toilets (D400,D401)* • Chemical toilets • Bath/shower blocks (D700)*	• Transition to long term cost effective solutions.	• Toilet blocks (D407,D408)* • Shower blocks • Water points / rainwater harvesting / tanks

* Design included in UNHCR Standard Drawings wash.unhcr.org/wash-technical-designs/

** Item Specification found in UNHCR WASH Standard Equipment Catalogue wash.unhcr.org/wash-equipment-catalogue/

Figure 23. Indicators and standards in the response phases (UNHCR, 2018c)

Site selection and planning

The WASH unit at the HQ is involved from the beginning in the site selection and planning processes.

Ideally, the WASH operators should already analyse possible sites in the contingency plan as part of the preparedness actions. However, in practice this will rarely happen as usually the political motivation is missed. Additionally, the contingency plan has always a level of uncertainty. Therefore, there is no certainty on the decisions that need to be taken. However, if a suitable site is already identified before the emergency and a first agreement with the government is established, the process of response can be accelerated at the outset of an emergency. In some areas, the influx of refugees is expected and taking these decisions before the emergency is essential to be able to quickly develop and implement a response strategy. Delay in the decision process aggravates the situation. At the outset of an emergency, people are hosted in a transit camp where they should be accommodated for not more than 72 hours/ 1 week. But if a site for a long-term accommodation is not already selected, the refugees get stuck in the transit camp for longer and the total population builds up due to the continuous influxes. This undermines the capacity to provide safe services. Only when the site is selected and the refugees start to be accommodated there, a more effective response can be actuated. The transit centre is again able to host refugees, which can already be directed to a long-term accommodation after around 2 days. If the site is selected before, all these issues can be avoided and the humanitarian operators can better focus on the development of the site itself.

Two factors can lead to delay in the site selection process:

1. Delay in the physical assessment;
2. Agreement with the government.

Usually the first can be done quite quickly. The main issue is instead to reach an agreement with the government. The government has to formal approve the site and all the stakeholders need to agree on that before the operations on the site can be actually made. Usually, only one site is proposed by the government and there is no possibility for discussions. Therefore, even if previous analysis on the site forecast possible hazards, there is no possibility to reconsider the decision until a disaster happens. In some cases, this pushes the government to start again the discussion on where re-accommodate the refugees.

Therefore, understanding the suitability of the site and engaging the stakeholders are important processes that should be pursued before the emergency. Currently, the site selection process takes places only at the outset of an emergency, when a large number of people cross the border. The newly arrived refugees are directed to a transit area, where they can be hosted immediately. If there is not a transit area, the refugees start to self-settle. In this case, there is the need to quickly decide if move or not the people from the area in which they self-settle.

In the site selection process, the first preference is hosting refugees in existing urban or rural communities. This option is preferred for two reasons: first, the refugees can have an easy access to the services and to the market. Second, the integration of the refugees in the host community is facilitated assuring a better livelihood and food security for the refugees. Currently, around the 60% of the refugees are hosted in this type of scenario while only the 40% of refugee are hosted in a new refugee camps.

In the first scenario, the infrastructures, services and resources already in place are analysed, in order to understand which, type of interventions or resources are needed to accommodate additional people. The water resources availability, the available food productive lands and the health and education services already in place are analysed. Through this analysis, two main information can be depicted: first, the number of people that can be accommodated in the area; and second, the additional infrastructures, upgrading or any other operations needed to cope with the increasing number of population.

In general, the site planners use an assessment template, which guides the valuation of the site. The most fundamental characteristic for a site is the availability of water sources. After analyzing the quantity of water available, an estimation of the number of people that can be accommodated in the site is computed. In analysing the water availability, the sustainability of the water extraction is also taken into consideration. Therefore, aquifer recharge is taken into account in the groundwater analysis, as well as the sustainable surface flow in the surface water analysis. In order to extract this information a hydrological assessment is done. At early stages, groundwater is preferred due to its better quality for domestic supply, which minimizes future operational treatment costs. If groundwater sources are not suitable in the site, surface water sources are considered for exploration (river or spring sources). The water quality is a relevant component in terms of cost of the treatment. If this cost is unsustainable, the source will be not selected. The term unsustainable is political as depends on how much money can be raised. Usually, the lowest long-term cost option is preferred. Therefore, an ideal situation is the use of a source with available water quantity and minimum treatment cost.

After having identified the suitable sources for water supply, an estimation on the amount of the people that can be hosted in the area is computed (holding capacity). Currently, only the domestic supply and the water supply for the institutional buildings are estimated. For the former, the water needed for drinking, cooking, laundry, bathroom, house cleaning is equal to 20 l/day/person, according to the standard in the protracted phase. For the latter, water needed for water supply and sanitation in hospitals, schools and nutrition centres are computed. The water needed for the agriculture activities, livestock or commercial activities is not taken into account. The agriculture demand, for example, will change according to the climate. In hot climate, the demand will be higher than in cold climate. Currently, the water used for these activities comes from the domestic water supply, leading to a quick depletion of the sources intended for it. Therefore, it is important to estimate from the beginning the amount of water needed for supporting future livelihood activities.

At the outset of an emergency, the WASH unit at the HQ contacts the WASH staff on the field in order to have a first understanding of the situation. If there is not an adequate staffing on the field for leadership, coordination or information management, an officer from the HQ is sent to the site. At this stage, an essential information is to understand where the refugees are going to. Based on that, satellite imageries are used to make a first assessment of the area. The satellite imageries are acquired from UNOSAT and Google Earth. In a preliminary assessment, the WASH unit aims to understand:

1. Number of people of the host community;
2. Availability of surface water;
3. Risk of flooding.

This information is taken from:

- satellite images from the area;
- available hydrological maps of the area;
- data on existing boreholes (boreholes database);
- historical data on precipitation and flood events.

It is important to mention that this is an iterative process. When time allows, the assessment goes even more in detail.

An initial assessment is made in around 3 weeks. Usually, in this time frame, the decision to be taken is whether move or not the refugees in case they spontaneously settled in an area. A second more detailed assessment is made within the 6 weeks, where the site is classified as suitable or not. After 3 months from an emergency has started, decision on the type of permanent infrastructures to be developed is made. In this time frame, usually the government gives its final approval for the use of the camp and the start of the operations. Ideally, between 3 and 6 months from an emergency, the detailed assessment of the water sources is already made, as well as the design of the camp for a long term development of the site.

Table 28. Time frame for decisions in the site selection process

3 weeks	If refugees are self-settled due to the absence of a transit centre, there is the need to decide if move or not the people to another area.
6 weeks	The proposed site is classified suitable or not. At this stage, it is important to have a clear understanding of: • Which source is used for water supply; • How many people can be accommodated according to the water need for domestic, institutional and future livelihood supplies; • Type of drinking water treatment; • Presence of water-related hazards; • Wastewater disposal; • Existing infrastructures and services.
3 months	Official agreement with the government. Information/knowledge: • Type of infrastructures to develop.
6 months	Complete design of the camp for a long-term development and its implementation. Information/knowledge: • Detailed hydrological assessment.

In terms of water resources, two main issues can lead to problematic accommodation of people:

- presence of flooding events. For this reason, there is the need to quickly assess the preferential flood paths in order to avoid the allocation of shelters along them;
- the aquifer becomes contaminated or over-exploited.

In an emergency phase, the driving process is to save lives and the environmental consideration comes secondly. Therefore, there is the need to quickly accommodate people in a safe area. In the case that only one site is given by the government, even if water related hazards are identified, the process of allocation of refugees needs to start due to the time pressure. Measures for mitigating risk of water-related hazards are usually postponed and often taken only when a disaster happen.

Over-exploitation of water is usually caused by the use of water for secondary activities as agriculture, commercial activities or large livestock. As the refugee response moves forward, it is important to have a sustainable management of the aquifer, defining a suitable extraction rate. By monitoring groundwater drawdowns, seasonal impacts of the refugees can be analyzed and usually, measures are needed for mitigating the assessed impact.

However, few are the cases where the over-exploitation of the water sources is directly caused by the refugees. In most of the cases, the host community activities are responsible for the groundwater drawdown. Refugees are easy political targets and their activities are often mistakenly related to water source depletion. Therefore, the hydrological assessments are needed also for providing a real picture of the situation.

On the other hand, the main cause of aquifer's contamination is the location of the latrines, which can increase the risk of groundwater pollution in the shallow aquifer if they are built too close to extraction wells. In the first 6 months, the humanitarian imperative is to provide an adequate amount of water, and to safe sanitation and hygiene in order to avoid the spread of diseases. Therefore, environmental issues as water contamination become secondary in emergency situations. In case of shallow groundwater contamination, techniques as chlorination can be used in order to improve water quality and continue the extraction. However, engineering solutions should be adopted from the beginning in order to predict and avoid or mitigate such future problems. Assuring a sufficient distance of latrines to water extraction points or using a deep aquifer for groundwater extraction are examples of possible measures to be adopted.

In case of fractured rock aquifer, aerial photographs and hydrogeological maps are used for identifying the fraction zones, which usually are potential sites for high yield boreholes. In case of uniform send or gravel aquifers, it is important to estimate the depth at which the drilling should focus in order to reach higher permeability zones

In the initial stage of the site selection, the budget does not play a major role because the amount that could be collected is hard to predict. After around 6 months from the start of the site selection process, an estimation of the required budget is made to provide a detailed picture of the amount for fund requesting.

Information that is usually hard to collect concerning groundwater:

- a detailed flood analysis. This is due to the lack of detailed topographic data. Flood assessments are generally made through satellite imageries. However, the resolution of such images can be quite rough, which aggravate image analyses and therefore models predictions;

- a detailed assessment on groundwater management. It is difficult to assess the impact of refugees to groundwater. Usually a groundwater assessment needs to be done over a long period of time, for understanding seasonal fluctuation and variation in recharge related to high and low rainfall periods. Until now, only a rough estimation of the impact of refugees on groundwater is made using the current water extraction and the historical groundwater recharge rate;

- identification of drilling sites for high yield boreholes. Hydrogeological analyses are usually used for guiding the drilling program and require many data, as geological maps, borehole logs and sometimes numerical models. This is a key information at the early stage of the decision process and very hard to have in a reliable manner under an emergency situation with a limited time for decisions.

At the beginning of the site selection process, the following units are involved:

- **WASH unit;**
- **site planning and shelter units**.

The latter are responsible for mapping the site, deciding the layouts of the roads and the location of infrastructures and buildings. More broadly, the **environment unit** is also involved, which looks at the environmental impact and potential mitigation measures within the site. Also, the **public health unit** is involved in a more broadly manner. They are the responsible for the identification of potential diseases outbreaks and the actuation of preventive and mitigation measures. For example, officers from the public health unit usually are the ones to assess the risk of cholera or apatite B in the site. Furthermore, their role in the planning process is mostly in the definition of the requirements for water supply and sanitation in hospitals.

The same is for the **education unit**, which defines the requirements for the educational institutions within the site. The **livelihood** unit is also broadly involved and it looks at the agriculture development for subsistence farming, livestock and commercial activities for the refugees. It is noteworthy to point that the activities related to subsistence farming and livestock can be high consumption water activities. Finally, the **energy unit** is also broadly involved. Together with the WASH unit, the officers from this unit assess the needed energy for water pumping and for sanitation facilities/processes. Additionally, they are responsible for the development of an energy strategy. Usually, the lack of energy provision, especially for cooking, leads to high degree of deforestation around the camp/site. This also increases the risk of landslides and flooding due to an increase in the runoff index.

Host community engagement

The comprehensive refugee response framework promotes the integration of refugees and the engagement of the host communities in the interventions. As a general rule, 30% of funds goes to the host community for improvement of local services, while 70% is exclusively allocated for refugee interventions. However, these percentages can vary according to place and number of the host and refugees population.

In order to avoid possible conflicts between host communities and incoming refugees, it is important to know:

- the water use consumption of the host community;
- the type of livelihood (e.g. agriculture, livestock);
- predict possible impacts that refugees can have on the host community.

In the estimation of the costs, we consider the full cycle of costs: capital cost, and operational and maintenance cost. One of the main objectives is to reduce operational and maintenance costs. Therefore, technologies with higher capital cost but lower operational costs are usually preferred (e.g. solar energy for (ground)water pumping). The capital cost is covered by initial funds, while the support for the long term operation varies in relation to the livelihood of the refugees. They will directly contribute to the cost of the services if a livelihood that provides them a sustainable income is guaranteed. If this is not the case, funds from the international community need to be collected.

Missing stakeholders in the site selection and planning processes

In the past, important stakeholders were missing at the outset of an emergency. Currently, the situation is improving. A wrong engagement of key partners was mainly due to a missing link between humanitarian action and development. One of the goals of the current comprehensive refugee response framework is the earlier engagement of the development actors in the response.

Usually, refugee situation develops to a protracted situation. This leads to the need of introducing development actions earlier in the response process with inclusive interventions that jointly engage both host and refugee communities.

In the government side, development actors comprise all partners involved in delivering sustainable development goals. Often, only governmental partners involved in refugees' issues and in emergency situations are engaged. However, there is the need to involve also the ministry of water and the ministry of environment from the beginning of the process to avoid future issues concerning those topics. Uganda is a good example of key stakeholders' engagement. There, the refugee response is often included within a broader water resource management assessment, which promotes a strategic development plan. Generally, other important stakeholders are international financial institutions for development, as the Word Bank and the Asian Development Bank. NGOs are also essential for supporting and coordinating development interventions as WaterAid.

Alternative sources for water supply

In many cases, rainwater is not analysed as potential water supply sources. This happens for two main reasons: first, the population does not have the traditional knowledge and practice to use rainwater harvesting; second, in some parts of the word there is not a homogeneous rainfall rate able to guarantee enough storage for satisfying the water demand. Therefore, this technology is not adopted for the domestic supply but it is used for providing water in the institutional level in some cases. This is usually related to their better facilities installation, as an adequate roof in terms of size and material for rainwater harvesting. Other interesting practice that should be further developed is the storage of part of the run-off through the construction of small dams and ponds. The water, which is not fully appropriated for human consumption prior treatment can be later used in agriculture and some economical activities.

Coordination among partners

Coordination among the different humanitarian organizations has improved a lot in recent years. Through the refugee coordination module, UNHCR or a delegated partner takes the lead for coordinating the different partners and sharing the information among them. This prevents any overlap, developing a unified strategy and unified design approach.

Information support for the decision process

Tools that can rapidly gain the needed information for supporting the site selection decision process from the water resource perspective would be relevant. The development of a methodology able to guide the use of a range of tools according to different time frames (6 weeks – 6 months) is also important. Ideally, such tools should provide an assessment of groundwater and surface water in both quantitatively and qualitatively ways, as well as provide an initial flood risk assessment.

d) *Livelihood officer: Jenny Beth Bistoyong (03/08/2018)*

Livelihood interventions

The livelihood unit is under the Resilience and Solutions division at the Geneva headquarters.

Livelihood interventions unit seeks to support the economic inclusion of refugees in the host community. The livelihood cycle program supports the refugee assistance in each phase (from the assessment to the monitoring). However, the importance of livelihood interventions can be often overlooked at the outset of an emergency.

In order to develop a livelihood strategy, an initial assessment on the refugee profiles is made in the transit centre, usually located. Through this assessment, refugees' skills based capacities, education levels and livelihood experiences are evaluated. The assessment results in the classification of refugees in wealth groups. Contemporarily, a context analysis is carried out. This last analysis aims to understand the legal framework in the host country, identifying possible limitations in the development of livelihood (e.g. right to work, right to access to services). The context analysis results together with refugee profiles are used for developing the socio-economic assessment, in which the current host communities' livelihood is also included.

Through a market assessment, current demands in the host country is identified. Comparing these assessments, it is possible to know challenges and opportunities for the development of a livelihood. The outcome is used for building a livelihood strategy in which interventions for removing possible challenges and/or rising skills are defined.

Site selection and planning

Through my personal experience, the site is selected by the government. Consequently, livelihood options are limited to available resources on the site. Hence, innovative technologies (such as fertilizers or rainwater harvesting) are often applied for maximizing the efficiency in the use of the available sources. Usually in such context, the livelihood officer is engaged in the planning phase with the main task of identifying possible activities for promoting integration and activities, which would enable future independence of the refugees. In case of agriculture activities, for example, the livelihood officer is the one in charge of identifying suitable areas and the one responsible for dividing it among the households. However, commonly the available area for agriculture activities is even not enough for guarantee independent subsistence.

Livelihood activities in the refugee camps

In rural areas, the most common activities are agricultures and livestock. While in urban areas, refugees can usually be involved in diverse activities.

Site selection process from the livelihood perspective

From the livelihood perspective, the market assessment would be an important first step in the site selection process. Through this analysis, opportunities for the development of activities can be identified. According to the refugee profile, this could better drive the allocation process of refugees in the available sites, looking at possible matches between local market demand and potential refugee skills. Characteristics that are essential for the development of the livelihood opportunities are: (1) the freedom of movement and (2) the right to work. Essential characteristics in the selected site for promoting economic activities are accessibility (e.g. by roads) and closeness to the market.

The information used for the development of the assessments are both primary and secondary data collected by identified respondents and sources.

Tools and policies have been only recently developed and guidelines are still missing. This is mainly because only now there is an attention on supporting long-term solutions for promoting economic inclusion, which is essential for ensuring economic independence of the refugees.

e) *Senior Environment Coordinator: Andrea Dekrout (07/08/2018)*

The senior environment coordinator at the HQ manages the unit of environment and globally supports the UNHCR environment staff. As few environmental officers are on the field, a major role of the HQ coordinator is to provide technical support to the development of the projects in the field and help in the emergency response.

The work of environmental officers focusses especially on the emergency phase. Currently, the purpose is to involve the environmental officer from the beginning of an emergency response.

The environmental unit works mainly in the rural context rather than in the urban context. This is because the main environmental impacts occur in rural settlements, where a high concentration of refugees is accommodated in diverse and independent settlements. In the case of the agricultural project, the environmental officers are involved in providing recommendations on improving soil quality. In urban areas, it is much harder to monitor and evaluate the environmental impact of refugees as they are fully integrated into the host community

Site selection and planning

Until now, the involvement of the environmental officer happens when the site is already selected. In this phase, the officer makes a field visit in order to have a first understanding of the key environmental issues. This leads to better recommendations on the site planning. Some typical recommendations concern, for example, the allocation of shelters to reduce the risk of landslides, and the extension of the buffer zone applied to protected areas and surface water bodies. In theory, a buffer zone of 25 km should be ensured between the site/camp and any key biodiversity or national forests. However, this is hardly the case. Consequently, the environmental officer is the one in charge of building a monitoring system to ensure a minimum impact on the biodiverse systems. However, the impact of the refugees on the environment can be hardly prevented or mitigated. For example, firewood collection is one the major activities on the camp that leads to disastrous consequences on the environment, as deforestation. This tends to occur when the strategy for energy supply in the camp is not well defined from the beginning of the interventions, leading to possible failures in energy supply. Firewood collection is usually illegal according to local legislations and restrictions on forest access are imposed. However, often this is not enough to avoid the collection of woods and the legal framework leads to complications for the implementation of a management system; actors in charge to control this phenomenon cannot be defined. This limits the available options for interventions, resulting in the development of measures for mitigating deforestation.

Most of the time, the main role of the environmental officer is managing the environmental impact by targeting the area where the access to the refugees should be limited, or by identifying set up opportunities (for e.g. where is the best place to accommodate the community to enforce a balance in the system and reducing environmental impacts). During the emergency phase, an essential task of the environmental officer is to reduce risks of damage to the ground. During the process of refugees' accommodation, one of the first interventions is the removal of the ground cover for shelters construction. However, preservation of the grass and top soil can be important to reduce erosion and hence reducing the risk of landslides in specific areas, which usually requires the presence of such professional. Though there will be always a deforestation in the area around the site, particular interventions can be adopted in order to protect rare species and minimize impacts to biodiversity.

Riparian zones are also important areas to be protected. In the planning phase, a buffer of around 100 m should be applied to the riparian zones, starting from the margins of river and water courses. Once this limitation is not respected, impacts in water quality and in local biota can arise in downstream areas. The removal of land cover has a strong impact on the downstream areas, especially when occurring near river corridors. This usually leads to an increase in local surface erosion, hence enlarging the amount of sediments being carried to rivers. Such process is cause of different impacts in the river system, such as river silting and flooding, as well as decreasing in water quality and impact on biota. As a rule of thumb a 50 m buffer around water courses is sufficient to decrease major impacts.

In order to limit environmental issues, key information for the site are

- avoid flood prone areas;

- avoid areas presenting a low vegetation index (areas more susceptible to soil erosion);

- protect areas around water bodies (e.g. riparian zones and spring areas)

Host community

From the environmental perspective, consultations with host communities are important for environmental assessments. For example, a better understanding of water related issues as possible risks for water sources can be achieved by acquiring basic information as local practices in the use, collection, and waste of water. Furthermore, a first estimate on the amount of people that can be hosted on the area is obtained as a result of this first rough hydrological assessment. The host community can have a better local knowledge of resources locations and impacts that refugees could bring to their lands, as areas chosen for refugees accommodation are usually areas previously used as refugee settlements.

Information system

Often, there is a need to identify key environmental risks and to provide recommendations in a very small time frame of just few days.

Concerning the actual available information system under use, big part of the data is collected directly at the local level through field visits. In some cases, maps and models from previous projects are available or they come as partners' information sources. If necessary, UNHCR commissions a detailed study. Satellite imageries are the first type of data required, from which first assessments are made. However, imageries present sometimes quite coarse resolution and there is the need to allocate a certain budget for requiring higher resolution data.

The main focus for the environmental unit is the soil degradation, the surface water resources, the vegetation index and the impact on the downstream areas. Groundwater is under the mandate of WASH as the assessment of this source is essential for implementing boreholes, which is usually made by this unit.

Usually, the water used for irrigation of small backyards is the treated water for the domestic consumption. This increases the pressure on the water sources. An important measure to be taken can be the implementation of rainwater harvesting collectors. However, this technology is rarely used. Another measure that could improve the reuse of rainwater is the adoption of runoff bands or small dams. In arid areas, where typical storms happen for short times, this measure allows to store water in the soil and bring grass back in areas that usually are arid, while also adding small amounts in the total water available.

Challenges in the planning phase according to the environmental perspective

One of the main challenges faced by the unit is to balance the technical interventions with the environmental impacts. Currently, there is not much attention on the impacts of interventions to the environment. An example of that is the sludge from drinking water treatment plants, which is commonly discharged without any treatment. However, the management of wastewater is in most cases correctly managed.

Another issue is the overexploitation of water sources. In general, there is not enough time to do a proper aquifer study before other partners have put in place their own boreholes. This is one of the weakest points in the system. To avoid greater impacts to local groundwater, surface water is usually directed for human consumption. Also in these cases, there is a need for a better assessment of impact in downstream areas.

f) *Protection Officer, UNHCR HQ: Elizabeth Morrissey (09/08/2018)*

Sexual and Gender Based Violence (SGVB) is an umbrella term for any action that concerns sexual violence, physical violence and psychological violence for men, women and kids. This unit safeguards asylum-seekers, IDPs and refugees. A first sphere of interest is the **establishment of services**. According to the different scenarios, a particular service is established such as medical services, social support (psychological service), safety (assessing possible threats to the life) and legal services for having access to the justice.

Another sphere of interest is the **prevention and response**. The goal is to try to prevent SGBV. When the people are in their country, there are not too many possibilities in preventing possible violence exploitation. During the refugee response, the goal is to ensure that refugees and other persons of concern receive protection and life-saving humanitarian assistance in a timely and effective manner that stems or diminishes harm, suffering and untoward hardship. Therefore, it is important to prevent any power abuse and exploitation. The third sphere of interest is **mitigation**. This in specific looks at the planning aspect, ensuring that the provided services are safe and do not harm. In this field, it is important to establish a collaboration with all units of the program and support management division, in order to review policies and procedures, looking at possible threat for the refugees. For example, important aspects in the WASH planning are:

(1) the allocation of the latrines in the camp; (2) the engagement and consultation with the refugee communities especially woman and girls; (3) the aesthetic design of the facilities; (4) the engagement of specific people to involve in the maintenance of the infrastructure;

Guidelines were developed to assist humanitarian actors in the prevention and mitigation of GBV across all sectors of humanitarian response (https://gbvguidelines.org/en/home/). In specific for the site planning, a guideline was developed by the International Organization for Migration (IOM) for the Global Shelter Cluster.

(https://www.sheltercluster.org/gbv-shelter-programming-working-group/documents/site-planning-and-gbv-booklet-second-edition).

Site selection and planning process

Often, just one officer from the SGVB is present in the field. Consequently, she/he represents all units of the division. The SGBV officer is involved at the site selection phase together with other key officers, creating a multifunctional team. This team comprises different expertise. In my personal experience, the site is selected by the government. Consequently, the multifunctional team is involved after the site selection. The team visits the site, for identifying potential areas of risk and potential issues that might arise from the prospective of men, women, girls and boys.

A SGBV policy guides the different units in the planning phase in order to reduce risk of exploitation and violence. From the SGVB prospective, in the site selection process, it is important to assess:

- distance from the water points;
- number of latrines per household;
- accessibility of the site;
- lighting;
- accessibility of the infrastructure in the different times of the day;
- profile of the users of the services;
- frequency in the use of the infrastructure.

It is important to avoid isolated site or site close to forests.

Considering instead the planning of WASH infrastructure, it is important to look at the different types of facility: sanitation facility, washing facility, water collection and hygiene (in specific also menstrual hygiene).

Ideally, if there is an option to decide among different locations, important elements related to water would be:

1. Safe access to the water sources;
2. Short distance to the water distribution;
3. Short waiting time;

In order to assess the water needs, it is important to clearly define the profile of the users. Questions as: "Who is using the water? How is the water used and/or lost? How much water is available?" need to be answered before the planning phase. For example, the lack of sufficient water in the school for female students and teachers during their menstruation period is one of the cause of absenteeism. This can lead the female students to quit definitely the school.

In general, important factors in the planning phase are:

1. the availability and accessibility of the facilities;

(maybe woman and girls prefer to use the latrines at early morning or late night as they don't want that the other people see that they are menstruating. Therefore, it is important to assess the safety of the area in different times of the day. Additionally, the distance to the facilities is also another important factor that affects the vulnerability of the refugees).

2. the design of the facilities (it can be important that latrines have doors);

3. symbols used to define woman and male.

Using Uganda as example, the distance of the boreholes from the households is a common issue. Only few locations, far from the camps, are suitable for drilling. Additionally, generally, the presence of rocky soil does not allow the construction of a network for transporting the water close to the camps. This forces refugees, especially young woman and children, to move early in the morning for the collection of water, increasing their vulnerability to violence. In the planning phase, the task of the SGVB officer is to identify the location of the different services that can decrease the exposure of the refugees to violence. However sometimes there are no many alternatives among which decide.

Refugees' profile

Newly arrived refugees are subjected to a registration in the transit centre carried out by UNHCR on behalf of the government or by the government itself. Through this process, information such as the name and the age is collected. These are used for having a first idea of the number of incoming people and for identifying refugees with specific needs. Later, a more accurate registration is carried out in order to define a detailed refugee profile. Through this process, the officers try to have an understanding of the culture, social norms and the legal system at which refugees were used to. In the protected response phase, a monitoring system is absent. Therefore, an up-to-date picture of the refugee camp is absent.

Information system

Key informants are interviewed for collecting information concerning habitudes and needs of refugee and host communities.

Issues in the site selection and planning processes

Main problems are the lack of planning and the limited consultation with the refugee and host communities. Their engagement in the planning process will instead allow the identification of possible risks.

When an agreement with the government is achieved, it is important to identify sources and measures for the establishment of a pacific coexistence. A defined strategy for the energy supply and the environment protection will prevent future issues. Usually, problems are caused by an insufficient understanding of the situation in the camps and needs of the community.

Missing stakeholders in the site selection and planning process

It is important to always consult with the community during the site selection and planning phase. Equally important is the engagement of the population for the maintenance of the infrastructure along the protracted phase. Not only the community leader should be involved in the planning process but also random members of the community. Community leaders could indeed not represent the needs of all community members, excluding minorities.

Concerning the UNHCR response in the site selection and planning phases, the intervention of a multifunctional team is essential for having a wide pictures of possible issues and for integrating interventions.

Possible improvements in the process

The program people in the field develop the budget after the design is completed. However, the money collected could be less than what is requested. In this case, UNHCR or other partners need to reduce the interventions. This decision should instead be taken by the community, who better knows which interventions need to be prioritized.

An important community approach process is **risk mapping** (or prioritize mapping). The refugee camp is designed together with the refugee's community, which decides the allocation of facilities such as latrines according to needs and habitude. Additionally, refugees are requested to prioritize the interventions. This procedure helps in redefine the budget once the money available for supporting the refugee response is known.

2.3 Interview form

Water Security in refugee settlements

Refugee allocation according to water security – UNHCR – Interview

From:	Alessia Matano`	**E-Mail:**	alessia.matano@deltares.nl
With:		**Date:** 2019-02-04	
Position:			
Department:			

First of all, thank you very much for your time and supporting this research!

INTRODUCTION

About me:

- Sanitary engineer (MSc), Italy – (University of Federico II in Naples)
- Master in Water Resource Management and Hydrology at TU-Delft in The Netherlands
  - IHE-Delft (Unesco partner) for optimization of De-(Centralised) WWTPs configuration in the Wadi Al Nar Wadi between the West Bank and Israel.
  - Global Reservoir Databases for reservoir modelling in Deltares, Institution for applied research in the field of Water and Subsurface
- Volunteer in the Hum-Tech Lab for the Rohingya crisis
- Currently working for Water Resources Management in refugee settlements in a joint project with Deltares and TU-Delft. In particular, my work focus on the site selection process at the contingency phase and the spatial accommodation of refugees in new or existing refugee settlements. The goal is the development of a methodology based on water security criteria able to support decision makers in planning a quick and adequate response at the outset of an emergency.

YOU?

Aim of this meeting / interview

The main purpose of this interview is to:

1. Needs assessment:

- Better understanding of the decision problem;

- Identifying gaps between a current situation and agreed standards;

- Identify stakeholders.

2. Role of UNHCR Geneva headquarters and the local UNHCR office

Procedure

A. Introduction of the foreseen study
B. Questions on UNHCR-Geneva structure, type of support during a refugee crises, site selection decision process.

[Based on your professional background, personal experience and your current position at UNHCR]

I expect this interview to take no longer than 40 minutes.

Confidentiality:

Before we start, I would like discuss with you how the information of this interview will be used.

Your confidentiality will be respected. Information that discloses your identity will not be released in publications or reports unless you explicitly agree with that.

How do you prefer to be cited?

By name, position, institution

Position and institution only

Neither name nor institution

Make a suggestion and send me any potential publications (e.g. reports, journal papers) beforehand. Unless I request changes within two weeks after reception, my agreement can be assumed.

Other: ____

May I record our meeting? The audio files and documentation will be archived as long as required by TU Delft policies for documentation of research data (currently 10 years).

☐ yes ☐ no

Please feel free to interrupt and ask questions anytime if something is unclear.

Part 1 – INTRODUCTION OF THE FORESEEN STUDY

Who?

Principal investigator: MSc Alessia Matano`
Sponsor: TU Delft and Deltares (joint collaboration)

What?

We are conducting this study to support UNHCR in the contingency planning with the development of a methodology based on water security criteria for accommodating refugees in existing or new settlements.

Our focus is on water security criteria. We want to investigate which information on the water conditions can support the decision problem in analysis.

Why?

Site selection is a critical factor in the ability to provide safe and healthy environment for refugees. The adoption of unsuitable locations triggers a number of issues along the monitoring, operation and maintenance phase that can be avoided through a more appropriate site location process. Poor refugee allocation can lead to serious issues for water provision, hygiene, safety and resource depletion or competition with the host communities.

Guidelines try to support the main stakeholders in this process, suggesting multi-sectorial factors and approaches. However, refugee camps are still often located in remote, isolated and inhospitable areas, making it impossible for refugees to contribute to the local economy and to integrate with the local population.

Water is one of the most critical factors in the site selection process of refugee camps and an understanding of the water condition is required in supporting the decision process.

How?

Investigation on the decision process will be carried out at the coordination and operational levels .

- Study trip in Geneva-UNHCR and fieldwork in Uganda:
    - Individual interviews (like this one): needs assessment, interactions, decision problem, values/objectives, stakeholders
    - Questionnaire-based: values/objectives

What's in it for you?

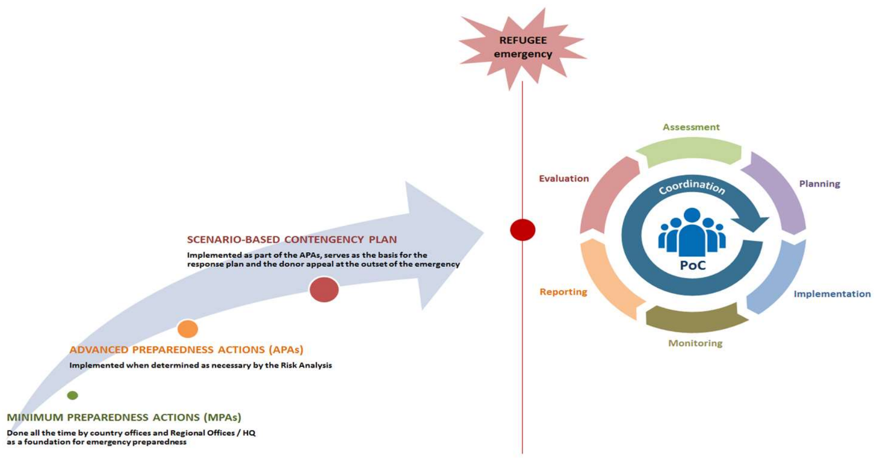
Expected insights:

- Characterization of the site selection decision problem and understanding of the procedure for refugee accommodation;
- Relevant information on the current water system and water conditions that can support the decision process;
- Resources available (tools and databases);
- Degree of collaboration and fragmentation (among departments, between the headquarter and the local UNHCR offices, between UNHCR and other humanitarian organizations);
- Identification of actors, roles and barriers in the refugee contingency planning (focus on the site selection and refugee accommodation);

Part 2 – Questions

- **Operational structure in UNHCR at the outset of an emergency**

1. What is **your position** within UNHCR (division and unit)? Which **role** does **your unit/section have**? Which **specific role** do you have?
2. Particularly, in which of these **phases** do you usually work?



3. What is the **general role** of **UNHCR Geneva**?
4. How do you **define** an **emergency situation** and when does it happen? And when instead do you define a **care and maintenance phase**, and a **durable solution**? How **long** does each phase usually last?
5. What's **your role** at the **outset of an emergency**? Which **decisions** do you take? Do you have any **time constraint** in taking these decisions?
6. Which **other UNHCR Geneva divisions** are involved at the outset of an emergency? Which **decisions** do they take? Do you have any **time constraint** in taking these decisions?

- **Site Selection and planning Process**

7. Which **role** do you have **in the site selection process** or **planning process** or **both**?
8. Which **decisions** do you take?
9. Which **information** do you need to take these decisions?
10. **Form where** do you **collect** this i**nformation**? (technical resources: tools, databases, surveys...)
11. Which information is usually **difficult to collect**?
12. Do you have any **time constrain** in collecting this information or taking certain decisions?
13. Do you **collaborate with other divisions** in the Geneva headquarters?
14. **How long** in general does the **site selection process** take? And the a**pproval from the government**?

15. With which **local UNHCR offices** do you collaborate in the site selection and planning phase? (**roles** and **decisions**) when this collaboration take place?

16. With which **local partners** do you mostly collaborate in the site selection and planning phase? when this collaboration take place?

17. Does any **important stakeholder miss** at the different decision stages? If so, who and why?

18. What are **the main issues** in identifying and selecting a site? What are the **main issues** in the **planning phase**? Which **aspect/phases** of the **site selection or planning** would you like to **improve**?

- **Newly arrived refugees**

19. Do you **explore** the possibility **to accommodate newly arrived refugees in existing camps**? does it usually happen?

20. If **yes,** according to your expertise, which **criteria** do you consider **important** in **accommodating newly arrived refugees?** For the **site selection** are there any **additional/or not relevant** criteria compared to the once previously identified?

21. If **not**, which criteria related to your specific work do you consider relevant at the **site selection phase**?

22. How **relevant** is the **budget available**? And does it **affect** the decision process?

23. **Which information** concerning **the newly refugees** do you think are needed?

    Which information concerning the **existing camps** are needed? (**water security condition**)

    Is this information **collected**? If not, **why**?

- **Criteria in the planning phase**

24. Do you think at **any criteria** relevant in the **planning phase** that are **important** to consider already **in the site selection** phase?

    (e.g equitable access to essential services, privacy and dignity, cultural adequacy, social cost, personal well-being. Do they affect the decision of which site select looking only at the water security conditions?)

- **Stakeholders and their participation/involvement**

25. Is there **collaboration among the different organizations** specifically working for refugees (ORAM, Refugees International, ...)?

    And with **others humanitarian organizations** (e.g. red cross)?

26. Does your work **depend** (or is i**nfluenced**) by any other **UN offices** (UN-OCHA)?

27. Is there anything you would like to add? Anything important I should keep in mind? Questions?

C. Survey form

Water Security for refugees



Motivation and background

We are conducting this study to investigate which water security criteria are relevant in the site selection and planning decision processes of refugee settlements. Decisions on site selection are very difficult to reverse and a poor refugee accommodation can lead to serious issues. Inadequate water condition in refugee settlements might lead to the decision to abandon the sites with high costs in re-accommodating the refugees already settled and consequent delay in accommodating newly-arrived refugees. A technical assessment of water security conditions is an important element in selecting and planning a site. A water security assessment roughly cover water supply and sanitation, water-related hazards, socio-economic development, preservation of ecosystems. In order to identify relevant criteria for assessing the suitability of the refugee site based on the hosting capacity, the problem decision needs to be reviewed, the objectives identified and prioritized. The insights generated by this survey will allow us to develop a list of water security criteria for the site selection and planning process and a methodology for supporting the identification of the most suitable option or combinations of options for accommodating the refugees. The approach aims to support the UNHCR response plan and the donor appeal at the outset of an emergency.

Aim

The aim of this questionnaire is to better understand the significant objectives related to water security aspects in the site selection and planning process by simulating a broader and deeper thinking.

We need your input!

Your unique knowledge and experience into the different phases of the humanitarian emergency preparedness and response plans are important for the success of this study. Please support our work by filling in this questionnaire. Indicate in the below questionnaire if you wish to receive a summary of the results.

We expect this questionnaire to take ca. 15-20 minutes of your time.

Instructions

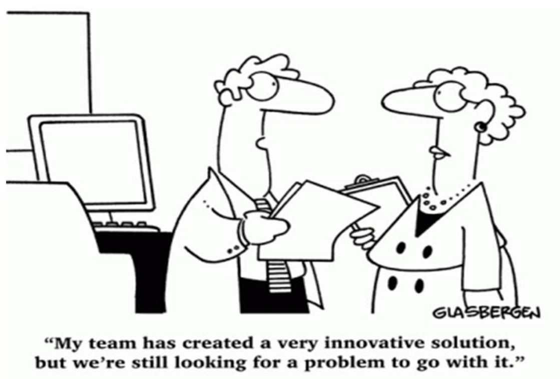
The questionnaire contains a number of statements, about which your opinion is asked. A limitation of the use of a questionnaire is that the statements and response categories cannot cover the full range of individual standpoints in detail. Please answer the questions by checking the answer that corresponds most closely to your opinion, even if your opinion is not fully represented by the given categories.

We are interested in your *personal* point of view. There are no correct or incorrect answers and also no answers that are better or worse than others.

Confidentiality and data handling

Based on TU Delft Research Ethics Guidelines and Deltares Confidentiality Policy, the information provided under this questionnaire will be not released in any form without your explicit agreement. Information and data that we receive from you will be used within this project only. For further information look at: https://www.tudelft.nl/over-tu-delft/strategie/strategiedocumenten-tu-delft/integriteitsbeleid/human-research-ethics/

Thank you for your collaboration!



Do you wish to leave us a comment?

Questions? Comments?

Please do not hesitate to contact us. We will be glad to assist you!

MSc Alessia Matano`

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Part 1 Respondent information

1.1 Please fill in the following fields

Initials:

Organization:

Position:

Department:

1.2 Which areas best describe your professional background or expertise? *Select max. 3 items.*

Technology, engineering	Management, administration	Infrastructure design, architecture	Policy, regulation, governance	Science, research	Organization support, logistics	Economics, finance

1.3 How many years of working experience do you have in emergencies and humanitarian crises? *Round accordingly.*

1.4 How many years of working experience do you have in UNHCR? *Round accordingly.*

1.5 What is your main task/responsibility in this organization?

1.6 What are your additional tasks or responsibilities?

1.7 Do you work mostly at ..?

Headquarters	Country level (capital)	Country level (sub-offices, field offices)

1.8 In which phases of assistance to refugees do you work the most?

Contingency	Emergency	Protracted/Durable Solution	Other (please specify)

2.0 What are the main topics that your work focus on?

Emergency Management	
Contingency Planning	
Immediate Response	
Coordination and site level organizations	
External relations	
Other (please specify):	
Operations Planning	
Site selection, planning and shelter	
Water	
Sanitation	
Environment, disasters and climate change	
Food and nutrition	
Health	
Supplies and transport	
Education	
Other (please specify):	
Support to operations	
Administration staffing and finance	
Communications	
Other (please specify):	
Other (please specify):	

Part 2 Goals

2.1 What matters to you to ensure water security when accommodating refugees in new or existing settlements?

Please specify the objectives (criteria, issues) that you will consider in evaluating and selecting sites for accommodating refugees and/or the site planning in new or existing settlements according to water security conditions.

A suitable site for the accommodation of refugees fulfils the following objectives… (Please specify as many objectives as come to your mind)

1.

2.

3.

4.

5.

6.

7.

8.

9.

10.

11.

12.

13.

14.

15.

16.

2.2 Expand your objective list

Research shows that in our first attempt we usually only generate about 30-50 % of the objectives that we consider relevant. Therefore, try to add at least the same number of goals as you mentioned in 2.1. Use the indicated categories to help you in generating a more comprehensive list of objectives.

1. SAFETY

1A.

1B.

1C.

1D.

2. OPPORTUNITIES AND RISK FOR THE HOST COMMUNITY

2E.

2F.

2G.

2H.

3. ACCESSIBILITY

3I.

3J.

3K.

3L.

4. ADEQUACY OF THE WATER SOURCES

4M.

4N.

4O.

4P.

5. SUSTAINABILITY

5Q.

5R.

5S.

5T.

6. FINANCE, COSTS

6U.

6V.

6X.

6W.

2.3 How relevant are these objectives to you in the context of water security?

Please first tick the objectives listed in the below table that are relevant to you.
Then, check the objectives you generated in questions 2.1 and 2.2 and compare these to the ones listed in the table below.

- If you have any similar objectives, please indicate the number and/or letter of your objective (from the list 2.1 and 2.2) under the column "Own goal";
- If your objective is not yet mentioned, add it at the bottom of the table.

Finally, take the five objectives that have the highest priority to you and rank these from 1 (highest) to 5 (lowest).

	I would like to chose a location that..	Relevant	Own goal	Top 5 (rank 1-5)
1	Minimize the exposure of people to water related hazards (floods, droughts,..)			
2	Minimize exposure to violence (e.g. woman and children)			
3	Minimize exposure to water-related diseases (e.g. water-borne diseases)			
4	High reliability of raw water quantity for immediate needs			
5	High reliability of the raw water quality			
6	Guarantee water for future needs (e.g. flexible host capacity, support income-generating activities)			
7	Improve current water services and/ infrastructure for the host communities and for the settled refugees. If missing, provide new ones.			
8	Improve economy of the host community (e.g. local scale)			
9	Avoid water competition between host and refugee communities			
10	Minimize investment costs			
11	Minimize operational and maintenance costs			
12	Ensure a high protection of the water sources and the natural protected areas			
13	Minimize the needs for difficult corrective measures(at the planning/designing phase and after)			
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				

2.4 Please complete the statements with regard to the five highest priority goals you selected in 2.3.
Please write the number of the goal next to 'Goal 1:', 'Goal 2:', 'Goal 3' etc. at least in the first table below and stick to this in the remainder so that it is clear which goals from 2.3. you refer to.

a. This goal is usually considered in the site selection and planning phase by the UNHCR headquarter office.

	Strongly agree (++)	Agree (+)	Neutral (+/-)	Disagree (-)	Strongly disagree (--)
Goal 1: ___					
Goal 2: ___					
Goal 3: ___					
Goal 4: ___					
Goal 5: ___					

b. This goal is usually considered in the site selection phase and planning by the country officers.

	Strongly agree (++)	Agree (+)	Neutral (+/-)	Disagree (-)	Strongly disagree (--)
Goal 1: ___					
Goal 2: ___					
Goal 3: ___					
Goal 4: ___					
Goal 5: ___					

c. This goal is usually considered in the site selection and planning phase by the government.

	Strongly agree (++)	Agree (+)	Neutral (+/-)	Disagree (-)	Strongly disagree (--)
Goal 1: ___					
Goal 2: ___					
Goal 3: ___					
Goal 4: ___					
Goal 5: ___					

Part 4 Other opinions

Members of an organization rarely decide what to do in their work based on their individual preferences only. Often, the opinion of other individuals or groups is taken into account.

3.1 Which individuals or groups do you think have a higher influence when deciding the accommodation of refugees? These individuals or groups can be operating within or outside your organization.

Individual/ group 1

Individual/ group 2

Individual/ group 3

3.2 To which extent are the opinions from these individuals or groups followed?

	Completely (++)	To a large extent (+)	Neutral (+/-)	Partly (-)	Not at all (--)
Individual/ group 1					
Individual/ group 2					
Individual/ group 3					

3.3 How much importance to you think that the individuals or groups give to your five highest priority goals in the current decision making process? *Please give your answer on a scale from -5 to +5, indicating*

-5 ...very little importance
0 ... neither important nor unimportant
+5...very high importance

Example: If you fill out +5 after goal 1 in the first column, you indicate that you expect option 1 to contribute very strongly to achieving goal 1.

	Goal 1 ____	Goal 2 ____	Goal 3 ____	Goal 4 ____	Goal 5 ____
Individual/ group 1					
Individual/ group 2					
Individual/ group 3					

Thank you very much for your participation!

Would you like to be informed about the results of this study?
You can leave your name and email in the boxes below.

Name	Email

D. Indicators for assessing the suitability of potential hosting refugee settlement

Table 29. Relevant factors for assessing the suitability of refugee hosting sites (Emergency Handbook 4th edition)

Topography, drainage, soil conditions	• The topography of the land should permit easy drainage and the site should be located above flood level. Rocky, impermeable soil should be avoided. Land covered with grass will prevent dust. Wherever possible, steep slopes, narrow valleys, and ravines should be avoided. • Ideally, a site should have a slope of 2%–4% for good drainage, and not more than 10% to avoid erosion and the need for expensive earthmoving for roads and building construction. • Avoid areas likely to become marshy or waterlogged during the rainy season. Consult national meteorological data and host communities before making a decision. • Soils that absorb surface water swiftly facilitate the construction and effectiveness of pit latrines. • Subsoil should permit good infiltration (permit soil to absorb water and retain solid waste in latrines). Very sandy soils may have good infiltration; but latrine pits may be less stable. • Pit latrines should not penetrate into the ground water. The groundwater table should be at least 3m.below the surface of the site. • Avoid excessively rocky or impermeable sites as they hamper both shelter and latrine construction. • If possible, select a site where the land is suitable for vegetable gardens or smallscale cultivation.
Water resources	• Choose locations that are reasonably close to an adequate source of good water, and ideally near high ground that has good surface water run-off and drainage. Once located, water sources should be protected. Ideally, no individual should have to walk for more than a few minutes. There should be at least one water point for every 250 people.

	• Ideally, hydrological surveys will provide information on the presence of water. A site should not be selected on the assumption that water will be found by drilling. Trucking water over long distances should be avoided if possible.
Land Rights	• UNHCR neither purchases nor rents land for refugee settlements. • Refugees should enjoy exclusive use of the site in which they live, by agreement with national and local authorities. • Governments often make public land available. • Private or communal land(including unclosed pastoral land) may only be used if the Government has agreed a formal legal arrangement with the owner(s), in accordance with the laws of the country. • The status of land occupied for sites should be clarified in writing by the Government. • In association with the Government and host community, agree and clarify the entitlement of refugees to carryout given activities (forage for food, collect firewood, collect timber and other shelter materials such as grass or mud, gather fodder and graze animals).
Accessibility	• Ensure the site has an adequate road infrastructure; access to it should be reliable, including during the rainy season. • Assess the site's proximity to national services, including health facilities, markets and towns. Access to mainstream services is encouraged wherever possible and avoids the need to develop parallel services for the camp population. • Liaise with development agencies, including UNDP and related Government ministries, to secure improvement of access routes. • UNHCR should fund the cost of building short access roads connecting the site to the main road.
Security	• The site should be located a sufficient distance from international borders (50km), conflict zones, and other potentially sensitive areas (such as military installations). Avoid locations that experience extreme climatic conditions, or present evident health (malaria), environmental or other risks. • High winds can damage temporary shelters and increase fire risks. • Evaluate seasonal variations.Sites that are ideal in the dry season may be uninhabitable in the rainy season. • Avoid locating refugees in places whose climate differs greatly from that to which they are accustomed.
Environment and	• Ensure the site has sufficient ground cover (grass, bushes and trees). Vegetation provides shade, protects from wind, and reduces erosion and dust.

Vegetation	• Avoid sites where dust clouds are common; these cause respiratory disease • Avoid sites within 1 day's walk of an environmentally protected area (such as a wild-life reserve). • Take steps to ensure access to a supply of firewood, in collaboration with local forestry authorities,and in negotiation with the host community.

Table 4 – Site selection factors of importance

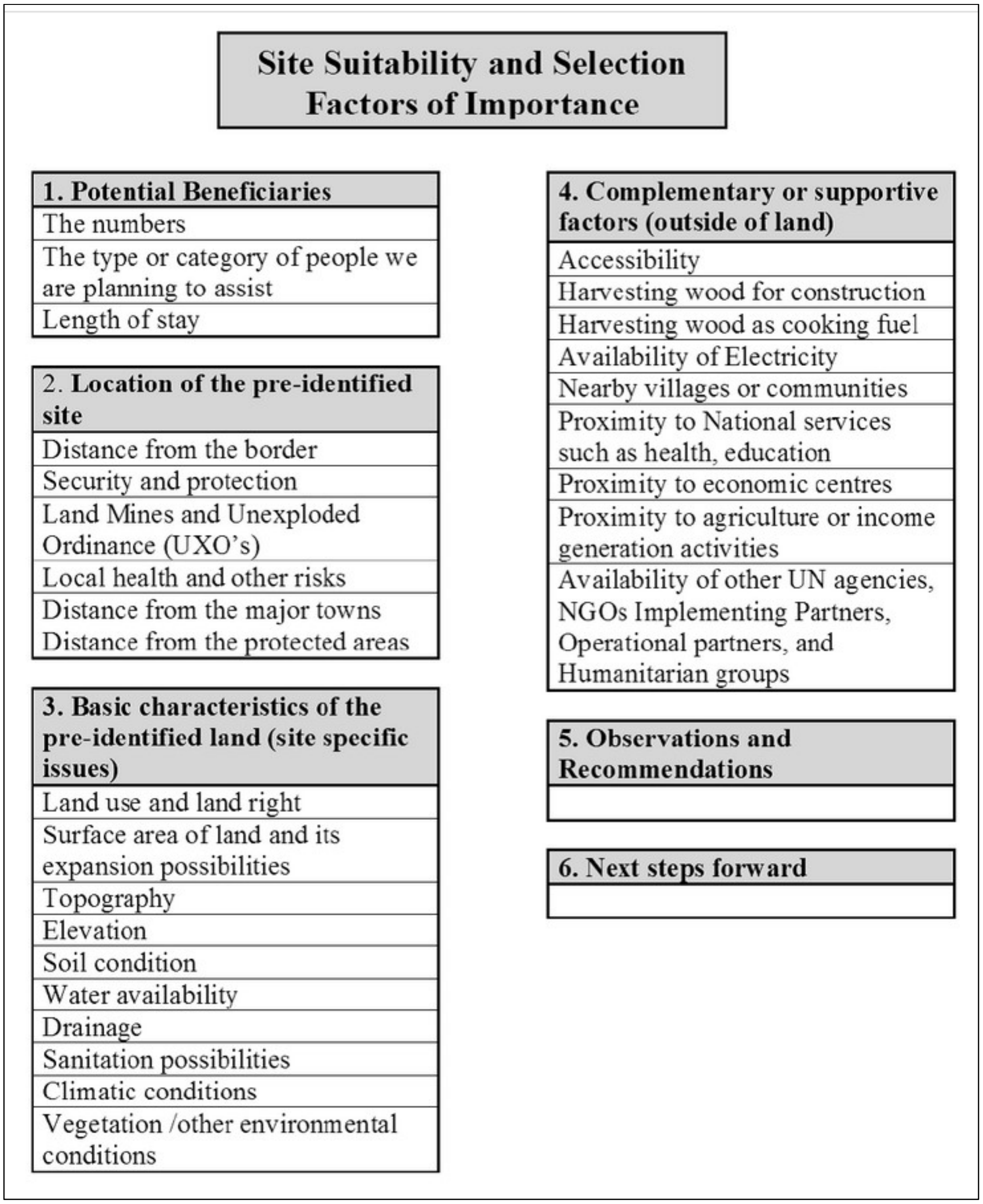


Figure 24. Site selection critical factors from the Emergency Handbook (UNHCR, 2007)

Description	Minimum standard
Topography	• easy drainage • above flood level • avoid rocky, impermeable soil • grass coverage to prevent dust • avoid steep slopes, narrow valleys and ravines • slope 2-4%, to avoid erosion and need for earth-moving for constructions • avoid areas that are likely to become marshy or waterlogged during rainy season • subsoil quality in relation to infiltration and pit latrine • groundwater table at least >3m below surface camp site • ***if possible, select a site where land is suitable for vegetable gardens or small scale cultivation***
Water resources	• Reasonably close to adequate source of good water • Near high grounds with good surface water run-off and drainage • At least one water point for 250 people
Land rights	• No purchase of rent • Exclusive use • Agreement local community on entitlement • refugees to carryout given activities
Accessibility	• Ensure adequate road infrastructure • Reliable, also in rain season • Site proximity to services
Security	• Sufficient distance from international borders • (>50km), conflict zones and other potential sensitive zones • **Avoid extreme climate conditions, environmental or other risks** • High winds can damage shelters and increase fire risks • Evaluate seasonal varieties
Environment and vegetation	• **Ensure sufficient ground cover Vegetation provides shade, protects from wind, and reduces erosion and dust** • Avoid sites where dust clouds are common • **Avoid sites within 1 day walk of an environmentally protected area** • Take steps to ensure access to supply of fire wood

Figure 25. Site selection critical factors and minimum standards from Rooij, Wascher, & Paulissen (2016)

E. Additional information for: Step (2) Generate Objectives

(1) Preliminary objectives hierarchy

A first scan of the available UN guidelines and scientific literature (Table 4) allowed to identify criteria, goals and indicators currently used in the decision process (Table 30). These were organised and structured in a means-ends network enabling a comprehensive and structured visualization of the criteria (Figure 26). The approach helped in identifying fundamental objectives while avoiding redundancy.

Table 30. Preliminary master list

Categories	Objectives	Sources
A. High Safety for the community	**Minimize the exposure of people to water related hazards (e.g. flooding, droughts, landslides,..);**	Verify the presence of unseen and/or irregular (but often locally known) risks such as flash flooding. (UNHCR, 2007) (Site selection, planning and shelter).
		Risks posed by natural hazards such as earthquakes, volcanic activity, landslides, flooding or high winds should inform the planning of shelter and settlement solutions (The Sphere Project, 2011). Surface water drainage and the risks of ponding or flooding should be assessed when selecting sites and planning temporary communal settlements (The Sphere Project, 2011).
		Safety from effects of landslides, floods, etc. (Trivedi & Singh, 2017)
		Flood and Drought Risk (Mong, Nelson, & Oni, 2014)
		Flood and Landslide Risk (Çetinkaya, Özceylan, Erbaş, & Kabak, 2016)
		The temporary shelter should be located at a reasonable distance from the danger zone in order to minimize the risks (Nappi & Souza, 2014)
		People should be accommodated in safety areas (Celik, 2017)
	Minimize exposure to violence (e.g. woman and children);	*The maximum distance between any shelter and a water distribution point should be not more than 100 m* (UNHCR, 2007) (Site selection, planning and shelter)
		Distance to water (Mong et al., 2014)
		Proximity to water source (Çetinkaya et al., 2016)
		Distance to surface water (Spink, 2015)
	Minimize exposure to water-related diseases (e.g. water-borne diseases);	*Settlement areas should be free of major environmental health hazards such as malaria, onchocerciasis...* (UNHCR, 2007) (Site selection, planning and shelter)
		Settlement locations should not be prone to diseases or contamination or have significant vector risks (The Sphere Project, 2011)
	High reliability of raw water quantity for	A specialist assessment of the availability of an adequate amount of water should be a prerequisite in selecting a site (UNHCR, 2007) (Site selection, planning and shelter)

B. High adequacy of the water sources	immediate needs	Ensure refugees have safe and equitable access to a sufficient quantity of water for drinking, cooking and personal and domestic hygiene. (UNHCR, 2017d)
		The availability of an adequate amount of water on a year-round basis has proved in practice to be the single most important criterion, and commonly the most problematic (UNHCR, 2007) (Site selection, planning and shelter)
		Ensure refugees have safe and equitable access to a sufficient quantity of water for drinking, cooking and personal and domestic hygiene (Emergency Handbook UNHCR, 2014)(UNHCR, 2017d)
		The amount of water available per day must meet certain standards (Nappi & Souza, 2014)
		Reliability of the water supply (Corsellis, 2001)
		Careful account should be taken of seasonal variation. Seasonal variation can have a considerable impact on the type and cost of shelter, infrastructure, heating fuel and even diet. (UNHCR, 2007) (Site selection, planning and shelter)
		Inter-annual water variability (Mong, Nelson, & Oni, 2014)
		Understanding of environmental risks or vulnerabilities; essential to inform planning and ensure that known vulnerabilities including impact of climate change are addressed as part of the response (The Sphere Project, 2011)
		Climatic condition should be suitable year-round (UNHCR, 2007) (Site selection, planning and shelter)
		The place used for shelter should be adaptable to climate variations (Nappi & Souza, 2014)
	High reliability of the raw water quality	Considerations in choosing between alternative sources of water in an emergency include: water quality, risk of contamination and ease of treatment if necessary (UNHCR, 2007) (Water)
		Preliminary assessments for site selection: how polluted is the water by sanitation or flooding? (Corsellis, 2001)
		New water sources should be tested invariably for physical, chemical, bacteriological and other impurities (Division of Operational Services UNHCR Geneva, 2006)
	Guarantee water for future needs (e.g. flexible host capacity, support income generating activities)	Consider possible income-generating activities; Potential for expansion to accommodate increase in the population due to new arrivals or natural increase; Proximity the IG/Agriculture (UNHCR, 2007) (Site selection, planning and shelter) As it is difficult to predict the life-span of a refugee camp, it is best to plan on a cost-effective, long-term basis. (UNHCR, 2007) (Water)
		Increasing the self-sufficiency of the forced migrants for food by siting to allow agriculture and livestock reduces relief aid required and increases community self-reliance. (Mong, Nelson, & Oni, 2014)

		Sufficient water available within a suitable distance throughout the year for forced migrants, hosts, agriculture, and livestock. (Corsellis, 2001)
C. Promote advantages for the host community	**Improve current water services and/or infrastructure for the host communities and for the settled refugees. If missing, provide new ones.**	The presence of UNHCR and thus, refugees, could actually benefit communities that had previously suffered from poor access to certain resources. (Mong, Nelson, & Oni, 2014)
		The objective is to maximise developmental opportunities for the host population (Corsellis, 2001)
	Improve local economy	Land availability and access for cultivation and grazing, and access to market areas and local services for particular economic activities should be considered. (The Sphere Project, 2011)
		Refugee camps become repositories of resources as relief supplies and food aid, vehicles, communication equipment, employment and transport contracts with relief agencies, and other locally valued and scarce materials. The refugees themselves bring human capital in the form of labour, skills and entrepreneurship, and they are conduits for remittance flows (Jacobsen, 2002)
	Avoid water competition between host and refugee communities	It is necessary to avoid long-term protection issues such us conflict with local communities (UNHCR, 2007) (Site selection, planning and shelter)
	Minimize environmental damage and vulnerability	Avoid water depletion (UNHCR, 2007) (Site selection, planning and shelter) Mitigate long-term environmental impact. Avoid depletion of the local environmental resources. (The Sphere Project, 2011)
		Avoid sites close to environmentally protected areas. A site should be located at least a day's walk from protected areas or reserves (UNHCR, 2007) (Site selection, planning and shelter)
D. Low Costs	**Minimize investment costs**	The selection of temporary shelter location is designed as optimal for efficient and effective relief activities. In this context, the cost of location, holding cost of inventory and distribution of relief goods should be minimized (Celik, 2017)
	Minimize operational and maintenance costs	The place used as temporary shelter should be undertaken in consultation with the competent authorities and grounded in a consensual strategy for services and maintenance at an affordable cost (Nappi & Souza, 2014)
		Suitable soil and other environmental features for the implementation of the water facilities; "Minimize the needs for difficult future measures"(UNHCR, 2007) (Site selection, planning and shelter)
	Minimize the time for interventions	Needs assessment UNHCR-Geneva (HQ)
	Minimize the needs for difficult corrective measures (at the	Understanding of environmental risks or vulnerabilities; essential to inform planning and ensure that known vulnerabilities including impact of climate change are addressed as part of the response (The Sphere Project, 2011)

	planning/designing phase and after)	Climatic condition should be suitable year-round (UNHCR, 2007) (Site selection, planning and shelter)
		The place used for shelter should be adaptable to climate variations (Nappi & Souza, 2014)
		Soil should be hard and resilient to flowing water or heavy rains. (Trivedi & Singh, 2017)
Equitable access to essential services	These objectives are out of the scope of the research as related to the planning phase of the refugee camps.	Climatic condition should be suitable year-round (UNHCR, 2007) (Site selection, planning and shelter)
Privacy and dignity	The adopted technologies and infrastructure need to suit the cultural differences while ensuring the respect of the privacy.	The place used for shelter should be adaptable to climate variations (Nappi & Souza, 2014)
Cultural adequacy		Soil should be hard and resilient to flowing water or heavy rains. (Trivedi & Singh, 2017)

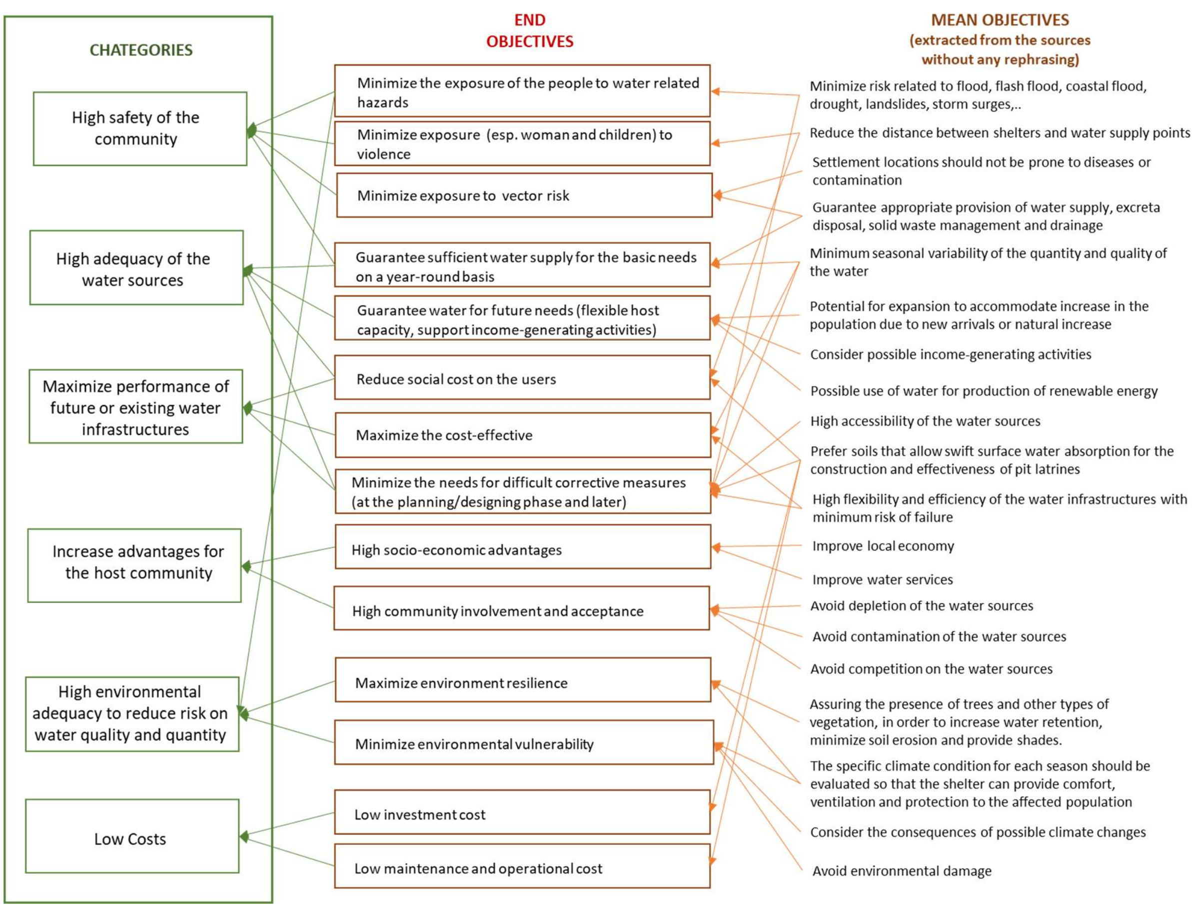


Figure 26. Means-ends network resulted from the literature review

(2) Semi-structured interviews

The criteria identified from the interviews were structured in a means-ends network (Figure 27).

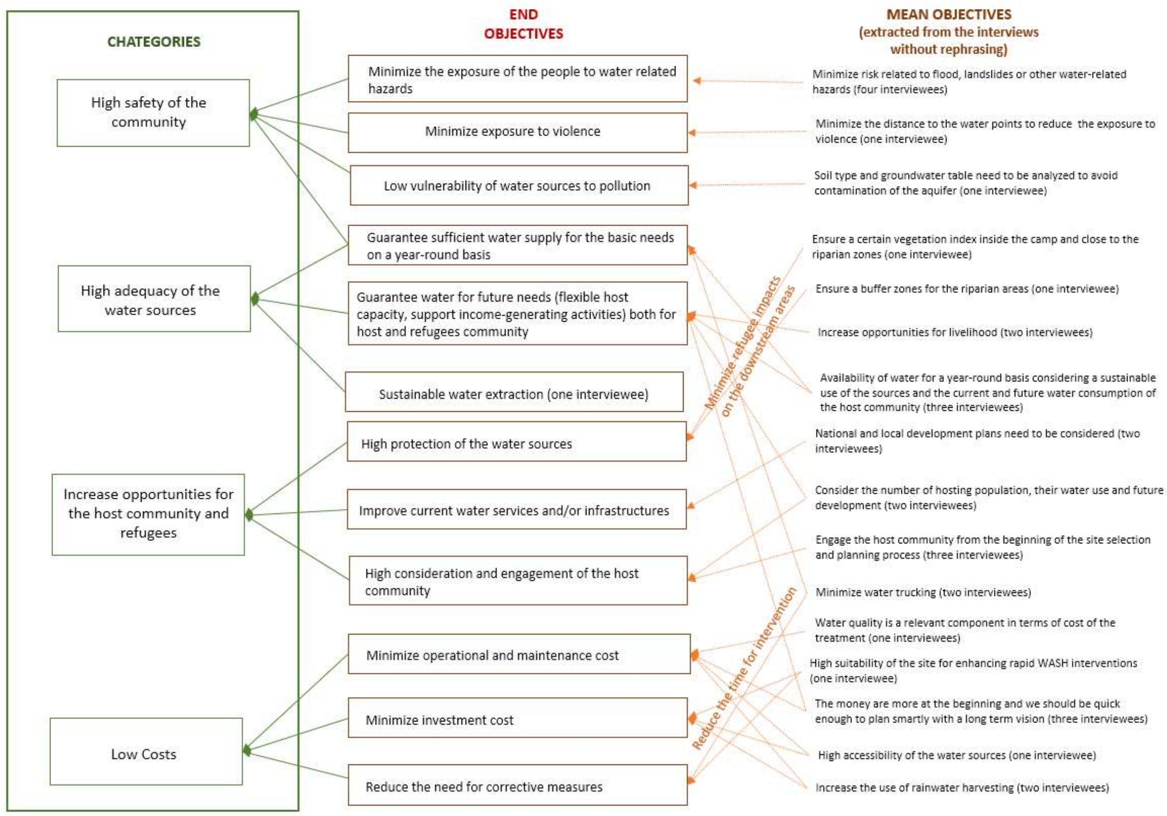


Figure 27. Means-ends network from semi-structured interviews at the UNHCR-HQ

High safety for the refugee communities

- Minimize risks related to flooding, landslides or other natural hazards. If areas prone to flooding are selected, it is important to identify the preferential flood paths in order to identify safety allocation for the shelters;
- Minimize the distance to the water points the exposure to violence (high accessibility of the water points);
- Type of soil and groundwater table are additional information relevant for the WASH operations to avoid contaminations of the aquifer;
- Minimize environmental impact related to the wastewater collection (e.g. latrines) -> (groundwater table);

High adequacy of the water sources

- Availability of water for a year-round basis considering a sustainable use of the sources and the current water consumption of the host community;
- Increase opportunities for livelihood, assuring water for future activities;
- Availability of water also for the host community. Look at the expected natural growth and the development plan of the host community. (*It is important to look at the expected natural growth of*

the population and the carrying capacity of the site when another village is built nearby and water resources are shared.); → high sufficient quantity for supporting livelihood;

- Sustainability of the water extraction;
- Sufficient quantity for supporting livelihood → (1) the water use of the host community is not taken into consideration; (3) the water needed to sustain future livelihood is not estimated;

Increase advantages/opportunities for the refugees and host community

- Ensure a certain vegetation index inside the camp and close to the riparian zones → minimize the risk of landslides and soil erosion, minimize risks for the downstream areas;
- Protection of the water bodies ensuring a buffer zones for the riparian areas;
- Availability of water also for the host community. Look at the expected natural growth and the development plan of the host community. (*It is important to look at the expected natural growth of the population and the carrying capacity of the site when another village is built nearby and water resources are shared.*); → effectively improvement of the hosting infrustructure;
- Minimize refugee impacts on the hosting sites → Low attention on environmental impacts in the refugee interventions (e.g. *sludge from drinking water treatment plants, which is commonly discharged without any treatment*);
- Improve current water services and infrastructure → national and local development plans are not considered (need to be considered according to the Master plan);
- Consider the number of inhabitants in the host community;

Low cost

- High suitability of the site for enhancing WASH interventions → minimizing investment cost and the time to carried out the interventions -> (soil content);
- Minimize operational and maintenance (O&M) costs -> (slope gradient and water quality);
  "The money is more at the beginning and we should be quick enough to plan smartly with a long term vision"
- Minimize investment costs;
- Minimize the time for interventions → minimize initial costs (water trucking) and accelerate the refugee response;
- Minimize operational and maintenance costs (e.g. minimize treatment cost) and the costs for any future measures;
- Sustainable costs;
- Minimize the distance to the water points for reducing operational costs
- High accessibility of the water sources to reduce initial and future costs;
- Increase the use of rainwater harvesting if this technology is appropriate according to the characteristics of the site;

(3) Survey

• Respondent Information

The respondents were all from UNHCR with the exception of one respondent from UN-Habitat. Additionally, the respondents are mainly belonging to the WASH unit.

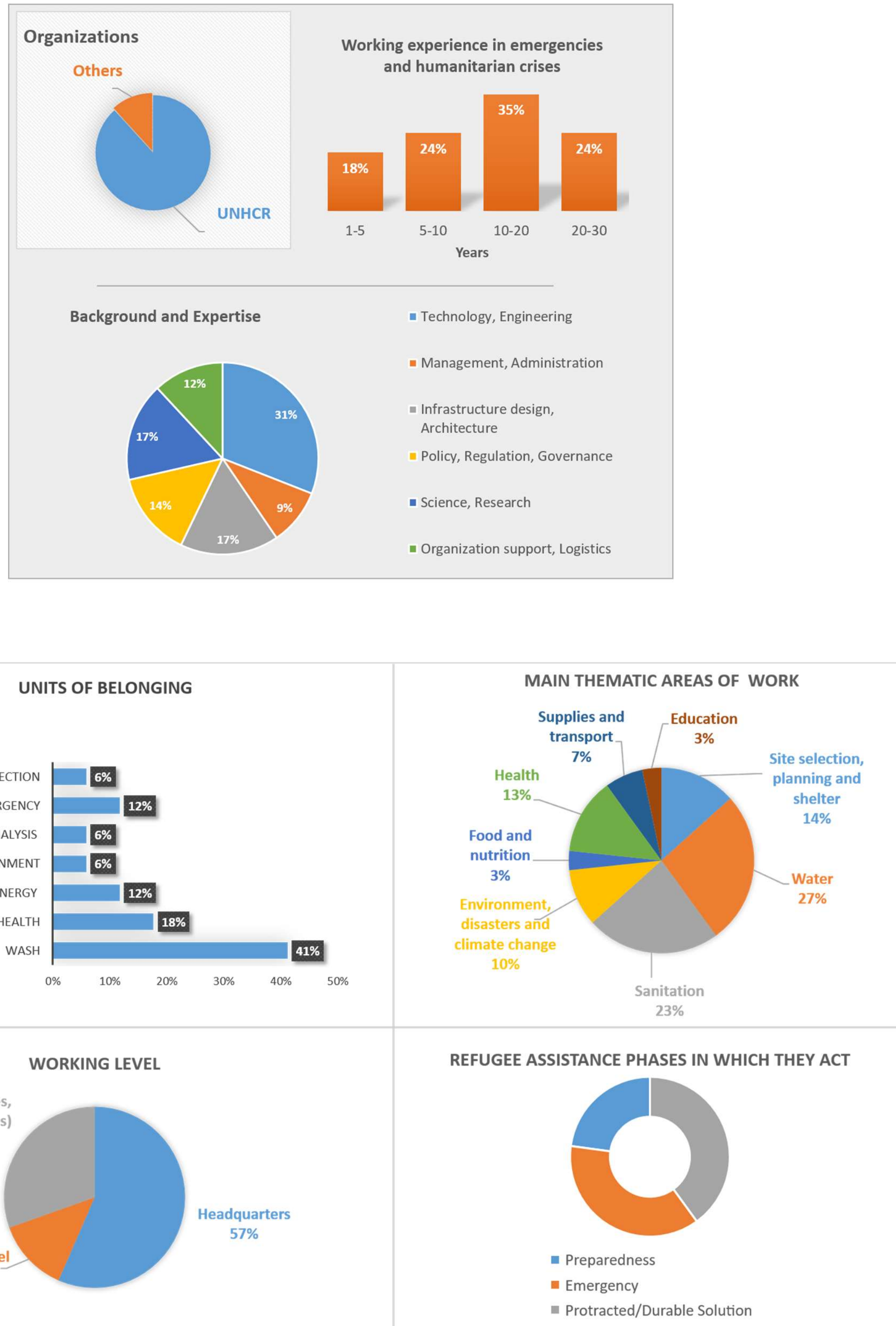


Figure 28. Respondents' information (the percentage refers on the analysis of 17 surveys in total)

- Stakeholders feedback on the master list (results of question 2.3 from the survey: Relevant Objectives and Top5)

In the questionnaire, we asked to the participant to tick the relevant objectives from a master list according to their personal experience. The number of times that each objective was selected as relevant was computed. The results were divided by the number of respondents in order to express in percentage the times in which each decision objectives was considered relevant (Figure 9).

From the first attempt, the objectives with the highest number of selection are:

Objectives	Percentage	n. of respondents
High protection of the water sources and natural protected areas	76%	17
Guarantee water for future needs (e.g flexible host capacity, support income generating activities)	71%	
Minimize exposure of people to water related hazards	71%	

However, in the second attempt, the objectives most frequently included in the top-5 are:

Objectives	Percentage	n. of respondents
Minimize exposure to water-related diseases (e.g. water-borne diseases)	94%	17
High protection of the water sources and natural protected areas	88%	
Minimize exposure of people to water related hazards	82%	
Avoid water competition between host and refugee communities	82%	

Minimize exposure to water-related diseases is the objective with the highest difference of percentage between the first and second attempt. This objective was judged relevant only by 11 respondents. However, when it was asked to rank from 0 to 5 the most relevant objective among the proposed list, the objective was included in the top-5 by 16 respondents, which seems a bit contradictory.

Almost all objectives were considered relevant by more than half of the respondents with the exception of the objectives below, which were considered relevant only by 6 respondents in the first attempt and by 8/9 in the second.

Objectives	Percentage in 1st and 2nd attempt	n. of respondents
Improve Economy of the host community (e.g. local scale)	35/47%	17
Minimize investment cost	35/53%	

Looking at the background and roles of the respondents, the objective "minimize investment cost" was considered relevant by the energy officers and by the WASH officers currently on the field.

In the survey, the respondents had to rank from the 1st (highest) to the 5th (lowest) position, the objectives that have the highest priority according to their personal opinion. In order to analyse the answers, a value of 5 was assigned to the objectives ranked in the first position, a value of 4 for the objectives ranked in the second position and so on. In this way, the values were summed up for each objective. The objectives with the highest scores are the ones included more times in the ranking list at the highest positions. From Figure 10, the objectives with the highest priority for the respondents were identified and a top 5 list was defined.

Key points survey:

- ❖ Almost all the objectives were considered relevant (with an acceptancy up to 60%) except for the objectives: “Improve economy of the host community” and “Minimize investment costs”;
- ❖ The objective “High reliability of raw water quantity for immediate needs” is ranked at the highest priority;
- ❖ The objectives “High protection of the water sources and natural protected areas” and “Guarantee water for future needs” are considered highly relevant. However, they do not have a high priority;
- ❖ The objectives “Improve economy of the host community” and “Minimize investment costs” are considered irrelevant by most of the respondents. Additionally, the lowest priority was assigned to them;
- ❖ The objective “Avoid water competition between refugee and host communities” is ranked at the fifth position of the top-5 priority list and it is considered relevant by (65%/)82% of the respondents;
- ❖ The objective “High reliability of raw water quality” is classified at the 5th position in the top-5 priority list and it is considered relevant by 53/65%;
- ❖ The objectives “Minimize exposure to water related hazards” and “Minimize exposure to water related diseases” are both considered relevant by more than the 65% of the respondents and are included in the top-5 of the highest priority respectively at the 4th and 2nd position.
- ❖ The objective: “Minimize exposure to violence” is at the 3rd position in the highest priority list and it is considered relevant by 65/76% of the respondents.
- ❖ The self-generated objectives mapped to the master list show a good comprehension of the objectives listed on the master list. This gives robustness to the results obtained from the survey;
- ❖ Only one participant listed more objectives that did not map to any objectives on the master list;

- ## Objectives Mapping (Results of question 2.3 from the survey: Own Goal)

In order to give reliability and robustness to the obtained results, the respondents were asked to match the self-generated objectives with the objectives in the master list if the respondent judged they present the same meaning. Additionally, the participants had to add their self-generated objective in the master list in case these were not already stated. Most of the self-generated objectives were mean objectives. Their mapping to the master list allows us to clarify which self-generated objective the participant associate to the objectives in the master list.

Table 31. Results from the mapping of the self-generated objectives in the master list

Objective in the Master list	Self-generated objective mapped to the master list
1. Minimize the exposure of people to water related hazards (floods, droughts...)	• Slope (>=3; <=5); • Safety/security (including protection from natural hazards); • No flood risk; • Hazards; • Safe from risk and exposure; • UNHCR protection and safety principle are followed; • DRR and prevention; • Contamination and pollution users from the sites; • Flood and drought risk (climate change resilience); • Topography and natural drainage; • Risk of flooding/water logging; • The settlement is not prone to flooding.
2. Minimize exposure to violence (e.g. woman and children)	• Safety and security; • Availability of water; • SGVB and exploitation; • Safe from risk and exposure; • Safety and security of collection for women and children; • UNHCR protection and safety principle are followed; • Closeness from local major urban and economical centre; • Proximity to resources; • Distance, reliability and quality; • Make sure that security measures are in place and assistance provided; • The host community culture matches to avoid conflicts.
3. Minimize exposure to water-related diseases (e.g. water-borne diseases)	• Water storage; • Water quality;

	• Safe water; • Risk mitigation from communicable diseases; • Bacteriological quality of source and chemical quality of source; • Quality of water acceptable and contamination and pollution; • Risk of contamination; • Health programs in place to prevent diseases (waterborne diseases); • The water quantity is adequate.
4. High reliability of raw water quantity for immediate needs	• Rainwater as potential source; • Reliable quantity; • Distance to water service; • Water Table; • Water availability; • Distance to water sources; • Capacity; • Enough water; • Enough water; • Bacteriological quality of source; • Chemical quality of source; • Distance to water point (no more than 200 m in urban area and 1 km in rural area); • Adequate quantity of water for domestic use 20l/day, commercial activities, agriculture and livestock; • Climate change resilient water source; • Adequate & reliable water source; • Access to water.
5. High reliability of the raw water quality	• Good quality at the taps; • Distance to water service; • Water Table; • Water Storage; • Water quality; • Good water quality; • Enough water; • Bacteriological quality of source; • Chemical quality of source; • Water with safe quality for proposed use; • Climate change resilient water source; • Protections concerns of water access and use; • Adequate & reliable water source; • Quality;

	• Clean water; • The water quality is good.
6. Guarantee water for future needs (e.g. flexible host capacity, support income-generating activities)	• Water quantity; • Enough water; • Peaceful coexistence; • Integration; • Long term supply; • The water quantity is adequate.
7. Improve current water services and/ infrastructure for the host communities and for the settled refugees. If missing, provide new ones	• Infrastructure improvement; • Host community interaction; • Availability of resources; • Peaceful coexistence; • Integration; • Opportunity for improved access to water supply for domestic /commercial/agriculture and livestock; • Community centres (health, shops, markets); • Joint water service provision. Although willingness and ability to pay may differ significantly between host community and refugees; • Local water development plans; • The cost of managing the settlements is reasonable hence in proximity to existing social structures.
8. Improve economy of the host community (e.g. local scale)	• Infrastructure improvement; • Incentive for the host community (cash programming); • Markets; • Livelihood development opportunities (host community opportunities and accessibility); • Proximity and access to local urban centres; • Local water development plans; • The host community benefits from refugee programme.
9. Avoid water competition between host and refugee communities	• Downstream water protection; • Sufficient supply for both community; • Infrastructure improvement; • Availability of resources; • Activities are not money consuming; • Availability of job opportunities; • Enough water; • Peaceful coexistence; • Integration; • Opportunity for sustainable integrated water resource management;

	• Risk of violence over competition for resources; • Conflict of interest over water source; • Availability of supplies.
10. Minimize investment costs	• Activities are not money consuming; • Minimal infrastructure capital expense (CAPEX); • The water source is low cost to maintain.
11. Minimize operational and maintenance costs	• Donor support; • Host government support; • Finance/cost for the minimum water requirement; • Cost of accessing or treating water supply is reasonable and benefit outweigh costs; • Quality from safety prospective; • Minimize operational expense (OPEX); • Ease of O&M; • The water source is low cost to maintain.
12. Ensure a high protection of the water sources and the natural protected areas	• Protection of the surface water; • Riparian protection; • Abstraction management; • Water quantity for future; • Water use (demand) does not exceed the sustainable water volume available; • Ecological balance (e.g. reforestation); • Depletion of local natural resources; • Minimal environmental footprint.
13. Minimize the needs for difficult corrective measures (at the planning/designing phase and after)	• Donor support; • Host government support; • Refugee resources.

- ## Opinions of other stakeholders (results of question 2.4 from the survey)

Previously, it was explicitly asked to the respondents to answer according to their personal opinion. In the section 2.4 of the questionnaire, it was asked to analyse the listed objectives according to the official position of UNHCR-HQ, sub-office and government. The intent was to investigate possible discrepancy between policies and guidelines with the reality in the field.

Legend:

(++)	Strongly agree
(+)	Agree
(+/-)	Neutral
(-)	Disagree
(--)	Strongly Disagree

n.	Objectives
1.	Minimize the exposure of people to water related hazards (floods, droughts...)
2.	Minimize exposure to violence (e.g. woman and children)
3.	Minimize exposure to water-related diseases (e.g. water-borne diseases)
4.	High reliability of raw water quantity for immediate needs
5.	High reliability of the raw water quality
6.	Guarantee water for future needs (e.g. flexible host capacity, support income-generating activities)
7.	Improve current water services and/ infrastructure for the host communities and for the settled refugees. If missing, provide new ones.
8.	Improve economy of the host community (e.g. local scale)
9.	Avoid water competition between host and refugee communities
10.	Minimize investment costs
11.	Minimize operational and maintenance costs
12.	Ensure a high protection of the water sources and the natural protected areas
13.	Minimize the needs for difficult corrective measures(at the planning/designing phase and after)

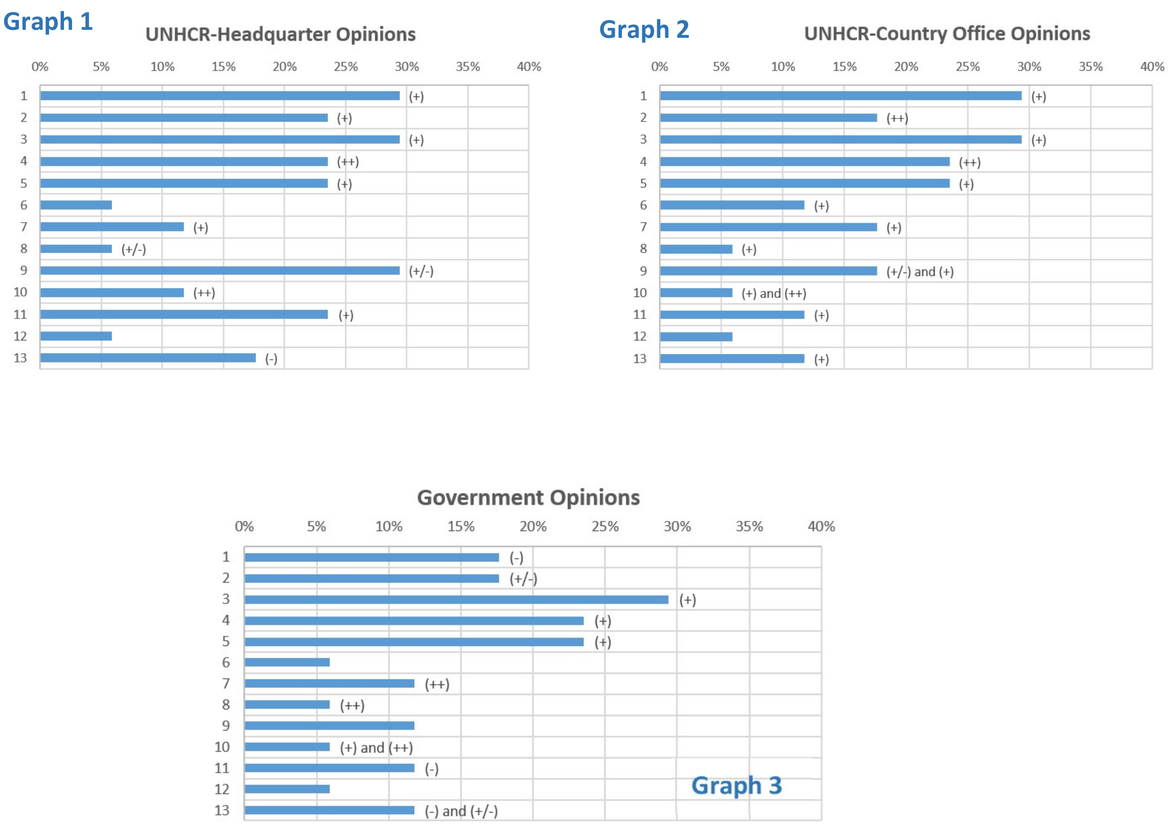


Figure 29. Stakeholders opinions

The number of times that the answer (from (--) to (++)) was selected was computed for each objective. This was divided by the total number of respondents, in order to extract the percentage of people that selects that specific answer for the analysed objective. Only the opinion selected by the majority of the respondents is shown in the graph. If a bar in the graph does not have a symbol is because the majority was not reached.

As showed in Graph 1, UNHCR headquarter considers in the site selection and planning phase almost all the objectives listed, with a particular attention for the goal: "guarantee high reliability of raw water quantity". The pattern in graph 2 is almost similar to the one in graph 1, showing agreement among the headquarter and the local UNHCR offices. Looking at graph 3, 17% of the total respondents think that the government does not considered the goal: "Minimize the exposure of people to water related hazards (floods, droughts...)" in the site selection and planning phase. On the other hand, the government strongly agrees on improving current water services and infrastructures and on improving economy of the host community. It also agrees on selecting a site with high reliability of row water quantity and quality and with a low risk of water-related diseases.

- Individuals and groups with a higher influence

Stakeholders in the decision process were investigated in the last section asking to the participant to list the organizations or groups that have the most influence in the decision process. The answers were grouped to obtain the frequency with which an answer was replicated by other respondents (Table 8). The hosting government was mentioned in all questionnaires.

F. Objectives, attributes and data source for the SNARA SDM-procedure

A narrative on the selected objectives and attributes is shown in paragraphs below. This aims to provide a clear understanding of selected criteria, while guiding future applications of the proposed decision structure. For some objectives, a list of global databases' sources is provided. These global data guide in selecting attributes more suitable to the local context.

Objective1. High safety for the refugee community

People's safety should be ensured against weather perils and disaster risks related to water. Two main categories of water-related disaster were identified: (1) water-related hazards and (2) water-related diseases. The former (1) concerns the exposure of newly arrived refugees to landslides, floods and drought. The latter (2) refers to *any significant or widespread adverse effects on human health, such as death, disability, illness or disorders, caused directly or indirectly by the condition, or changes in the quantity or quality of any waters* (Stanwell Smith, 2003). The provision of an adequate amount of water can prevent the spread of diseases caused by poor hygiene. However, the objective "high reliability of raw water quantity" was not defined under "high safety". The objective was considered a fundamental objective in the presented hierarchy given its self-related importance found both in the interviews and survey. Clear decision-makers' preferences can, indeed, be elicited for this objective while the same is not true for other sub-level objectives. However, dependency among different objectives' levels is preferably avoided (Eisenfuhr, Weber, & Langer, 2010).

6.1.1.1 Sub-Objective: Minimize exposure of people to water-related hazards

The majority of people of concern to UNHCR (including refugees, asylum-seekers, returnees, internally displaced and stateless persons) are concentrated in disaster-prone areas and so-called climate change hotspots around the globe, facing a high risk of secondary or repeated displacement. A survey conducted by (UNHCR, 2016b) found that refugees and internally displaced persons were exposed to 150 disasters in 16 countries between 2013 and 2014, confirming their vulnerability to disasters associated with natural hazards. Refugee camps are often sited on land classified as not-suitable for human settlement. A first understanding on the potential water-related hazards in the investigated site can support the decision process by informing decision-makers on the risk for the people of concern. Possible attributes are the cost of the interventions needed to mitigate the impact of potential natural disasters and to strength the resilience and, adaptive capacity of people at risk.

Attributes were not explored in detail as the objective is outside the WASH mandate.

6.1.1.2 Sub-Objective: Minimize exposure to water-related diseases

The objective seeks to reduce health risk in refugee settlement related to: (1) Exposure to contaminated water, (2) Presence of vector which lives adjacent to a water habitat and, (3) Poor hygiene (insufficient water quantity or wrong cultural practices). These can all have an impact on the health if water is mismanaged. Referring to the first two spheres, the fundamental objective was disaggregated as follows:

1. **Low direct exposure to contaminated water;**
2. **Low indirect exposure to contaminated water;**
3. **Low exposure to endemic water-vector diseases;**

Direct exposure to contaminated water refers to the water supplied by the water system (tap water from motorised boreholes, drinking water treatment plant, rainwater harvesting tanks, hand pumps), while indirect exposure refers to the exposure to water at the source. The objectives comprehensively look at the risk reduction of all water-related diseases identified by WHO (Table 32). The hierarchy structure and respective attributes are shown in Figure 30.

Table 32. Classification of water-related diseases (Stanwell Smith, 2003)

Category	Description of category	Type of water exposure	Subcategories	Example(s)
Waterborne microbiological diseases	Diseases related to consumption of pathogens consumed in water; most due to human or animal faecal contamination of water	Drinking water	(i)Treated or untreated (raw) water (ii)Public(municipal) supplies or private supplies	Cholera, Typhoid fever, viral gastroenteritis e.g. due to Norovirus
Waterborne chemical diseases	Diseases related to ingestion of toxic substances in water	Drinking water	(i)Treated or untreated (raw) water (ii)Public(municipal) supplies or private supplies	Arsenicosis
Water hygiene diseases	Diseases whose incidence, prevalence or severity can be reduced by using safe (clean) water to improve personal and domestic hygiene	Any water used for washing/personal hygiene	(i)Diseases related to variations in water quality (ii) Diseases related to water shortage	Scabies, shigellosis; trachoma
Water contact diseases	Caused by skin contact with pathogen–infested water or with chemical-contaminated water	Recreational water	(i)Fresh water sources (ii)Marine waters	Schistosomiasis (bilharzia); cyanobacteria
Water vector habitat diseases	Diseases were vector lives all or part of its life or adjacent to a water habitat	Untreated freshwater sources	(i)Rivers, streams (ii) Small collections of stagnant water e.g. water butts	Malaria (mosquitoes); filiariasis (mosquitoes); onchocerciasis (aquatic flies); schistosomiasis (snails); trypanosomiasis (tsetse flies)
Excreta disposal diseases	Diseases related to unsanitary disposal of human waste (faeces and urine)	Drinking water and untreated water sources	(i)Diseases related to human/animal water in drinking water (ii)Diseases related to direct /indirect contact with faeces/urine	Ascariasis; faecal-oral infections e.g. shigellosis; schistosomiasis; trachoma
Water aerosol diseases	Diseases related to respiratory transmission, where a water aerosol containing suspended pathogens enters airway	Drinking or raw water sources	(i)Water used in industrial/residential buildings (ii)Raw water sources	Legionellosis (legionnaires' diseases; humidifier fever); Norwalk-like viral gastroenteris

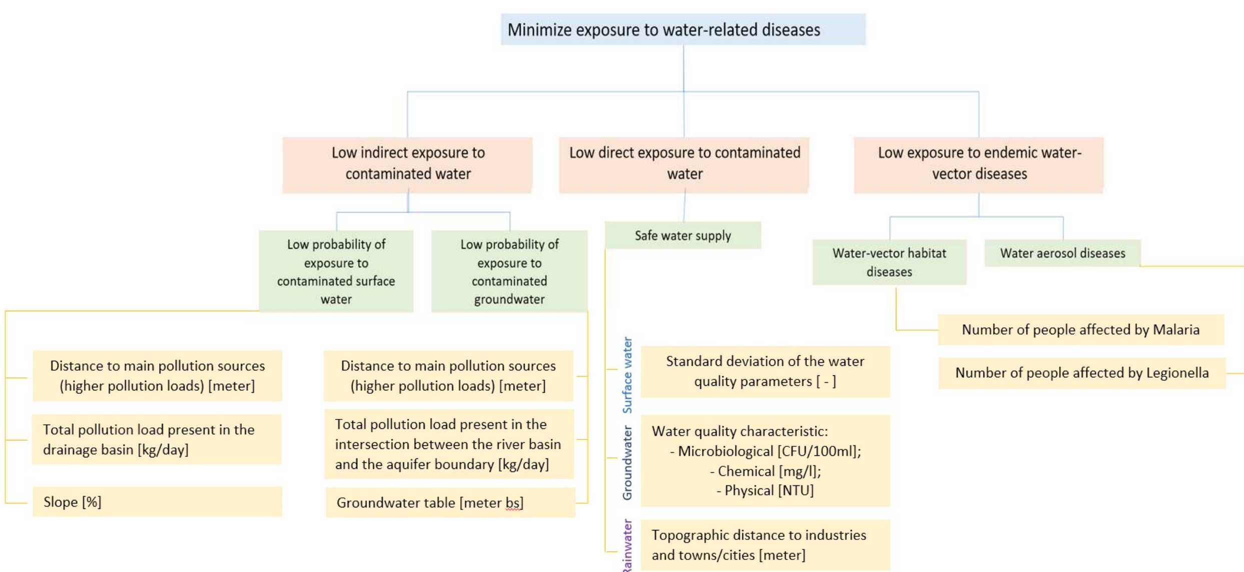


Figure 30. Minimize exposure to water-related diseases. Sub-level objectives are shown in orange (second-level) and in green (lowest level) boxes. Attributes are coloured in yellow.

I. Low indirect exposure to contaminated water

Refugees can be indirectly exposed to water-diseases through the use of contaminated water from polluted sources.

In order to consider the particular case of each water source, the sub-objective was broken down in:

1. Low probability of exposure to contaminated surface water;
2. Low probability of exposure to contaminated groundwater.

Attributes

Water quality at the source cannot be easily assessed in many geographic areas due to the presence of few monitoring stations and the challenge of measuring water-quality from satellite data and global models. However, such tools can give a first understanding of the vulnerability of the water sources to potential contamination and the presence of possible hazards. In this context, hazard is defined as a potential source of contamination resulting from human activities, taking place mainly at the land surface (ADPS, 2008; Mimi & Assi, 2009; Zwahlen, 2004). Therefore, the probability of indirect exposure to contaminated water can be assessed as the probability of contamination of groundwater and surface water.

The probability that groundwater will become contaminated to an unacceptable level depends on the activities on the immediately overlying land-surface, as well as on the vulnerability of the aquifer to contamination. The same is true for surface water, where hazard can be defined by the pollution loads existing in the catchment that drains toward the analysed area.

1. Low probability of exposure to contaminated **surface water sources** is computed through three indicators:

(1) Total pollution loads in the catchment (kg/day);

(2) Flow distance to the main pollution sources (meter);

(3) Slope of the area (%).

In the below sub-sections, the computation of the attributes is further explained.

(1) Total pollution loads in the catchment (kg/day);

Domestic, industrial, agriculture and wastewater pollution loads can be computed to assess the attribute. Their impacts on water sources depend on their degree of harmfulness, which can be determined by both the toxicity and the quantity of the harmful substances as the following relation (Mimi & Assi, 2009):

$$Pollution\ load = (Domestic + Agriculture + Industry)_{load}$$

The assessment of domestic wastewater loads can rely on standard values for BOD (40 g per person equivalent (PE) per day), total nitrogen (5 g/PE/day), total phosphorus (2 g/PE/day) or faecal coliform (170 * 10^{10} CFU/cap/year). The values above were extracted from (UNEP, 2016) and the (Ministry of Water and Environment (MWE), 2013) and reflect the levels for populations in developing countries with a relatively low protein intake. A detailed overview of faecal emission rate per region is shown in (Fonseca A., 2018). These values represent the amount of pollutants produced per capita and not the amount that actually reaches the water bodies. Furthermore, attributes can be computed considering the type of treatment systems (e.g. differently for urban and/or rural areas) allowing an estimative of pollution reduction.

In developing countries, domestic wastewater is more efficiently treated in urban areas than in rural areas. In the former, system for collection and treatment are in place, whereas in the latter open defecation or latrines are common waste disposal practices (Ministry of Water and Environment (MWE), 2013). Additionally, decay of the pollutants can take place if the wastewater flows through a wetland before reaching its final destination. Agriculture pollution load can be estimated through the excreta production of livestock. Table 5.10 below presents standard values for different animals and nutrients in excreta.

Table 33. Nutrients in excreta of different type of animals (Ministry of Water and Environment (MWE), 2013)

	Cattle	Goat	Sheep	Pig	Poultry	Hippo	Buffalo	Elephant	Zebra	Giraffe
Slaughtered weight (kg)	250	12	15	80	2	1500	500	2500	250	700
N (kg N/year)	50	10	10	12	0.6	300	100	500	50	140
P (kg/year)	10	2	2	4	0.2	60	20	100	10	30
No. of animals per TLU	1.0	20.8	16.7	3.1	125.0	0.2	0.5	0.1	1.0	0.4
N (kg/TLU/year)	50.0	208.3	166.7	37.5	75.0	50.0	50,0	50’0	50.0	50.0
P (kg /TLU/year)	10.0	41.7	33.3	12.5	23.8	10.0	10.0	10.0	10.0	10.7

Table 34. Faecal coliform production of different type of animals (ASAE,2003) (FAO,2003)

Animals	Faecal coliform production (10^{10} CFU/year)
Cattle	2555
Pig	657
Chicken	15
Goat	821
Sheep	821

Pollution loads from industries can be distinguished according to their production process. Sector-specific concentrations of pollutants from industries sources are provided by (Ministry of Water and Environment (MWE), 2013).

Table 35. Sector-specific concentration of pollutants from industrial sources (Ministry of Water and Environment (MWE), 2013)

Sector	Sector-specific concentrations (g/m^3)			No. of Samples (1999-2010)		
	BOD_5	TN	TP	BOD_5	TN	TP
Breweries	501	10.7	1.2	5	5	5
Cardboard production	100	20.0	2.0	1	0	1
Cement manufacturing	100	20.0	2.0	0	0	0
Dairy processing	200	20.0	4.0	0	0	0
Distilleries	200	20.0	4.0	2	1	2
Fish processing	99	19.5	1.0	53	12	55
Flower farms	50	10.0	2.0	0	0	3
Food and Beverage processing	48	21.8	1.7	16	5	9
Institutions/offices	76	38.0	10.0	3	0	1
Integrated steel mills	100	20.0	4.0	0	0	0
Meat Processing	200	20.0	4.0	1	0	0
Metal Workshop	100	20.0	4.0	2	0	0
Mining	342	8.0	0.9	2	1	1
Municipal Waste Water Treatment plant	76	38.0	10.0	38	11	24
Paint Industry	100	20.0	4.0	2	0	0
Poultry Production	200	20.0	4.0	1	0	0
Pulp and Paper mills	200	20.0	4.0	1	1	0
Sugar Manufacturing	232	5.7	2.9	16	7	11
Tanning and Leather Finishing	100	20.0	4.0	1	1	1
Tea Estate	99	20.0	9.1	14	3	6
Textile manufacturing	200	20.0	4.0	2	0	2
Vegetable Oil processing	45	9.2	1.6	6	2	5
Waste management facilities	100	20.0	4.0	2	2	0

(2) Flow distance to the main pollution sources (meter);

Greater are the distances between pollution source and investigated area, greater is the time for natural decay process to take place. This ensures a better reduction of the pollutants. For flow distance (or downslope distance) is meant the natural path of a water drop to reach the investigated areas starting from the location of the pollution source. Main pollution sources can be identified by asking to the decision makers to select a threshold values of pollution loads.

(3) Slope of the area [%]

The vulnerability of surface water is computed considering the average slope of the investigated site. Vulnerability of surface water sources are mainly related to the natural drainage of the area. Flat areas promote the formation of stagnant water which leads to a decrease in the water quality, whereas a fast runoff can lead to soil erosion, increasing sediments transport toward rivers and lakes.

2. Low probability of exposure to contaminated groundwater is computed through two indicators**:**

(1) Total pollution loads in the intersection areas between aquifer boundary and river basin (Kg/day);
(2) Groundwater table (meter below the surface).

(1) **Total pollution loads in the intersection areas between aquifer boundary and river basin (Kg/day);**

The main hazards for the groundwater are constituted by the activities on the immediately overlying land-surface and inside the aquifer boundary (Mimi & Assi, 2009). If information concerning the boundary of the aquifer is available, pollution loads can be computed in the intersection area between the river basins and the aquifer boundary (with the approximation that hazards located outside the river basin will not constitute high risk, as travel times are considered long enough for natural decay). If no information concerning the aquifer boundary is available, hazards comprised in a buffer area of the analysed location should be accounted. The radius of influence changes according to characteristic of the aquifer. Values for pollution loads of different sources are the same as presented above in Table 33, Table 34 and, Table 35.

2.Groundwater table depth (meter below the surface)

The vulnerability of the aquifer depends on many factors as soil infiltration capacity, hydraulic conductivity, recharge, etc. The National Water Well Association (NWWA) and the US Environmental Protection Agency (EPA) identified seven factors for evaluating pollution potential in the aquifer:

D- Depth to water;
R- (Net) Recharge;
A- Aquifer media
S- Soil Media
T- Topography (slope)
I- Impact of the vadose zone media
C- Conductivity (hydraulic) of the aquifer

These factors were ranked and weighted for assessing the vulnerability score of the aquifer in an index model called DRASTIC (EPA, 1987). Examples of GIS application of the method can be found in (Al-Abadi, Al-Shamma'a, & Aljabbar, 2017). The score of DRASTIC model could be used to spatially assess the vulnerability of the aquifer. However, it is preferable to avoid the use of qualitative attributes especially if partly proxy and partly constructed. Difficult is indeed a complete elicitation of preference from stakeholders, which could be influenced by the construction of the attributes itself (Ralph L. Keeney, 2002; Ralph L. Keeney & Gregory, 2005).

Therefore, it would be preferable to use all the cited attributes. If no data are available, a first estimation of the vulnerability can rely on the depth to groundwater. A groundwater table close to surface leads to a higher risk of aquifer contamination, especially through leakages from latrines system if this is preferred as main faecal disposal system in refugee camps.

(2) Low direct exposure to contaminated water

For direct exposure to contaminated water is intended the potential risk that the provided water can have for people's health, as well as how the water supplied constitute a risk for the health of the refugees, strongly depending on the selected water source. Water supplied for different uses need to comply with the WHO water quality standards, (Figure 31). A common attribute is, hence, parameters such as the concentration of faecal coliform, BOD, Total-N, etc. However, these values are hardly available in an emergency setting. Furthermore, in a refugee's context, groundwater and collected rainwater treatment processes are hardy in place, whereas they are present for surface water. In the latter case, a treatment plant is, indeed, designed. However, according to the information collected during the fieldwork, raw water quality analyses are usually made only at the design phase of the treatment plant and whenever the implementer WASH partner is changed. Therefore, strong variations in the water quality can be a risk for the safety of the people. According to these findings the selected attributes are shown in Table 36

Table 36. Attribute description to measure safe water supply in refugee hosting sites

Objective	Attribute	Description
Safe water supply for: Domestic use; Irrigation use; Livestock use; Production use;	**Surface water sourcing:** standard deviation of the water quality parameters in a year [-] *Proxy indicator:* range size (Max-Min) of water quality parameters. (unit measure depends by the parameter selected) (if no time series of the water quality parameters are available, the proxy indicator can be used)	In drinking water treatment process, chemical substances (such as chlorine or ammonium) are dosed according to a simple manual water quality tests at the outflow made by water quality operators. Surface water quality at the source is, rarely measured. Hence, no monitoring systems exist to inform variations in the quality. If water quality at the outflow is not constantly measured, there is the risk that the pre-calculated dose is inadequate. Usually, only one water quality operator is in charge of the whole water system in one or more refugee settlements, with the risk that strong variation of water quality at the source cannot be captured in time.
	Deep and shallow groundwater sourcing: - Microbiological [e.g. CFU/100ml]; - Chemical [e.g. mg/l]; - Physical parameters [e.g. NTU];	No treatments are guarantee for water extracted from aquifer, so that, the *microbiological, chemical and physical water quality parameters* at the source can be compared with the inter/national agencies standards for agriculture, livestock, domestic and industrial use (Figure 32 and Figure 33).
	Rainwater harvesting: Topographic distance to industries and cities [meter]	It is not predictable that a treatment system will be adopted for rainwater harvesting system. Therefore, the quality of the rainwater should be compared with inter/national agencies standards. However, this information can be hardly available. Therefore, a proxy indicator is the *topographic distance* of the site to potential air pollution sources. These can be towns/cities (traffic pollution) and industries.

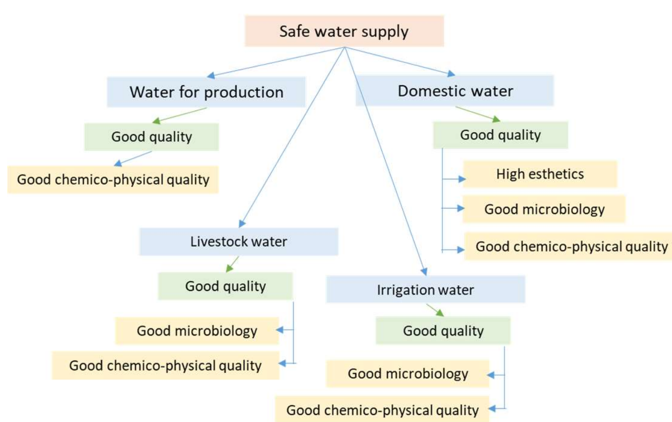


Figure 31. Common lower-level objectives of safe water supply for different water use

To support the selection of suitable attributes in the site in analysis, global data could be used. These can provide a first understanding of the water quality issues in the analysed aquifer guiding the selection of water quality parameters for estimating the attributes. This is because suitable quality parameters for computing the attributes can differ according to the geographic area. The contamination of groundwater by natural arsenic is well reported in some areas (Argentina, Chile, Mexico, China, Hungary,..)(Abedin & Shaw, 2013) . Aquifers in Italy and France do not incur in the same risk.

The IGRAC centre collected groundwater quality data over the world in a web-portal (https://apps.geodan.nl/igrac/ggis-viewer/viewer/gwquality/public/default). The International Centre for Water Resources and Global Change (ICWRGC) is also carrying out similar analyses, operating the GEMStat water quality database which account for four million entries for rivers, lakes, reservoirs, wetlands and groundwater systems from 75 countries and approximately 4000 stations. http://portal.gemstat.org/ These global databases can both offer an overview of the water quality condition that could help in better identifying which water quality parameters could be used for computing the attribute related to safe water supply from aquifers.

Concerning risk for the health due to the use of rainwater, the microbiological contamination of the harvested water result from many factors including animal droppings on the catchment roof, dead animals and insects or organic material on the roof or in gutters, soil, agricultural or industrial waste or human sewage being washed into tanks (Priscilla et all., 2006). In the decision analysis, only the distance to towns or industries was selected as attribute. However, attributes that comprehensively assess the risk of pollution of harvested rainwater should also consider for example the distance to agriculture areas and type of technology used for collecting the water.

	WHO	ECE	Canada	USA	Russia
Colour (TCU)	15	20	15	15	20
Total dissolved solids (mg/l)	1,000		500	500	1000
Turbidity (NTU)	5	4	5	0.5-1.0	
pH	<0.8	6.5-8.5	6.5-8.5	6.5-8.5	6.0-9.0
Dissolved oxygen (mg/l)					4.0
Ammoniacal nitrogen (mg/l)					2.0
Ammonium (mg/l)		0.5			2.0
Nitate N (mg/l)	13	13	10	10	
Phosphorus (mg/l)		5.0			
BOD (mg/l)					3.0
Sodium (mg/l)	200	150			
Chloride (mg/l)	250	25	250	250	350
Chlorine (mg/l)	5				
Sulphate (mg/l)	250	250	500	250	500
Sulphide (mg/l)			0.05		
Fluoride (mg/l)	1.5	1.5	1.5	2.0	1.5
Boron (mg/l)	0.3	1.0	5.0		0.3
Cyanide (mg/l)	0.07	0.05	0.2	0.2	0.07
Aluminium (mg/l)	0.2	0.2			0.5
Arsenic (mg/l)	0.01	0.05	0.05	0.05	0.01
Barium (mg/l)	0.7	0.1	1.0	2.0	0.7
Cadmium (mg/l)	0.003	0.005	0.005	0.005	0.003
Chromium (mg/l)	0.05	0.05	0.05	0.1	0.05
Cobalt (mg/l)					0.1
Copper (mg/l)	2.0	0.1-3.0	1.0	1.0	2.0
Iron (mg/l)	0.3	0.2	0.3	0.3	0.3
Lead (mg/l)	0.01	0.05	0.05	0.015	0.01
Manganese (mg/l)	0.5	0.05	0.05	0.05	0.5
Mercury (mg/l)	0.001	0.001	0.001	0.002	0.001
Nickel (mg/l)	0.02	0.05			0.02
Selenium (mg/l)	0.01	0.01	0.01	0.05	0.01
Zinc (mg/l)	3.0	0.1-5.0	5.0	5.0	5.0
Oil products (mg/l)	0.01				0.1
Total pesticides (µg/l)		0.5	100		
Aldrin and Dieldrin (µg/l)	0.03		0.7		
DDT (µg/l)	2.0		30.0		2.0
Lindane (µg/l)	2.0		4.0	0.2	2.0
Methoxychlor (µg/l)	20		100	40	
Benzene (µg/l)	10			5	
Pentachlorphenol (µg/l)	9			10	10
Phenols (µg/l)		0.5	2.0		1.0
Detergents (mg/l)		0.2		0.5	0.5
Faecal coliforms /100ml	0	0	0		0
Total coliforms /100ml	0		10	1	0.3

Source: Water Quality Assessment, WHO/UNEP

Figure 32. Water quality standards for drinking use according to different inter/national's agencies

Examples of water quality criteria for irrigation water (mg/l)

	FAO	Canada	Nigeria
Aluminium	5.0	5.0	5.0
Arsenic	0.1	0.1	0.1
Cadmium	0.01	0.01	0.01
Chromium	0.1	0.1	0.1
Copper	0.2	0.2-1.0[1]	0.2-1.0[1]
Manganese	0.2	0.2	0.2
Nickel	0.2	0.2	0.2
Zinc	2.0	1.0-5.0[2]	0.0-5.0[2]

[1] Range for sensitive and tolerant crops resp.
[2] Range for soil pH > 6.5 and < 6.5 resp.
Source: Water Pollution Control, WHO/UNEP 1998

Example of water quality criteria for livestock water (mg/l)

	Canadian criteria
Nitrate + nitrite	100
Sulphates	1,000
Total dissolve solids (TDS)	3,000
Blue-green algae	Avoid heavy growth of blue-green algae
Pathogens and parasites	Water of high hygienic standard should be used

Source: Water pollution Control, WHO/UNEP 1998

Figure 33. Water quality standards for irrigation and livestock use according to different inter/national's agencies

(3) Low exposure to endemic water-vector diseases

Water-vector habitat diseases refer to any illness transmitted by vector that lives in the water habitat in analysis. The presence of this vector is favourite by certain type of climate and ecosystem (National Research Council (US) Committee on Climate, Ecosystems, & Infectious Diseases and Human Health, 2001).

According to WHO, common water-vector habitat diseases and aerosol diseases are Malaria and Legionellosis *(Stanwell Smith, 2003)* (Table 32). Indicators to assess the exposure to these diseases can be respectively: the number of people affected by Malaria and Legionellosis.

Objective 2. High reliability of raw water quantity

International legal instruments recognize the right of sufficient water for personal and domestic uses essential for human survival (Sandison & Davidson, 2011). Water is a critical determinant for survival in the initial stages of an emergency. For this reason, sites selected for providing first shelters to refugees have to ensure access to sufficient drinking water. This right is inextricably related to other human rights, including the right to health, the right to housing and the right to adequate food. Commonly, sites are selected according to space availability, under the assumption that water can be bring later extending the nearby water system or by merely drilling the local aquifer. According to the Emergency Handbook (UNHCR, 2007), the availability of an adequate amount of water on a year-round basis has proved in practice to be the single most important criterion, and commonly the most problematic in the site selection. For this reason, the objective was structured in the objectives hierarchy as a fundamental objective.

High reliability of raw water quantity is broken down into two sub-level objectives:

- Sustainable yield of water;
- High reliability;

Figure 34, presents a summary of the objectives' hierarchy for the analysed objective including (respective) attributes.

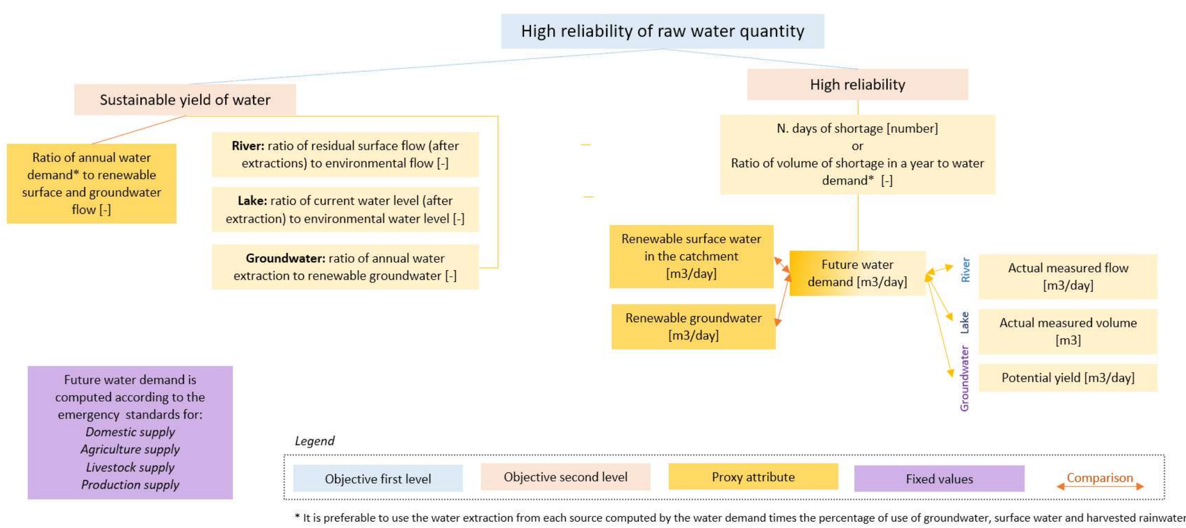


Figure 34. Sub-objectives and attributes of the fundamental objectives: High reliability of raw water quantity

6.1.1.3 Sub-Objective: Sustainable yield of water

Water supply interventions along the refugee response need to look also at the environmental water security. Sustainable water extractions aim to support ecosystem services, avoiding depletion of water sources. The imperative to save lifes has shifted the environmental issues to a second place, especially in areas where no adequate water resource management plans are in place. This resulted in exploitation of water sources which are unsustainable at the long-term and can, therefore, result in conflicts with the host community.

Attributes

The defined attribute for sustainable yield of water comprises different components according to the water source used for the extraction (Table 37). Terms of equations for different water sources are explained in detail below

Table 37. Attribute description to measure sustainable yield of water in refugee hosting sites

Sourcing		Natural Attribute	Proxy Attributes	Description
Surface water	River	$\frac{projected\ flow}{environmental\ flow}$ [-]	$\frac{(water\ abstraction)_{SW}}{catchment\ yield}$ [-]	The ecological status of the water bodies can be seriously damaged if over-abstractions take place. Environmental flow and minimum ecological lake level refers to the water considered sufficient for protecting the structure and function of an ecosystem and its dependent species.
	Lakes	$\frac{projected\ water\ level}{minimum\ ecological\ lake\ level}$ [-]		
Ground water	Deep and shallow aquifer	$\frac{(water\ abstraction)_{GW}}{0.30 * groundwater\ recharge}$ [-]	-	GW is one of the main source used for supplying water in refugee hosting sites. If the GW abstraction exceeds the recharge, seasonal or permanent drawdown of the GW table is possible. This is a threat for the reliability of the water at the long term both for host and refugee's community. Additionally, environmental issues can rise.

Surface water sourcing

Projected flow is the flow in the river in case refugees will be allocated in the investigated site and the new water needs are met from abstraction to this source. This can be computed as follows:

$$projected\ flow = flow\ gauge - (new\ water\ abstraction)_{sw}$$

The water abstraction from surface water sourcing can be computed from the total new water demand and the percentage of water source used.

Environmental flow is defined as the minimum flows required to protect and maintain aquatic resources in streams and rivers (Özdemir, Karaka, & Erkus, 2005). There is a range of methods available for assessing instream flow requirements (Figure 35). Handbooks as (HR Wallingford & DFID, 2003) or (Özdemir et al., 2005), can help in identifying the suitable method for the specific application according to the available data.

Environmental flow assessment methods
Hydrological index methodologies discussed include: • Tennant method; • Texas method; • Flow duration curve method; • Aquatic base flow method; • Range of variability approach. **Hydraulic rating methodologies** discussed include: • Wetted perimeter method. **Habitat simulation methodologies** discussed include • Building block methodology **Holistic methodologies** discussed include: • Instream flow incremental methodology.

Figure 35. Environmental flow assessment method (HR Wallingford & DFID, 2003)

Minimum ecological lake level is the critical level below which there should be no further withdrawal to decrease the water level and hence, ensuring the protection of lake ecosystems (Doulgeris et al., 2017). This should be compared with the projected water level of the lake in case the investigated site is selected as refuge hosting area and the lake is used as source of water. Projected water level can be computed according to equation 1 if the relation level-area is not known:

$$projected\ water\ level = \frac{Current\ lake\ volume\ - (new\ water\ abstraction)_{sw}}{lake\ surface\ area}$$

In the above equation we are using the approximation of rectangular reservoir.

Methods for estimating minimum ecological lake level are shown by (Doulgeris et al., 2017). If the level-area-storage curve is known an improved method can be adopted according to (Shang, 2013).

Water level of the lake and flow of the river can be identified through field measurement or extracted by a hydrological model.

A proxy attributes for the estimation of the sustainable extraction of water from surface water sources is computed through the estimation of the catchment yield. This is the amount of run-off that can be expected to come from the catchment to the potential point of abstraction.

Groundwater sourcing

As a rule of thumb, the groundwater abstraction is considered sustainable if does not exceed the 30% of the recharge. Among different methods, groundwater recharge can be computed via hydrological modelling. Consequently, this value should be compared with the total water abstraction from the aquifer (inside the aquifer boundary) in order to evaluate its sustainability.

6.1.1.4 Sub-Objective: High reliability

Seasonal climate variations and seasonal water consumptions variations affect water availability. Therefore, this need to be taken into account in the estimation of the reliability of the raw water quantity. Table 38 provides the description of the selected attributes concerning high reliability. Two attributes are suggested for the estimation of the groundwater, surface water and rainwater reliability sourcing in the analysed locations. The first attribute refers to the number of days with shortage, which can be used when decision makers consider shortage as inacceptable, even if small along the year. The second, instead, provides to decision makers the information of the amount of water not available over a year. This, compared with the water demand, better allows to elicit decision makers' preferences. Locations that present a high number of days with shortage could be still considered an acceptable option if the shortage volume is low compared to the water demand that needed to be met.

In computing the reliability of water, potential storage is not taken into account. This means that we compare the amount of water available from a source in a day with the amount of water that we need to abstract from it. However, storage interventions could be applied to increase reliability of a water source during dry spells. The effectiveness of storage measures could be analysed by using monthly precipitation values instead of daily values.

Table 38. Attribute description to measure high reliability of water in refugee hosting sites

Sourcing		Natural Attribute (1)	Natural Attribute (2)	Description
Surface water	River	n. days of shortage = f (new water abstraction, current flow)	$\frac{(volume\ of\ shortage)_{river}}{(new\ water\ abstraction)_{SW}}$	In geographic areas where potential evaporation is high, variation of the water levels can be significant to the extent to threat the supply of water.
	Lakes	n. days of shortage = f (new water abstraction, current lake volume)	$\frac{(volume\ of\ shortage)_{lake}}{(new\ water\ abstraction)_{SW}}$	
Ground water	Deep and shallow aquifer	n. days of shortage = f (new groundwater abstraction, current aquifer volume)	$\frac{(volume\ of\ shortage)_{GW}}{(new\ water\ abstraction)_{GW}}$	GW table variations strongly depend on how much the aquifer depends on recharge, either from rain or surface waters, as well as how dynamic and fast the system respond to that.
Rainwater		n. days of shortage = f (new rainwater collection, available volume of rainwater harvested)	$\frac{(volume\ of\ shortage)_{RW}}{(new\ water\ harvested)_{RW}}$	Rainwater is usually not considered as a main supply source given its high variability, especially among different seasons. However, some institutional buildings rely only on this source, making important to understand how much water could be taken from it, minimizing potential shortages.

Using attribute number two, an overall attribute value for the objective can be obtained by adding the attributes' values when no explicit preference concerning the reliability of different sources can be elicited from the stakeholders.

$$Attribute_{High\ reliability} = \frac{(volume\ of\ shortage)_{SW}}{(new\ water\ abstraction)_{SW}} + \frac{(volume\ of\ shortage)_{GW}}{(new\ water\ abstraction)_{GW}} + \frac{(volume\ of\ shortage)_{RW}}{(new\ water\ harvested)_{RW}}$$

Objective 3. High acceptance and integration of the refugees in the host community

One of the focuses of the CRRF is the refugee and host population empowerment. This is, for example, framed in Uganda refugee policy under the ReHoPe program. This fosters an area-based approach for the benefit of refugee and host communities (UNHCR, 2017c). According to this new policy, risks and opportunities for both host community and refugees need to be taken into account in the site selection and planning process. Both aim to improve the integration of refugees in the hosting site.

The objective is disaggregated in two sub-objectives, explained in detail the following sub-sections:

- Minimize refugee impacts on the hosting site;

- Improve current water services and infrastructures.

6.1.1.5 Sub-Objective: Minimize refugee impact on the hosting sites

For rural populations in developing countries, the natural environment is particularly linked to economic welfare. Populations depend on their surroundings for water, food, shelter and medicine. Refugee influxes intensify environmental problems such as land cover degradation, pollution of water sources and soil erosion, since such fluxes result in rising populations, inappropriate management and lack of services. Deforestation is the main known environmental problem associated with refugee-affected areas. However, a less well-known problem is the impact of refugee settlement on the downstream areas of the catchment. The reduction of vegetation coverage leads to an increase of sediment influx to surface water bodies, which, consequently, causes an increase in the risk of flooding in downstream areas. Additionally, inappropriate waste management leads to an increase in the pollution loads, which flow towards downstream areas as well. All these issues are potentially increased as environmental considerations are seen as secondary goal front refugee safety. For this reason, it is important to identify sites that could minimize the impact of refugees on the environment and hence, on the host community. Two proxy attributes were identified in this sense:

- Distance to environmentally sensitive areas;

- Vegetation coverage index;

Table 39. Attributes description to measure minimize refugee impact on the hosting sites

Attribute	Unit of measure	Description
Distance to environmentally sensitive areas (ESA)	[meter]	Sites located close to ESA could worsen the impacts of refugee settlements on the environment.
Vegetation coverage index*	[-]	Areas having a low vegetation index are more susceptible to soil erosion due to increased runoff. Moreover, adequate riparian vegetation traps sediment and pollutants, increasing water quality condition and reducing refugee impact on downstream areas.

*Vegetation coverage index could be computed using, for example, the NDVI index, the LAI index or the fraction vegetation. Further, land cover maps from remoting sense data could be used for this purpose.

6.1.1.6 Sub-Objective: Improve current water services and infrastructures for the host community

Refugee influxes are usually seen as a financial burden for hosting countries, rather than an economic opportunity (Social Humanitarian Cultural Comittee UN, 2002). Refugees can compete with local communities for scarce resources such as land, jobs and even environmental needs (e.g. water, firewood), and overwhelm existing infrastructure such as schools, housing and health facilities (Jacobsen, 2002).

However, opportunities for (improving) the host communities can be also identified during refugee influxes. Refugee camps become repositories of resources as relief supplies, food, medicines, and improved water services. Since most refugee situations are extended in time (e.g. in Africa), these resources are available to the host country for an extended period of time (Jacobsen, 2002). Concerning specifically the water sector, host communities benefit from water services and infrastructure addressed to refugees. Additionally, according to the CRRF, about 30% of the investment cost in the refugee response needs to be allocated for improving local services in the host community. These interventions aim to promote integration of refugees and engagement of the host communities, but also to avoid an overloading of water infrastructures intended to refugees when local water services are insufficient.

Table 40. Attributes description to measure improve current water services and infrastructures for the host community

Attribute (1)	Unit of measure	Description
$\frac{0.30 * investment\ cost}{host\ population}$	[Currency/capita]	According to the CRRF, 30% of the local investment cost need to be allocated for improving local services. Hence, the proposed attribute estimates the benefit on the local water services by computing the budget that each person in the host community will virtually receive if refugees is settled nearby their villages.
Attribute (2)		
$\frac{1}{percentage\ of\ access\ to\ safe\ water}$	[-]	If no information of the total investment is available, the proxy of the marginal return of the investment intended for the refugees can be consider as an attribute. This will depend on the current water supply coverage in the host community. If this percentage is really low for a certain area, the marginal return in investing in that area will be higher than investing in an area with higher coverage percentage. Access to safe water attribute ranges from 0 to 1. An access to safe water equals to 0 leads to infinite marginal return value. Access to safe water equal to 1 (maximum possible value) leads to a marginal return equal to 1 (minimum possible value).

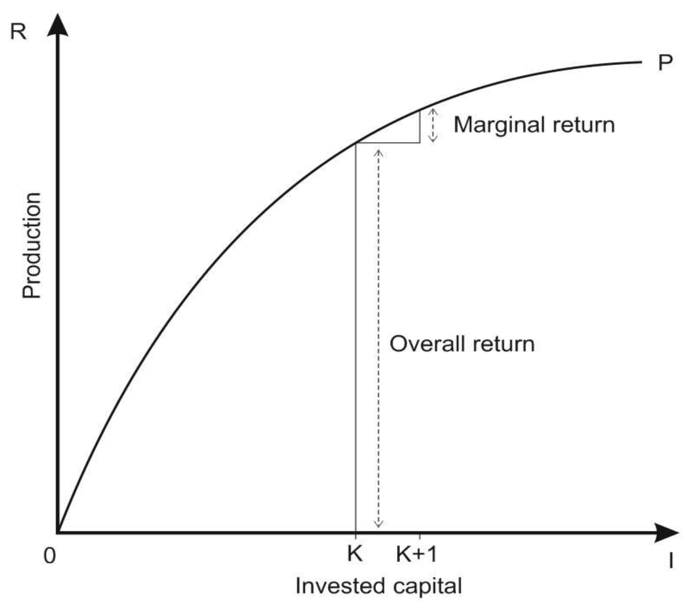


Figure 36. Marginal and average return

Objective 4. Minimize Costs

To enable an economically sustainable refugees' response, sites should be selected by looking at the full cycle cost along the life of the refugee camps. Sites which characteristics results in minimum costs along the refugee response should, hence, be preferred. To comprehensively look at the costs, the objective was disaggregated in two sub level objectives:

1. Initial costs
2. Future costs

Initial costs comprise the capital costs and the cost for water trucking. On the other hand, future costs refer to the cost of the operational & maintenance costs and the costs of corrective measures. Usually, initial costs are covered by initial funds, while the support for the long term operation varies in relation to the livelihood of the refugees. They will directly contribute to the cost of the services if a livelihood that provides them a sustainable income is guaranteed. If this is not the case, funds from the international community need to be collected.

For the fundamental objective in analysis, the operational and maintenance costs and the costs for corrective measures were seen as most important by the majority of the respondents of the survey, considering investment costs as irrelevant. Investing in low operational cost solutions reduces the cost of the refugee response on medium and long terms. Sustainable cost over long term strengths the self-resilience of refugees, which could directly contribute to the cost of the services. Additionally, funds available along the life-time of the refugee camp decrease considerably comparing to the ones available at the beginning of the refugee response. The reasons above cited, justify the preference of the stakeholders at the UNHCR-HQ for locations with low operational costs' interventions. However, according to face-to-face interviews in Uganda, the objective "low investment costs" is judged as relevant by UNHCR officers in the field, for which available funds at the beginning of the refugee response are almost sufficient to meet the essential refugee needs. Therefore, the sub-objective ''low investment costs'' was included to cover all pillars of the economic sustainability of the water security in the site.

6.1.1.7 Sub-Objective: Minimise Investment Costs

Initial funds could be not sufficient to finance all WASH interventions required in new or existing refugee-hosting sites for coping with new influxes. This happens especially in areas where important and large infrastructures need to be developed. Insufficient funds lead to delay in the planning phase and in budget cut, prioritising some interventions on others.

Investment costs comprise the cost for the **water system supply** and **the sanitation costs** (Figure 30). For the former, the cost varies according to the type of source selected. In case of groundwater, the cost is composed of, for example, drilling, well construction, pumping system, testing and disinfection system and transmission pipe lines. In case of surface water, the cost is composed, for example, by intake system, drinking water treatment plant, pumping system and transmission pipe lines. For the sanitation cost, common adopted faecal disposal systems are the latrines, which cost is composed of the materials need for their construction. The typology of latrines depends by the soil type (e.g. raised latrines in rocky soil). During the emergency phase, common latrines are usually built, while in the transition and protracted phases materials for household latrines are provided to the refugees.

The objective "low sanitation cost" was formulated as low excreta management. This was done because this research aims to support the refugee hosting site decision process in developing countries, where sewage systems and wastewater treatment plants are rarely used. Therefore, the adoption of latrines for excreta disposal system reflects most of the condition of refugee camps in such locations. In the case of wastewater treatment plants exist or are to be put in place, the objective needs to be reframed. If so, the cost of the plant should be accounted according to the amount of wastewater produced and the type of technology adopted. A method for this computation is suggested by (Matano`, 2017).

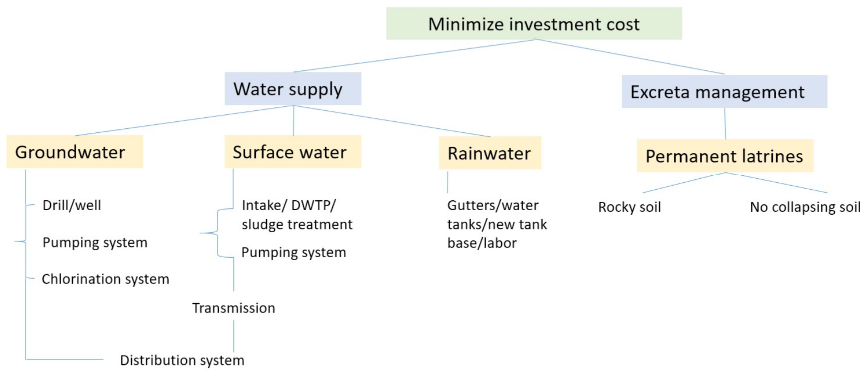


Figure 37. Hierarchy of minimize investment cost

The sub-objective minimize investment cost is, hence, composed of:

- Minimize capital cost for the water supply system from groundwater;
- Minimize capital cost for the water supply system from surface water;
- Minimize capital cost for the water supply system from rainwater;
- Minimize capital cost for the excreta management;

In order to estimate all components of surface water, groundwater, and rainwater supply system cost, specific information of the planning phase such as the location of the boreholes, reservoirs, and repartition of the flow are needed. However, this information is rarely available during the site selection process. Therefore, the costs of the water system can be estimated as a function of the key factors that mainly affect the overall value. These were identified through an influence diagram (Figure 38), in which all items cost were analysed according to information gather by interviews with experts. The key factors help in defining a correlation between each cost item and characteristic of the area/ planning setting of the water supply system. For a detailed estimation of such cost items, a first planning of the site need to be made.

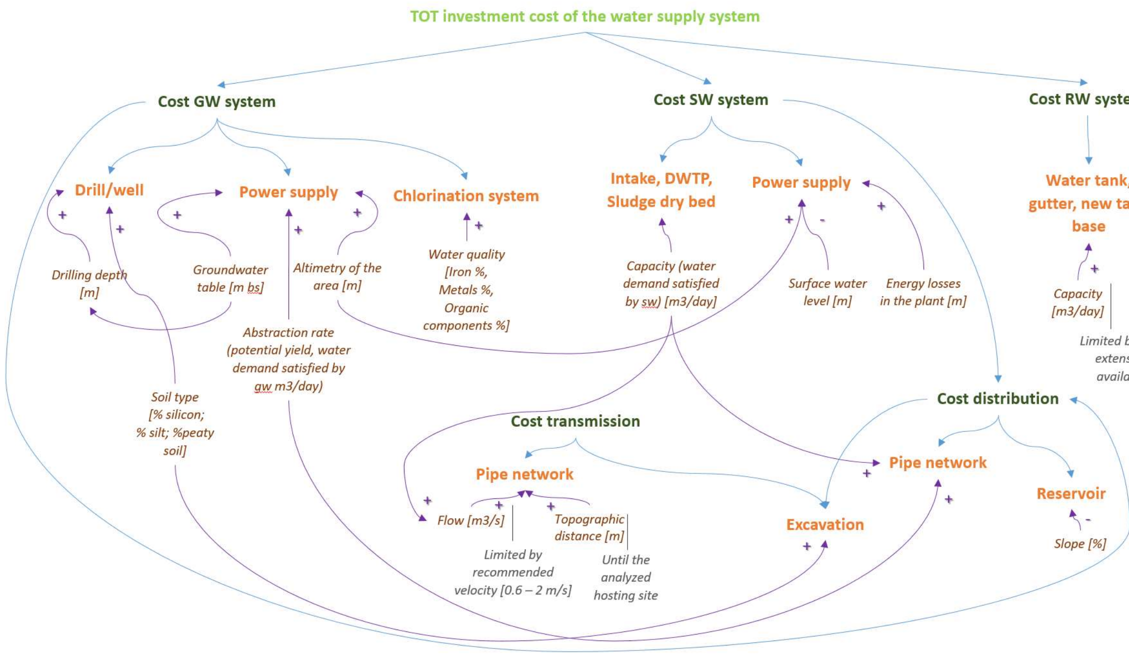


Figure 38. Influence diagram for investment of the water supply system

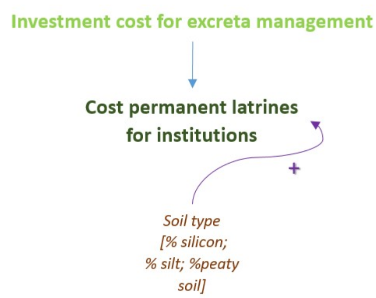


Figure 39. Influence diagram for investment of the excreta management system

According to the region in which the decision process is investigated, a study of the water system and sanitation costs could be carried out to identify the items that influence the total cost at most. For the Uganda application, a study of each cost item was made in order to identify the items that influence the total cost most. After their identification, a correlation of these costs with the related discriminant factors was carried out.

6.1.1.8 Sub-Objective: Minimise Water Trucking Costs

Water trucking is a common relief intervention at the outset of an emergency for addressing basic water needs while the water supply system is being built. This intervention is highly expensive, unsustainable and difficult to manage, implement and monitor. Therefore, the use of water truck should be reduced at the lower possible. The cost depends on different factors, as identified in the influence diagram (Figure 40).

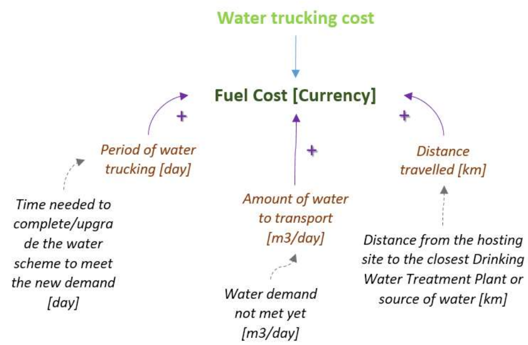


Figure 40. Influence diagram of water trucking cost

Generally, water is trucked until the water system is not completely functionally. The time needed to complete the water scheme depends on the water source used. In case that water is extracted from the aquifer, the construction of all the water scheme takes around six months for a small settlement (from 10,000 to 15,000 people). The time increases if the water scheme depends on boreholes and not hand pumps (from one month to one month and a half). In big settlement (from 30,000 up to 100,000), it can take around nine months. In case the water is extracted from surface water, the time needed to complete the water scheme is about nine months. In this case, the time does not depend on the size of the settlement but on the capacity of the source and the population projections. If newly arrived refugees are settled nearby existing water system, this will be extended/upgraded to the new site, reducing the time required for the intervention (personal communication, David Njoroge and Samuel Davis from UNHCR WASH)

Table 41. Time needed for complete the water scheme in Uganda

Sourcing	***Settlement size (n. people)***	***Time for a new water scheme [months]***	***Time for upgrading an existing water scheme [months]***
Surface water	-	9	2-3
Groundwater	Hand pumps	1	1
	Borehole (10,000 – 15,000)	6	2
	Borehole (30,000 – 100,000)	9	2-3

6.1.1.9 Sub-Objective: Minimise Operational and Maintenance Costs

To enhance the self-sustainability of the refugee community, alternatives that reduce the operational and maintenance costs should be selected. Financial resources significantly decrease during post-emergency conditions. Therefore, the long-term sustainability in term of O&M costs of the water infrastructure is a prerequisite for an integrated and sustainable development of water and sanitation services.

Operational costs in water infrastructure are mostly for acquiring and managing consumables such as energy, processed water and chemicals, as well as disposing of waste. The maintenance costs include all costs for repair and replacement of parts of installations within the predicted lifetime of the water supply system. All cost items which form the overall O&M cost for system using groundwater or surface water sourcing are shown in Figure 41. These were further analysed in the influence diagram (Figure 42).

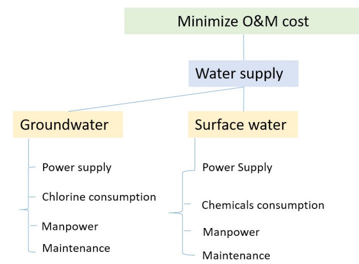


Figure 41. Cost items for O&M costs of water supply systems using groundwater and surface water as main water source

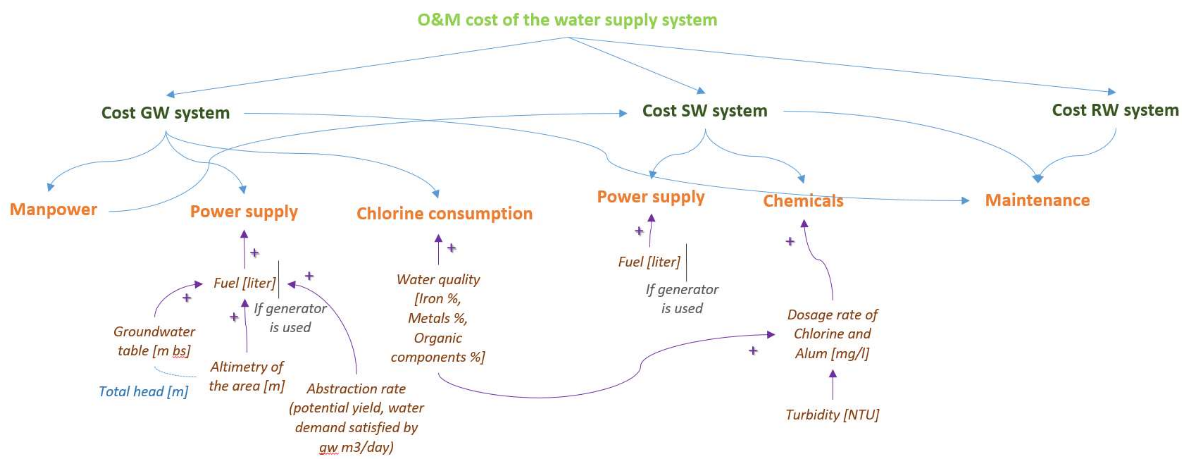


Figure 42. Influence diagram of O&M costs of the water supply system

The Influence diagram identifies the local factors influencing each cost item according to face-to-face interviews with experts in the field. Knowing the preliminary design of the water scheme, these can be used for a detailed assessment of the O&M costs However, if this information is not available yet, an analysis of the O&M costs for the region in analysis can be carried out to identify the items that most affect the overall cost. These can be used in the computation of the attribute.

6.1.1.10Sub-Objective: Minimise corrective measures

The selection of the refugee hosting site should aim to minimize expenses on adjustments or the need of exceptional interventions due to the inadequacy of the location (e.g. presence of black cotton soil, steep slope). This will enhance rapid WASH intervention. In case that there is need for corrective measures, these will usually not be carried out within the first months of an emergency due to the high economic and human effort needed. According to the Master plan and UNHCR guidelines, which define standard for the suitability of the site, the fundamental objective was disaggregated in three sub-level objectives:

- Reduce earth-moving for building construction;

- Good drainage;

- Reduce soil failure.

The first two can be assessed by using the slope as a proxy attribute. The latter can be estimated according to the percentage of vertisol, which is a soil presenting a high content of expansive clay minerals (also known as black cotton soil)). Highly expansive soils may cause deterioration of the pipes by the movements related to their expansion and their contraction under different wet and dry climate alternations (UNHCR, 1992). Additionally, flood issues are frequent due to the low hydraulic conductivity of these soils. An adequate slope can reduce the risk of soil erosion and enhance a good drainage. According to (UNHCR, 2007)a site should have a slope between 2%–4% for good drainage to protect building infrastructure, and not more than 10% to avoid erosion and the need for expensive earth-moving for roads and building construction. Flat sites (0-2%) often face drainage problems and are likely to become marshy in the wet season.

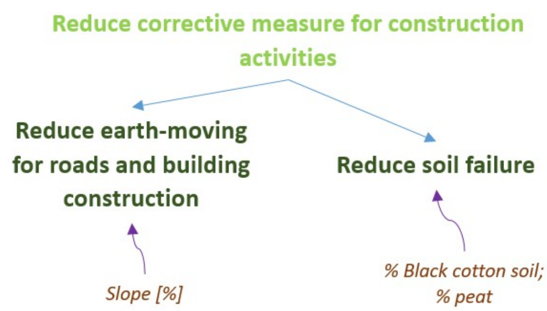


Figure 43. Hierarchy of "Reduce corrective measure for construction activities"

G. Water demand assessment for refugee hosting sites - Standards

For the objectives "high reliability" and "low cost", the attributes' values are a function of the water abstraction in the site in analysis. The latter needs to account for the current and projected water demand of the hosting community and the water demand of the newly arrived refugees. In emergency situations, the minimum standards defined by the 'Sphere project' on water availability, endorsed by UNHCR, prevail. The standards are considered minimums and context specific indicators are critical to adapt them to the expected needs according to different cultural situations.

The sphere standards provide the basic requirement for suppling sufficient water for drinking, cooking and for personal and domestic hygiene uses. However, water is also needed for supporting subsistence and income generated activities while enabling refugee livelihood in the site. In a longer term, water sustains refugees' livelihood through food production and the development of small industries, enhancing economic growth in the settlement. Long-term planning well accomplishes the comprehensive refugee response plan (CRRF), whose goal is the self-resilience of the refugees.

Water demand for satisfying domestic, production and commercial needs in the transition and post-emergency situations has been estimated according to standards set by UNHCR. In the following paragraphs, the water use standards are further explored to guide the computation of the potential water demand in refugee settlements. As water required for agriculture and small commercial activities have not yet further explored by UNHCR, the missing standards were set according to data collected from fieldwork and additional literature values.

i. Water demand per domestic use

Standards for domestic water use are explored by the Sphere project (Sandison & Davidson, 2011) and the UNHCR Handbook for Emergency (UNHCR, 2007). The former refers to the minimum water required in an emergency situation, which are also adopted by UNHCR. The latter, further develops the standards for transition and protracted phases.

Domestic supply. According to Sphere, the average water used for drinking, cooking and personal hygiene in the households is at least 15 litres per person per day (Figure 44). Along the transition and protracted phases, UNHCR establishes different water supply targets respectively equal to 15 - 20 l/p/d and 20+ l/d/p.

Survival needs: water intake (drinking and food)	2.5–3 litres per day	Depends on the climate and individual physiology
Basic hygiene practices	2–6 litres per day	Depends on social and cultural norms
Basic cooking needs	3–6 litres per day	Depends on food type and social and cultural norms
Total basic water needs	7.5–15 litres per day	

Figure 44. Basic survival water needs: composition (Sandison & Davidson, 2011)

Institutions supply. The Sphere project also identifies the minimum water quantities for different institutions in emergency condition (Figure 45).

Health centres and hospitals	5 litres per outpatient 40–60 litres per inpatient per day Additional quantities may be needed for laundry equipment, flushing toilets, etc.
Cholera centres	60 litres per patient per day 15 litres per carer per day
Therapeutic feeding centres	30 litres per inpatient per day 15 litres per carer per day
Reception/transit centres	15 litres per person per day if stay is more than one day 3 litres per person per day if stay is limited to day-time
Schools	3 litres per pupil per day for drinking and hand washing (Use for toilets not included: see Public toilets below)
Mosques	2–5 litres per person per day for washing and drinking
Public toilets	1–2 litres per user per day for hand washing 2–8 litres per cubicle per day for toilet cleaning
All flushing toilets	20–40 litres per user per day for conventional flushing toilets connected to a sewer 3–5 litres per user per day for pour-flush toilets
Anal washing	1–2 litres per person per day

Figure 45. Minimum water quantities for institutions and other uses, Sphere project (Sandison & Davidson, 2011)

The standards used for transition and protracted phases identified by UNHCR are presented in Figure 46 below.

UNHCR WASH Standards for Communal Buildings	
Schools	Average 3 liters of potable water available per pupil per day 400 of pupils per usable handpump/well 200 pupils per usable water tap 50 pupils per latrine/toilet (30 girls per toilet, 60 boys per toilet – add urinals for boys)
Health Clinics / Nutrition Feeding Centre	Average 10 liters of potable water available per outpatient per day Average 50 liters of potable water available per inpatient/bed per day 1 separated water point per health facility 20 outpatients per latrine/toilet 10 inpatients/beds per latrine/toilet

Figure 46. Water quantities for institutions, UNHCR Standards (UNHCR, 2018d)

ii. Water demand per livestock

Livestock. Sphere standards for livestock depend on the size of the animals, as summarized in the Figure 28

Livestock	20–30 litres per large or medium animal per day 5 litres per small animal per day

Figure 47. Minimum water quantities for livestock, Sphere project (Sandison & Davidson, 2011)

However, the Ugandan directorate of Water Resource Management also provides indication concerning the required amount of water for different livestock type. The classification of the animals is based on the Livestock Tropical Unit (LTU): standard measure used to appreciate grazing requirements. One LTU is equivalent to an animal of 250 kg. Tthe following conversion factors are used for animals in sub-Saharan Africa: cattle (indigenous) = 0.7 LTU, cattle (exotic dairy) = 1.0 LTU, goats and sheep = 0.15 LTU, pigs = 0.4 LTU and poultry=0.01LTU. The water demands of livestock can be estimated by assuming that one LTU consumes 50 l/day, which equals 18.25 m3/annum.

Table 42. Livestock water requirement according to Uganda Directorate of Water Resources Management.

Livestock type	LTU	Required water (l/d)
Cattle (indigenous)	0.7	35
Cattle (exotic dairy)	1	50
Goats	0.15	7.5
Sheep	0.15	7.5
Pigs	0.4	20

iii. Water demand per agriculture

Agriculture. The crop water requirements depend on the type of crop, water table depth, terrain slope, climate, and soil type (Frenken & Gillet, 2012). The three latest factors compute the conveyance losses in the area in analysis. The crop water needs can be supplied by:

- rainfall;
- irrigation;
- rainfall and irrigation.

In some cases, part of the crop water need is supplied by groundwater through capillary rise, if the groundwater table is shallow enough for roots to reach it. Therefore, the irrigation water need is computed with the following equation:

$$IN = \left(ET_C - (\,PE + GE)\right) * \frac{IA}{1000}$$

IN: Irrigation water need [m3/month];

ET_C: Crop evapotranspiration [mm/month];

PE: Effective precipitation [mm/month];

GE: Effective groundwater (or charge in soil moisture) [mm/month];

IA: Area actually cultivated as percentage of cell area for the given grid cell [m2].

From an agricultural production perspective, the effective precipitation (PE) is the portion of total annual precipitation which is used directly and/or indirectly for crop production at the site where it falls. It, hence, considers the water intercepted by living or dry vegetation that is lost by evaporation from the soil surface and that fraction which percolates deeply in the ground. (FAO, 1991) provides a way to estimate the PE, which can be applied in areas presenting a maximum of slope between 4-5 %:

Pe = 0.8 * P - 25 with P>75 mm/month

Pe = 0.6 * P – 10 with P<75 mm/month

where P = rainfall or precipitation (mm/month) and Pe = effective rainfall (or effective precipitation) (mm/month).

The evapotranspiration of a crop (ET_C) is obtained by multiplying the reference evapotranspiration (ET_O) with a crop and growing stage specific coefficient (K_C):

$$ET_C = K_C * ET_O$$

The reference crop evapotranspiration ET_0 can be estimated through the pan evaporation method (FAO, 1998). If no data on pan evaporation are available the Blaney-Criddle method can be used, according to the equation below:

$$ET_O = p * (0.46 * T_{mean} + 8)$$

ET_O: Reference crop evapotranspiration [mm/day];

T_{mean}: Mean daily temperature [° C];

p: Mean daily percentage of annual daytime hours.

The Blaney-Criddle Method always refers to mean monthly values, both for the temperature and the ET_O. If in a local meteorological station, the daily minimum and maximum temperatures are measured, the mean daily temperature is calculated as follows:

$$T_{max} = \frac{\sum(T_{max} \; during \; the \; month)}{n. days \; of \; the \; month}$$

$$T_{min} = \frac{\sum(T_{min} \; during \; the \; month)}{n. days \; of \; the \; month}$$

$$T_{mean} = \frac{T_{max} + T_{min}}{2}$$

To be able to obtain the p value, it is essential to know the approximate latitude of the area: the number of degrees north or south of the Equator.

The crop factor (K_C) varies according to the growth stage of the crop. There are four growth stages to distinguish:

- the initial stage: when the crop uses little water;
- the crop development stage, when the water consumption increases;
- the mid-season stage, when water consumption reaches a peak;
- the late-season stage, when the maturing crop once again requires less water.

Table 43 contains crop factors for the most commonly crops grown under water harvesting (FAO, 1991).

Table 43. Crop factors and number of days of different growth stages

Crop	Initial stage	(days)	Crop dev. stage	(days)	Mid-season stage	(days)	Late season	(days)	Season average.
Cotton	0.45	(30)	0.75	(50)	1.15	(55)	0.75	(45)	0.82
Maize	0.40	(20)	0.80	(35)	1.15	(40)	0.70	(30)	0.82
Millet	0.35	(15)	0.70	(25)	1.10	(40)	0.65	(25)	0.79
Sorghum	0.35	(20)	0.75	(30)	1.10	(40)	0.65	(30)	0.78
Grain/small	0.35	(20)	0.75	(30)	1.10	(60)	0.65	(40)	0.78
Legumes	0.45	(15)	0.75	(25)	1.10	(35)	0.50	(15)	0.79
Groundnuts	0.45	(25)	0.75	(35)	1.05	(45)	0.70	(25)	0,79

Table 8 VALUES OF THE CROP FACTOR (Kc) FOR VARIOUS CROPS AND GROWTH STAGE

Crop	Initial stage	Crop dev. stage	Mid-season stage	Late season stage
Barley/Oats/Wheat	0.35	0.75	1.15	0.45
Bean, green	0.35	0.70	1.10	0.90
Bean, dry	0.35	0.70	1.10	0.30
Cabbage/Carrot	0.45	0.75	1.05	0.90
Cotton/Flax	0.45	0.75	1.15	0.75
Cucumber/Squash	0.45	0.70	0.90	0.75
Eggplant/Tomato	0.45	0.75	1.15	0.80
Grain/small	0.35	0.75	1.10	0.65
Lentil/Pulses	0.45	0.75	1.10	0.50
Lettuce/Spinach	0.45	0.60	1.00	0.90
Maize, sweet	0.40	0.80	1.15	1.00
Maize, grain	0.40	0.80	1.15	0.70
Melon	0.45	0.75	1.00	0.75
Millet	0.35	0.70	1.10	0.65
Onion, green	0.50	0.70	1.00	1.00
Onion, dry	0.50	0.75	1.05	0.85
Peanut/Groundnut	0.45	0.75	1.05	0.70
Pea, fresh	0.45	0.80	1.15	1.05
Pepper, fresh	0.35	0.70	1.05	0.90
Potato	0.45	0.75	1.15	0.85
Radish	0.45	0.60	0.90	0.90
Sorghum	0.35	0.75	1.10	0.65
Soybean	0.35	0.75	1.10	0.60
Sugarbeet	0.45	0.80	1.15	0.80
Sunflower	0.35	0.75	1.15	0.55
Tobacco	0.35	0.75	1.10	0.90

The Ugandan Water Resource Management directorate has also estimated crop factors for different crop types (Table 44) (Ministry of Water and Environment (MWE), 2013)

Table 44. Crop factors according to the Ugandan Water Resource Management directorate

Rice		Vegetables		Maize		Beans	
days	CF	days	CF	days	CF	days	CF
20	1.05	20	0.7	20	0.30	20	0.40
30	1.10	30	0.875	35	0.90	30	0.90
40	1.20	30	1.05	40	1.20	40	1.15
30	1.05	15	0.95	30	0.35	20	0.35

The crop coefficient varies according to four different growing stages: the initial phase (just after sowing), the development phase, the mid-phase and the late phase (when the crop is ripening to be harvested) (FAO, 1998a). The rate of transpiration coming from a cultivated area per day and per grid cell is calculated by multiplying the area cultivated by the ETc.

$$ET_{Cc} = IA * (CI * K_C * ET_O)$$

ET_{Cc}: Evapotranspiration on a cultivated cell on day [mm/day];

IA: Area actually cultivated as percentage of cell area for the given grid cell [ha];

K_C: Crop coefficient, varying for each crop and each growth stage [-];

CI: Cropping intensity [-];

ET_O: Reference crop evapotranspiration [mm/day].

iv. Water demand per commercial use

Common activities at high water consumption in refugee camps are, for example, production of bricks and charcoals. Additionally, the presence of a vocational training centre leads to an increase in the water consumption. No available guidelines provide an estimation of the water consumed by these activities. Therefore, face-to-face interviews were carried out during the fieldwork in the refugee settlement of

Nakivale (Uganda) to acquire a first understanding of the amount of water needed in each case. The amount of water necessary for each activity in the particular case of Nakivale settlement is presented in a separate document: “Nakivale Refugee Settlement: report on water supply and water needs".

H. Water demand estimation of refugees and host community

In the computation of the water demand of the host community, the domestic, livestock, irrigation, industrial and aquaculture water requirement were taken into account. Data related on the water demand per use were extracted from (MWE (Ugandan Directorate of Water Resources Management), 2012). These were elaborated in order to consider only the water demand inside the catchment Rwizi (with the assumption that the water requirements are homogeneously spread in each district). In the assessment conducted by MWE, the water demand in 2011 has been reported together with projection for the year 2015. In the computation, the value related to the year 2011 were used (Table 45) with the exception of the water demand for industry, where the reliability of the projection was assessed through data collected in the field (Table 46).

Table 45. Water requirement for different use in each district

District	% area of District in Rwizi Basin	Livestock water requirement 2011 (mil m^3/y)	Aquaculture water requirement 2011 (mil m^3/y)	Irrigation Water Demand 2010/11 (mil m^3/y)
Buhweju	35%	0.26	0.56	-
Bushenyi	11%	0.23	0.20	0.02
Isingiro	46%	1.10	1.75	0.49
Kiruhura	30%	1.15	0.25	0.19
Lwengo	48%	0.26	1.20	0.19
Lyantonde	25%	0.16	0.13	0.02
Mbarara	71%	1.33	3.77	0.17
Ntungamo	9%	0.17	0.25	0.04
Rakai	63%	1.50	0.86	0.32
Sheema	80%	0.55	1.19	0.19

Table 46. Industrial water requirement in each district

District	% area of District in Rwizi Basin	2010/2011 (m3/y)	2015 (m3/y)
Buhweju	35%	8,400	10,100
Bushenyi	11%	1,100	1,400
Isingiro	46%	7,453	19,300
Kiruhura	30%	9,454	11,378
Lwengo	48%	190.55	238.19
Lyantonde	25%	400	500
Mbarara	71%	357,847[3]	429,416
Ntungamo	9%	2,043	2,452
Rakai	63%	48,474	58,143
Sheema	80%	600	700

In order to compute the total water demand of the host community inside the refugee camp boundary (buffer area), a grid shapefile (1x1 km) of the catchment was created and for each cell the respective water demand was assigned. This was computed considering an homogeneous distribution of the water requirements among the cells in which the district was partitioned (Table 47).

[3] The values in blue are elaborated from data collected in the field

Table 47. Water requirement in each cell of the shapefile grid

District	n. cell	Irrigation m3/y	Livestock m3/year	Aquaculture m3/year	Industrial m3/year
BUHWEJU	376	0.00	690.51	1489.36	26.86
SHEEMA	672	282.74	818.45	1770.83	1.04
BUSHENYI	119	168.07	1934.45	1680.67	11.76
MBARARA	1693	99.21	788.45	2229.59	253.64
NTUNGAMO	294	149.67	563.05	855.27	8.34
ISINGIRO	1615	303.84	679.34	1083.50	11.95
KIRUHURA	1806	106.52	636.08	140.00	6.30
LYANTONDE	301	66.75	542.34	442.22	1.66
LWENGO	608	316.41	423.09	1974.44	0.39
RAKAI	2963	108.78	507.64	290.08	19.62

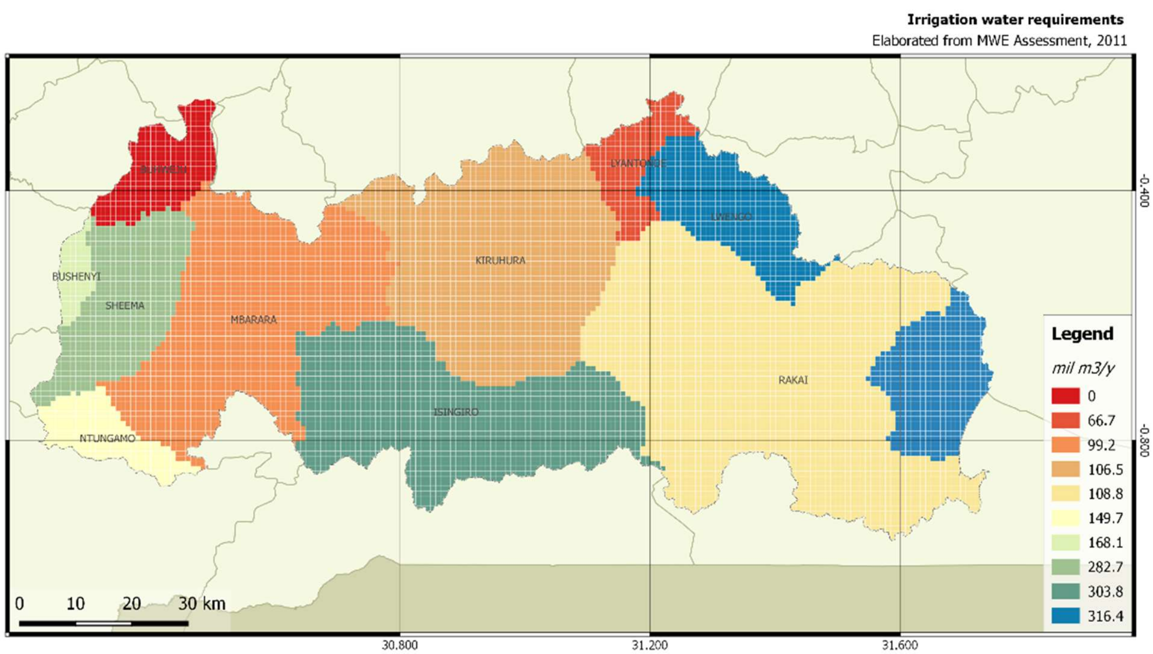


Figure 48. Irrigation water requirements at district scale, in Rwizi catchment

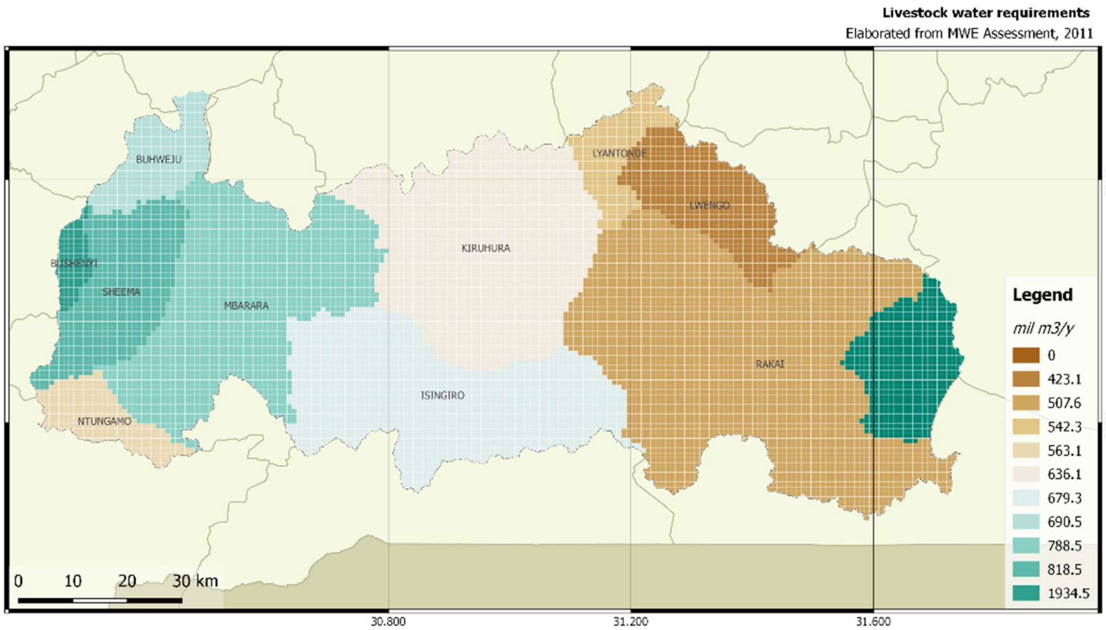


Figure 49. Livestock water requirements at district scale, in Rwizi catchment

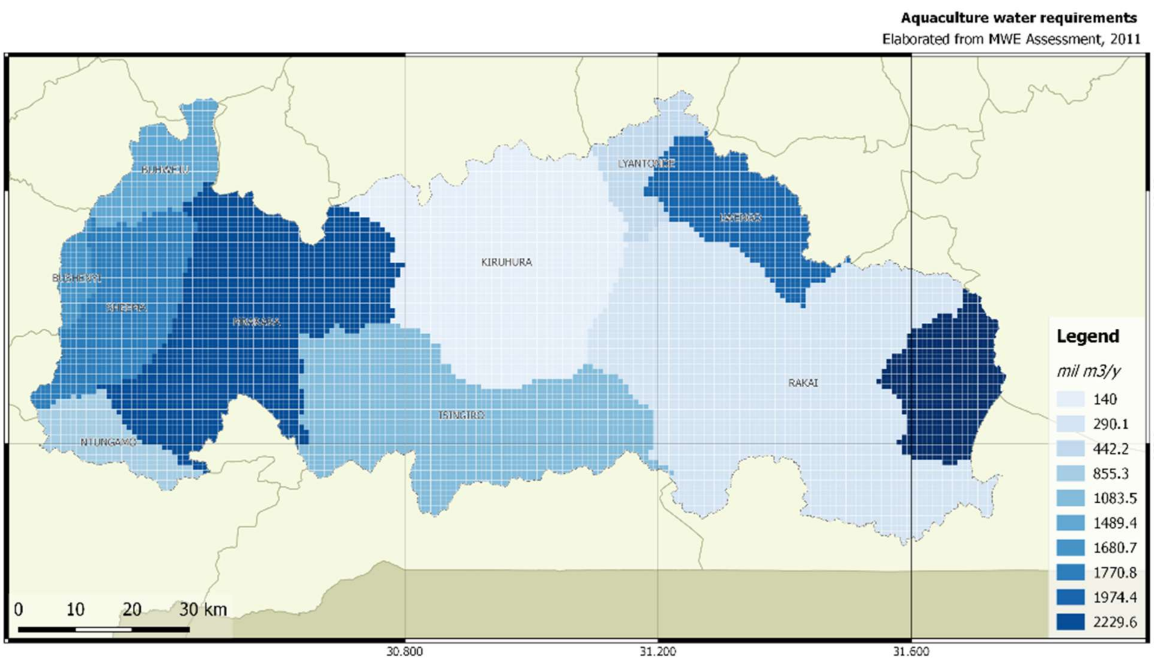


Figure 50. Aquaculture water requirements at district scale, in Rwizi catchment

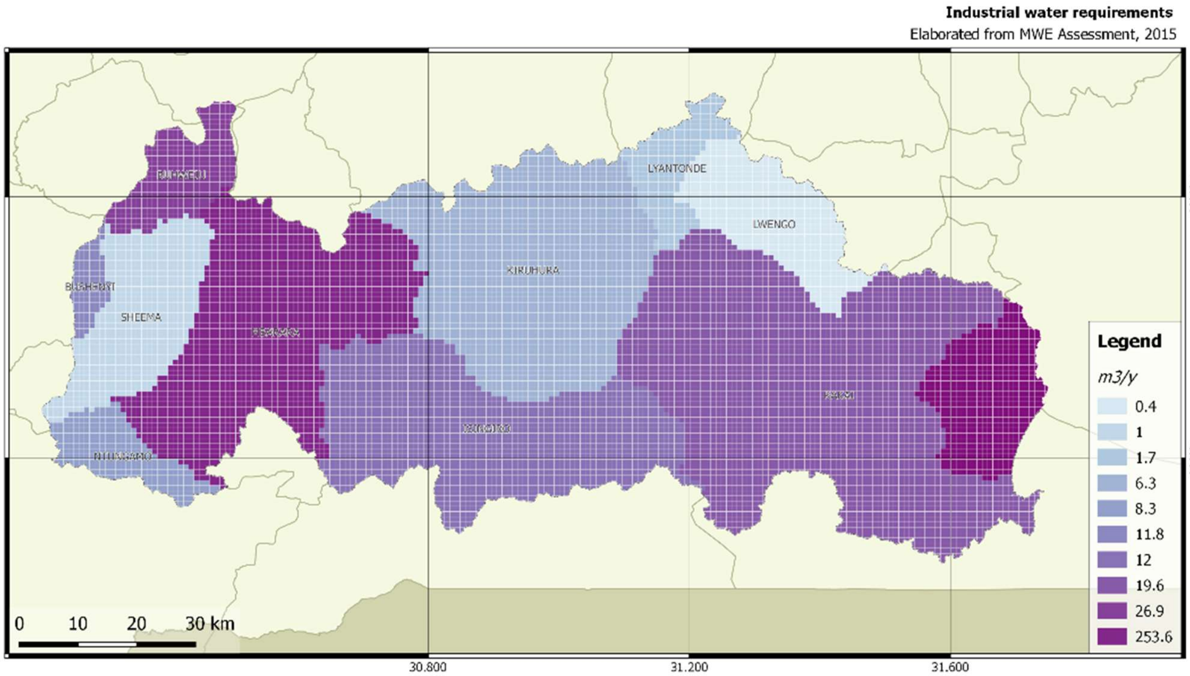


Figure 51. Industrial water requirements at district scale, in Rwizi catchment

For the computation of the domestic water demand the global population raster file for Uganda was used (Figure 61). A shapefile grid with the outline of the catchment was created. Through join attribute, the sub-county names were assigned to each cell and through zonal statistic the population rate was saved as attribute. Knowing at which sub-county each cell belongs to, it was possible to join the related water demand per capita. The total domestic water demand in each cell was finally computed multiplying the two parameters (population and water demand (m3/d/person). For the computation of the projected domestic water demand in 2033, a population growth of 3.5% was considered (Equation 1).

$$Pop_{future} = Pop_{present} * (1 + i)^n$$

Equation 1

Where:

Pop_{future} : future population;

$Pop_{present}$: present population;

i : growth rate;

n : number of years

To verify how much the resolution of the grid affected the result, the total demand in Mbarara Municipality present in the grid was compared with the value collected from the NWSC. The sum of the water demand of the cells falling in the boundary of the municipality is 5632.23 m3/day while the value provided by NWSC is 5540.556 m3/day.

The water domestic demand per capita was elaborated from MWE (Ugandan Directorate of Water Resources Management), 2012 (Table 48).

Table 48. Domestic water demand per district by MWE, 2011

District	2011			
	Population		domestic water demand	
	Rural	Urban	m3/year	l/person/day
Bushweju	35,881	1968	227,875	16
Sheema	169,379	3,457	982,549	16
Bushenyi	23,962	1,314	152,180	16
Mbarara	316,103	31,263	2,519,293	20
Ntungamo	392,402	16,350	2,409,490	16
Isingiro	398,190	10,210	343,131	2
Kiruhura	156,041	4,001	918,216	16
Lyantonde	76,339	2,361	455,658	16
Lwengo	256,953	7,947	1,533,721	16
Rakai	455,007	16,503	2,754,694	16

The values reported by the assessment reflect the situation in 2011 and do not consider the water demand of the refugee camps that already exist in the catchment. The water demand per Isingiro and Mbarara reported in the assessment is lower compared to what was found in the field. Therefore, according to field visit and the percentage of safe water access from the water atlas slight changes were made to the above table (Table 49).

Table 49. Domestic water demand per district used in the analysis

District	l/person/day	Source
Bushweju	18	Projection NWSC
Sheema	18	Projection NWSC
Bushenyi	18	Projection NWSC
Mbarara	28	Value obtained by Mbarara NWSC
Ntungamo	18	Projection NWSC
Isingiro	15	Increase according to the % of access to safe water from the Water Atlas
Kiruhura	18	Projection NWSC
Lyantonde	18	Projection NWSC
Lwengo	18	Projection NWSC
Rakai Upstream	13	Water Atlas
Rakai Downstream	22	Water Atlas

In the estimation of the refugee water demand, the domestic and agriculture water needs were computed. However, for the proposed application, it was not possible to compute the water demand per institution and commercial activities, as no information on the characteristic of the population were included in the analyzed scenarios.

The domestic water demand was computed considering the water standard of 20 l/p/d. In the computation of the livestock water requirements, the number of animals was computed comparing the current livestock in Nakivale with the refugee population.

n. small animals per person	n. big animals per person
1.37	0.158

The water consumption for big and small animals was computed according to the Sphere project standards (Figure 47). The agriculture water demand was instead computed using the Cropping Periods List, which was downloaded from the dataset MIRCA2000 (http://www.uni-frankfurt.de/45218031/data_download)

This provides a text file indicating for each grid cell, growing periods of irrigated and rainfed crops and their sub-crops including the related growing areas (in hectares). The data has a spatial resolution of 30 arc-minute by 30 arc-minute grid cells. Grid cells that do not contain any irrigated area are not listed in these files.

The developed Python algorithm identifies the cells in the list that fall in the analyzed site. If there are rainfed crops the algorithm will not compute the irrigation water requirement. If the crop is irrigated, the algorithm extracts from the text file the crop factor and compute the irrigation according to the equations suggested by FAO. The crop coefficient values were added to the database from (FAO, 1998a).

Table 50. Reference values used in MIRCA2000 with the addition of crop coefficient factor from FAO, 1998a

ID-Irrigated	ID-rainfed	Crop Class	Kc
1	27	Wheat	1.15
2	28	Maize	1.15
3	29	Rice	1.2
4	30	Barley	1.15
5	31	Rye	1
6	32	Millet	1
7	33	Sorghum	1.15
8	34	Soybeans	1.15
9	35	Sunflower	1
10	36	Potatoes	0.4
11	37	Cassava	0.8
12	38	Sugar cane	1
13	39	Sugar beet	1
14	40	Oil palm	1
15	41	Rapeseed / Canola	1
16	42	Groundnuts / Peanuts	1.15
17	43	Pulses	1.15
18	44	Citrus	0.6
19	45	Date palm	0.95
20	46	Grapes / Vine	0.8
21	47	Cotton	1.15
22	48	Cocoa	1
23	49	Coffee	1
24	50	Others perennial	1
25	51	Fodder grasses	0.7
26	52	Others annual.	1

Water gap was computed comparing the domestic water demand of the host community (or existent refugee camp in case of Nakivale settlement) with the government and UNHCR standards, both equal to 20 l/p/day. If the water demand per person is less than this standard, the needed water to reach the target is computed as follows:

$$\textbf{Water gap} \begin{cases} 0 & wd \geq target \\ target - wd & wd < target \end{cases}$$

Equation 2

Where:

wd: current water demand

[l/p/d];

$target$: government target (20 l/p/d for the Ugandan government)

Because the water requirement for the existent refugee camps is not considered in Government assessments, this was included in the algorithm according to the data collected in the fieldwork.

Table 51. Water requirements for Nakivale refugee settlment

Population Nakivale	86211
Growth rate	2%
Domestic water demand	20 l/person/day
Livestock water demand	119 m3/day
n. children from 5 to 11	10550
Water requirement for institution	3 l/student/day
Vocational center water requirement	3.4 m3/day
Water demand for commercial activities	24.8 m3/day

I. Water balance model

Knowledge on the water storage and movements within the components of the hydrological cycle provides a resource for decision-makers to quantify the different types of water security threats, and devise strategies for better allocation and management of freshwater resources (Thapa, Ishidaira, Pandey, & Shakya, 2017). The study of the water balance components in the catchment was carried out through the development of a simple hydrological model based only on global data. The purpose of the hydrological model was to establish a quantitative link between the system input (climate drivers), the state (storage) and the output (hydrological response) with the use of a small number of parameters. This was achieved with the application of an empirical method applied to a semi-distributed spatial scale for run-off estimations and a water balance method for computing groundwater recharge.

A general water balance equation is:

$$P = Q + ET + R$$

Where:

P is precipitation [mm/day];

Q is the surface runoff [mm/day];

ET is the actual evapotranspiration [mm/day];

R is the groundwater recharge [mm/day];

Computation of the catchment yield (Runoff)

Runoff is a part of the total precipitation remaining after withdrawing of losses consisting of infiltration, evapotranspiration, interception and depression storage. This precipitation is transformed by the surface watershed into direct runoff. As no river discharge data were available, the runoff was estimated on the basis of the so-called Curve Number (CN) method (Figure 52). This empirical method was developed by the Soil Conservation Service in 1972.

Figure 52. Schematization of a black box model

According to the method, the runoff can be calculated as follows:

$$Q_{ti} = \begin{cases} 0 & for\ P_{ti} \leq I_a \\ \dfrac{(P_{ti} - I_a)^2}{(P_{ti} - I_a + S)} & for\ P_{ti} > I_a \end{cases}$$

Q_{ti}: Runoff in time from t_0 to t_i (mm);

P_{ti}: Total rainfall in time from t_0 to t_i (mm);

I_a: Initial losses (mm);

S: Maximum potential retention of the watershed (difference between total rainfall and direct runoff after a long time) (mm);

The initial losses (I_a) takes into account the losses for interception and depression storage. This is usually estimated equal to the 20% of the maximum potential retention (S). The parameter S is related to the CN (Curve Number) value which depends on soil type, land use, soil conservation practices and antecedent moisture conditions.

$$S = 254 * \left(\frac{100}{CN} - 1\right)$$

A CN value equal to 0 means that the soil is completely porous, while a value equal to 100 corresponds to impervious soil. Its value is tabulated by SCS in relation to the type of soil. Four different classes were identified:

Class A: Soils having high infiltration rates (low runoff potential);

Class B: Soils having moderate infiltration rates;

Class C: Soils having slow infiltration rates;

Class D: Soils having very slow infiltration rates (high runoff potential);

The method was applied using daily rainfall value obtained from satellite data (time series from 1979 to 2009 were extracted from MSWEP). In reality, CN method is meant for a rainfall event (not for daily rainfall, per se). A rainfall event is defined as the period between two non-rainfall(dry) periods. Therefore, it is better to calculate the runoff by considering rainfall events over a year (Sulis & Sechi, 2013). However, rainfall event data are difficult to obtain when few rain gauges are located in the catchment in analysis. The use of daily rainfall can, hence, introduce an error. Though, in many application the CN method was used also with daily rainfall data showing quite interesting results (Jenifa Latha, Saravanan, & Palanichamy, 2010).

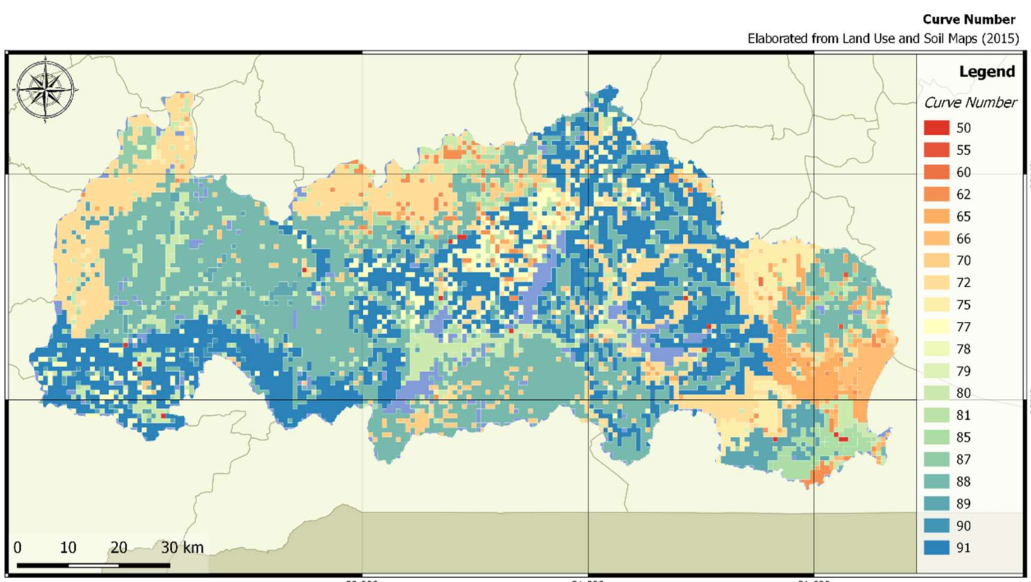


Figure 53. Curve number values in the Rwizi catchment

According to soil and land use maps, zones with similar emergent behaviour were identified. The respective curve number was assigned to them using the values listed in (USDA, 1986) (Figure 53).

Computation of the groundwater recharge

To estimate groundwater recharge rates, a water balance method for the root zone was applied. According to (Nonner & Stigter, 2016) the water balance can be formulates as follows:

$$P = Q + ET + R + \Delta S_{root} + Q_{cap}$$

Where:

P : Precipitation;

Q : Surface runoff;

ET : Actual evapo-transpiration;

R : Groundwater recharge (percolation at lower boundary of the root zone);

ΔS_{root} : Change in water (soil moisture) storage in the root zone;

Q_{cap} : Capillary rise at lower boundary of the root zone;

The water balance has been modelled through a Python algorithm adopting mm as the unit for volume per unit area and a monthly step. The adoption of monthly steps reduces the error given by high seasonal variation. This 1D-hydrodynamic model was executed using precipitation time series over more than 30 years and for each area characterised by a certain pattern (Figure 54). The Q_{cap} parameter was neglected as no time series of the groundwater table were available.

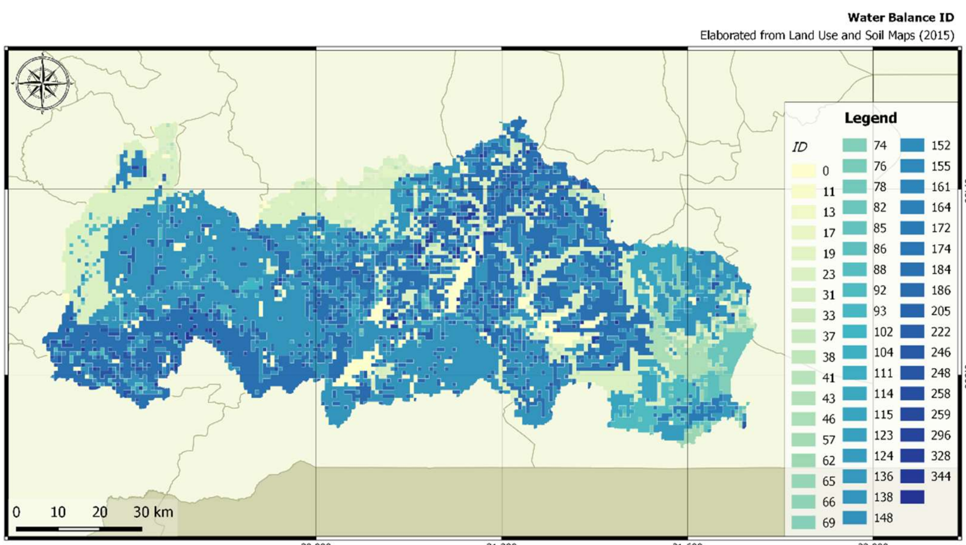
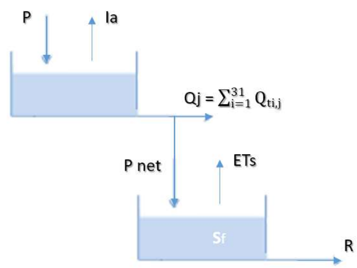


Figure 54. Areas' ID with different patterns

Table 52. Input parameters for recharge calculation and respective sources

Parameter	Source
Monthly rainfall data	MSWEP: 3-hourly 0.25° global gridded precipitation (1979–2015)

Monthly potential evapotraspiration	Earth2Observe: 0.25° global gridded evapotraspiration (1979–2015) obtained applying the PenmanMonteith to WRR2 forcing
Available soil moisture at field capacity	Fetter 1994 and Rosetta
Crop Coefficient	(FAO, 1998b; Sharma & Thakur, 2007)
Runoff	CN method



Below the equations used in the model:

1) $Q_j = \sum_{i=1}^{31} Q_{ti,j}$

Monthly step (j):

2) $P_{net,j} = P_j - Q_j$

3) $PET_{crop,j} = PET_j - Kc$

4) $$ET_{sm,j} = \begin{cases} \min(PET_{crop,j}\ ;\ \ (P_{net,j} + S_{root,j}) & for\ (P_{net,j} + S_{root,j}) \leq S_{r\_evap} \\ \min\left(\frac{(P_{net,j}+S_{root,j})}{S_{r_{evap}}} * PET_{crop,j}; P_{net,j} + S_{root,j}\right) & for\ (P_{net,j} + S_{root,j}) > S_{r\_evap} \end{cases}$$

5) $S_{root,j+1} = \min(P_{net,j} + S_{root,j} - ET_{sm,j};\ S_{fc})$

6) $\Delta S_{root,j} = S_{root,j+1} - S_{root,j}$

7) $$R_j = \begin{cases} P_{net,j} + S_{root,j} - ET_{sm,j} - S_{fc} & for\ (P_{net,j} + S_{root,j} - ET_{sm,j}) > S_{fc} \\ 0 & for\ (P_{net,j} + S_{root,j} - ET_{sm,j}) \leq S_{fc} \end{cases}$$

$P_{ti,j}$: Input of daily rainfall data [mm/day];

$Q_{ti,j}$: Computation of the daily runoff [mm/day];

P_j : Input of monthly rainfall data [mm/month]

$Q_{m,j}$: Computation of the monthly runoff [mm/month];

$P_{net,j}$: Computation of the net precipitation as rainfall minus runoff [mm/month];

PET_j : Input of potential evaporation [mm/month];

Kc : Crop coefficient;

$PET_{crop,j}$: Computation of potential (crop) evapotranspiration [mm/month];

$S_{root,j+1}$: Computation of new soil moisture content at the end of the monthly time step [mm];

S_{r_evap} : Computation of available soil moisture at reduction evaporation (as fraction), computed as S_{fc} * 0.5;

S_{fc} : Input of available soil moisture at field capacity (as fraction);

$ET_{sm,j}$: Computation of actual evapotranspiration from soil moisture.

Results

For a quantitative assessment, rates and periods of recharge were computed through calculation of water balance for each zone in which the catchment has been split. The method was applied using satellite data for precipitation and total potential evaporation. The average yearly values were compared with literature value to verify the accuracy of the former (Table 53).

For each location, the algorithm delineates the watershed and for each zone within the area computes the water balance. The sum of the monthly recharge over the delineated watershed were used for computing the criteria. At the end of the computation, the algorithm check the water balance equation (Equation 3) and if an error occur a warning text appears on the console.

Table 53. Comparison between global and literature data

Forcing (***average***)	**Global data** *(EarthH2Observer,2017)*	**Literature value** *(Ministry of Water and Environment (MWE), 2013)*
Precipitation [mm/year]	1300	1400
PET [mm/year]	1022	1300

$$\sum_{n=0}^{252} R_{n,i} + \sum_{n=0}^{252} AET_{n,i} + \sum_{n=0}^{252} Q_{n,i} + \sum_{n=0}^{252} \Delta S_{n,i} = \sum_{n=0}^{252} P_{n,i}$$

Equation 3

Where n is the number of iterations (252 months) while i is the number of zones inside the analysed watershed for which the water balance is computed.

Natural groundwater recharge is strongly dependent on climate conditions and seasonal variations since its main source is precipitation. Therefore, no main difference in the general patterns can be identified among the location A, B and C, besides a clear increase in the rates over all water balance parameters resulting from the increase of the watershed size in analysis. Looking individually at each graph, a general pattern of recharge is observed, mainly from mid-September to November and from March to May coinciding with the wet season in the area.

It is also important to highlight the occurrence of recharge even in months when the monthly average values of AET are higher or almost equal to the monthly precipitations. This happens because in particular zones, precipitation exceeds AET rates and percolation of water from the root zone occurs. However, summing up the water parameters over all zones in the analyzed watershed, the high value of precipitation in some zone compensate the low value in other zones. This can be observed, especially in months from December to February when a minor recharge takes place in some zones.

Finally, AET exceeds precipitation rates when soil moisture evaporate (negative ΔS values). In this case, water content in the soil reduces.

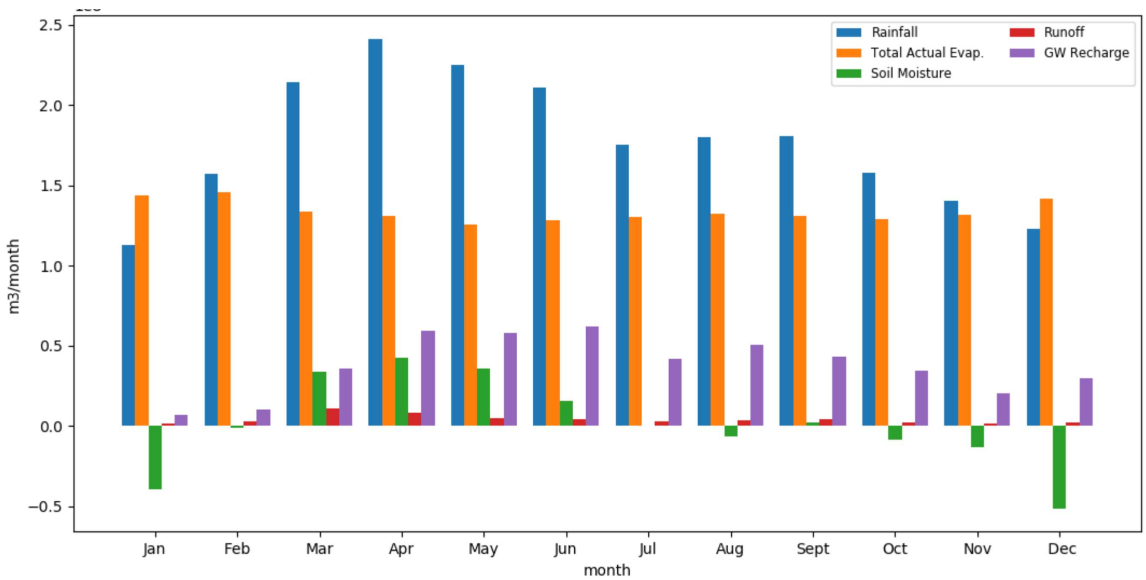


Figure 55. Monthly average values of water balance components for simulated years (1993-2015) over the watershed of location A. Values expressed in m^3/month

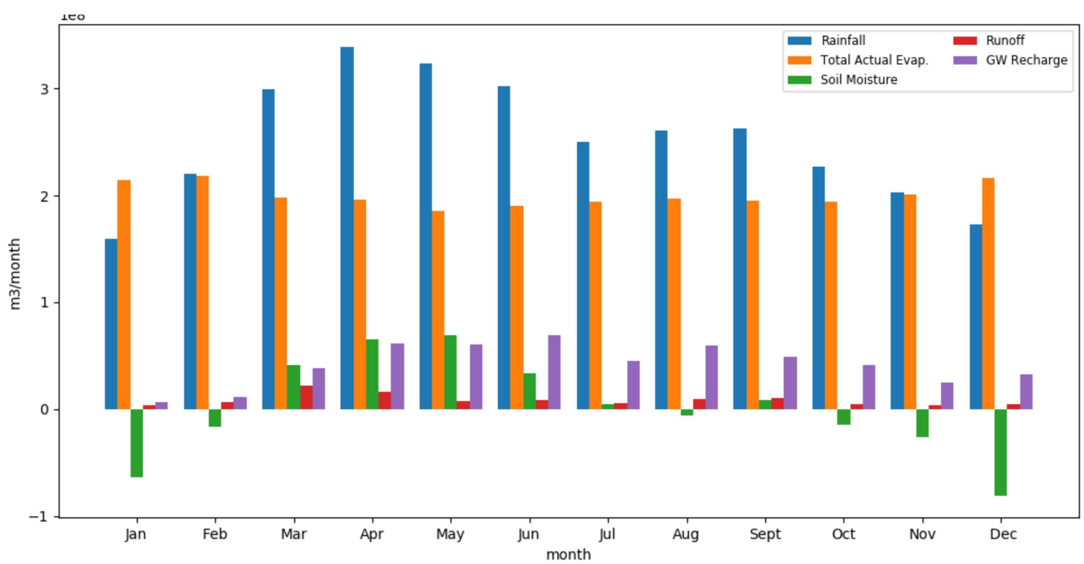


Figure 56. Monthly average values of water balance components for simulated years (1993-2015) over the watershed of location B. Values expressed in m^3/month

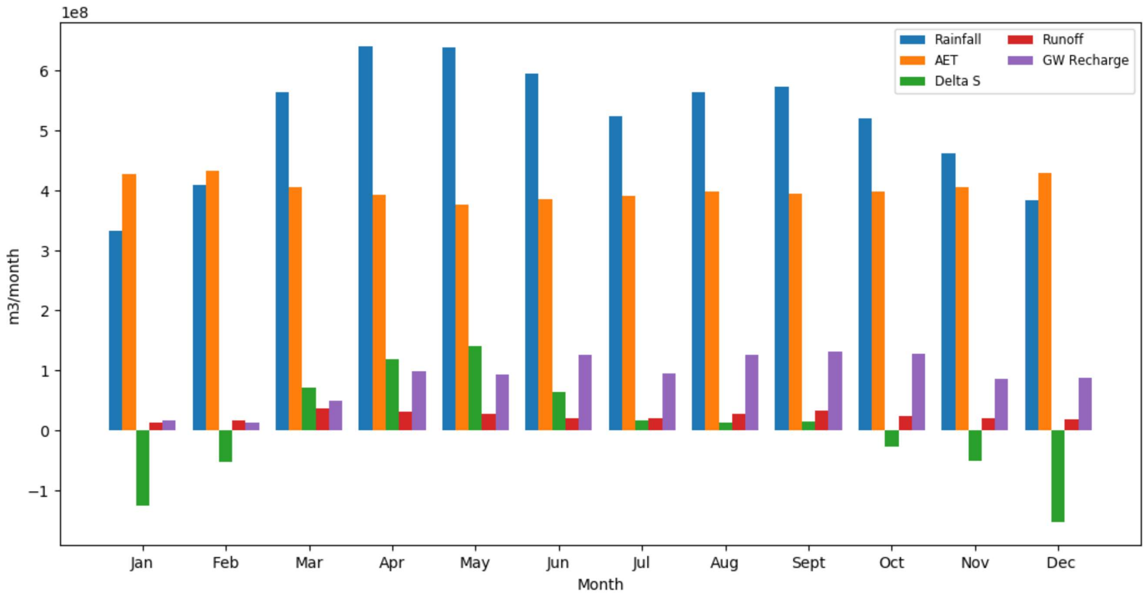


Figure 57. Monthly average values of water balance components for simulated years (1993-2015) over the watershed of location C. Values expressed in m^3/month

a) Water Balance Model: Data elaboration

- **Soil type analysis**

The soil types in the Rwizi basin were analyzed and the area of domain was identified in the soil texture triangle (Figure 58).

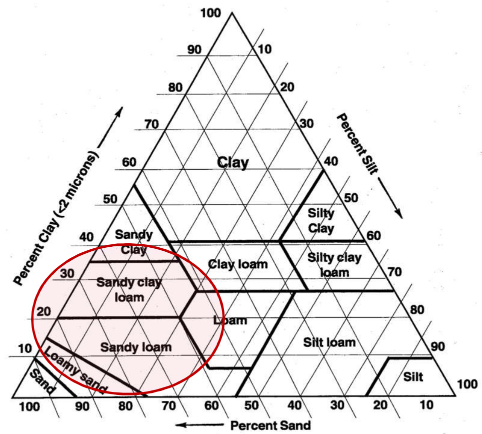


Figure 58. Soil texture triangle for Rwizi basin

Soil type	Extension [%]
Brown loamy sands	0.88
Dark brown sandy loams over dark grey clays	7.95
Grey coarse sands	3.78
Grey sands	1.15
Humose loams with dark subsoil horizons	0.66
Humose sandy loams with dark subsoil horizons	0.73
Peat or peaty sands and clays	7.35
Red and brown sandy loams over murram and ironstone	0.00
Red sandy clay loams	1.15
Red sandy clay loams often underlain by soft laterite	0.07
Reddish and reddish brown gritty clay loams	0.51
Reddish brown clay loams	14.61
Reddish brown sandy loam on red clay loams	2.66
Shallow humose loams over rock rubble	7.73

Shallow, drak brown sandy loams	1.96
Water	1.74
Yellowish red Clay Loams	8.94
Yellowish red gravelly loams	5.88
Yellowish red loams and sandy loams with occasional soft laterite	22.55
Yellowish red loams underlain by soft laterite	2.34
Yellowish red sandy loams and loams underlain by soft laterite	3.50
Yellowish-brown loams and sandy clay loams with dark subsoil horizons	3.87

Rwizi Catchment			Classification Fetter and Rosetta 1993		Class ID
Soil type	***Area [m2]***	***%***	***Available soil moisture***	***Soil Type***	
Brown loamy sands	72751290.2	0.88	0.15	Sandy loam	1
Dark brown sandy loams over dark grey clays	660498757	7.95	0.15	Sandy loam	1
Grey coarse sands	313701147	3.78	0.05	Sand	2
Grey sands	95670737.3	1.15	0.3217	coarse to medium sand	3
Humose loams with dark subsoil horizons	55078265.2	0.66	0.15	Sandy loam	1
Humose sandy loams with dark subsoil horizons	60909987.7	0.73	0.15	Sandy loam	1
Peat or peaty sands and clays	610225044	7.35	0.09	sands and clay	4
Red and brown sandy loams over murram and ironstone	136971.24	0.00	0.23	Loam	5
Red sandy clay loams	95239909.5	1.15	0.2	Light clay loam	6
Red sandy clay loams often underlain by soft laterite	5605655.3	0.07	0.2	Light clay loam	6
Reddish and reddish brown gritty clay loams	42452880.1	0.51	0.13	Clay	7
Reddish brown clay loams	1213556043	14.61	0.18	Heavy clay loam	8
Reddish brown sandy loam on red clay loams	220601188	2.66	0.2	Light clay loam	6
Shallow humose loams over rock rubble	641544130	7.73	0.2	Light clay loam	6
Shallow, dark brown sandy loams	162429506	1.96	0.2	Light clay loam	6
Water	144201123	1.74		Water	0
Yellowish red Clay Loams	742054341	8.94	0.18	Heavy clay loam	8
Yellowish red gravelly loams	487961655	5.88	0.18	Heavy clay loam	8
Yellowish red loams and sandy loams with occasional soft laterite	1872194155	22.55	0.2	Light clay loam	6
Yellowish red loams underlain by soft laterite	194388594	2.34	0.23	Loam	5
Yellowish red sandy loams and loams underlain by soft laterite	290706850	3.50	0.15	Sandy loam	1
Yellowish-brown loams and sandy clay loams with dark subsoil horizons	321739120	3.87	0.15	Sandy loam	1

- **Land cover analysis**

Land Use	Tot Area [km2]	Percentage [%]
Bare land	12.01	0.15
Broadleaved tree plantation	12.43	0.15
Built-up area	37.35	0.45
Bushland	371.75	4.53
Commercial Farmland	29.43	0.36
Coniferous Plantations	0.08	0.00
Depleted Tropical High Forest	8.85	0.11
Grassland	549.07	6.69
Open water	149.64	1.82
Permanent wetland	429.63	5.23
Seasonal wetland	243.96	2.97
Subsistence farmland	6186.41	75.33
Tropical High Forest Well Stocked	76.04	0.93
Woodland	105.83	1.29

- **Water Balance analysis – Identification of areas with similar pattern**

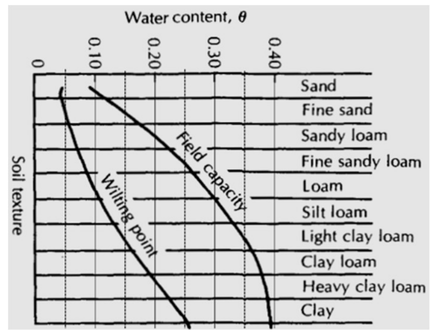
Water Balance Classes					Inputs water balance model					
Soil Type ID	**Land Cover ID**	**frequency [n. cells]**	**Soil Type**	**Land Cover**	**Available moisture at field capacity (as fraction) 1)**	**Depth of root zone droot (cm)**	**Extinction depth dext (cm)**	**Curve Number**	**ID_WB**	**Kc**
Combination above 200										
1	23	204	Sandy loam	crop	0.15	100	170	72	23	1
6	23	204	Light clay loam	crop	0.2	100	300	88	138	1
Combination above 100										
8	23	180	Heavy clay loam	crop	0.18	100	550	91	184	1
6	31	149	Light clay loam	tropical forest	0.2	250	400	70	186	0.86
8	31	141	Heavy clay loam	tropical forest	0.18	250	655	77	248	0.86
8	19	110	Heavy clay loam	Bushland	0.18	160	600	77	152	0.7
4	23	103	sands and clay	crop	0.09	100	310	89	92	1
Combination above 50										
1	31	88	Sandy loam	tropical forest	0.15	250	330	80	31	0.86

6	37	76	Light clay loam	Permanent wetland	0.2	100	200	80	222	0.83
4	37	76	sands and clay	Permanent wetland	0.09	100	210	80	148	0.83
2	19	67	Sand	Bushland	0.05	160	197	62	19	0.7
6	19	65	Light clay loam	Bushland	0.2	160	350	85	114	0.7
Combination below 50										
1	41	39	Sandy loam	Seasonal wetland	0.15	50	120	65	41	0.83
8	41	37	Heavy clay loam	Seasonal wetland	0.18	50	250	81	328	0.83
8	37	29	Heavy clay loam	Permanent wetland	0.18	100	350	85	296	0.83
6	41	27	Light clay loam	Seasonal wetland	0.2	50	200	80	246	0.83
1	37	26	Sandy loam	Permanent wetland	0.15	100	180	75	37	0.83
4	19	25	sands and clay	Bushland	0.09	160	360	85	76	0.7
3	23	24	coarse to medium sand	crop	0.3217	100	150	65	69	1
2	23	17	Sand	crop	0.05	100	145	65	46	1
3	41	16	coarse to medium sand	Seasonal wetland	0.3217	50	100	85	123	0.83
4	43	14	sands and clay	woodland	0.09	600	410	85	172	0.86
8	43	13	Heavy clay loam	woodland	0.18	600	610	90	344	0.86
2	41	13	Sand	Seasonal wetland	0.05	50	100	66	82	0.83
4	31	13	sands and clay	tropical forest	0.09	250	410	85	124	0.86
2	31	12	Sand	tropical forest	0.05	250	250	62	62	0.86
4	41	11	sands and clay	Seasonal wetland	0.09	50	260	50	164	0.83
6	17	10	Light clay loam	Built-up area	0.2	20	0	89	102	0.16
2	43	8	Sand	woodland	0.05	600	250	80	86	0.86
8	17	7	Heavy clay loam	Built-up area	0.18	20	0	89	136	0.16
1	43	7	Sandy loam	woodland	0.15	600	330	65	43	0.86
2	19	7	Sand	Bushland	0.05	160	198	70	38	0.7
6	43	7	Light clay loam	woodland	0.2	600	350	80	258	0.86
2	37	6	Sand	Permanent wetland	0.05	100	120	65	74	0.83
5	23	6	Loam	crop	0.23	100	370	75	115	1
6	13	6	Light clay loam	Broadleaved tree plantation	0.2	250	350	70	78	0.9
5	13	5	Loam	Broadleaved tree plantation	0.23	250	430	70	65	0.9
6	11	5	Light clay loam	Bare land	0.2	10	200	80	66	0.2
3	19	5	coarse to medium sand	Bushland	0.3217	160	200	85	57	0.7
8	11	4	Heavy clay loam	Bare land	0.18	10	410	80	88	0.2
1	17	4	Sandy loam	Built-up area	0.15	20	0	50	17	0.16
1	11	2	Sandy loam	Bare land	0.15	10	130	60	11	0.2
3	11	2	coarse to medium sand	Bare land	0.3217	10	70	55	33	0.2
3	37	2	coarse to medium sand	Permanent wetland	0.3217	100	120	75	111	0.83

7	23	2	Clay	crop	0.13	100	715	87	161	1
7	37	2	Clay	Permanent wetland	0.13	100	650	78	259	0.83
1	13	1	Sandy loam	Broadleaved tree plantation	0.15	250	300	80	13	0.9
8	13	1	Heavy clay loam	Broadleaved tree plantation	0.18	250	400	80	104	0.9
3	31	1	coarse to medium sand	tropical forest	0.3217	250	300	80	93	0.86
5	17	1	Loam	Built-up area	0.23	20	0	79	85	0.16
5	31	1	Loam	tropical forest	0.23	250	470	62	155	0.86
5	41	1	Loam	Seasonal wetland	0.23	50	330	70	205	0.83
6	29	1	Light clay loam	Coniferous Plantations	0.2	200	350	70	174	1

- **Recharge computation – Available soil moisture and field capacity**

Soil data	Available moisture at field capacity	Source
coarse to medium sand	0.05	Fetter
grey sands	0.32	Rosetta
sand to silt	0.2	
silt to clay	0.2	Fetter
silt-clay	0.19	
clay	0.13	



Land Cover	kc	Source
Built-up area	0.16	(Sharma & Thakur, 2007)
crop	1	(FAO, 1998b)
wetland	0.83	(Sharma & Thakur, 2007)
Bushland	0.7	(FAO, 1998b)
tropical forest	0.86	(Sharma & Thakur, 2007)
Broadleaved tree plantation	0.9	(FAO, 1998b)
Bare land	0.2	(Sharma & Thakur, 2007)
Coniferous Plantations	1	(FAO, 1998b)
woodland	0.86	(FAO, 1998b)

J. Computation of attribute scores for the application in Uganda

High safety for the refugees

Low direct exposure to contaminated water

To quantify the objective: "low direct exposure to contaminated water" three proxy attributes were identified. Each attribute refers to different water sources (surface water, groundwater and rainwater) that could be used in the water supply system. This has allowed us to separately assess the risk of polluted supplied water according to the water sourcing used.

Attribute 1: Slope

To assess the vulnerability of the surface water source to pollutants, the percentage of slope was selected as attribute. This was computed as the average of the slope values in a buffer area (extension of the potential refugee camp according to the number of refugees allocated in the investigated site). The slope map was elaborated from the Digital Elevation Model (retrieved as GMTED2010, 15-arc sec resolution from Danielson & Gesch, 2011).

The DEM was clipped according to the catchment in analysis and filled by Fill Sink tool in QGIS 2.14.12. Slope GDAL in Processing Toolbox was used for developing the slope map. The option "scale (ratio of vertical units to horizontal units)" was set to 111120 with vertical units in meters (370400 if the vertical units are in feet) and CRS: 4326 (Figure 59). This parameter could be set to 1 only when the measuring units of the CRS and the elevation measuring units are the same.

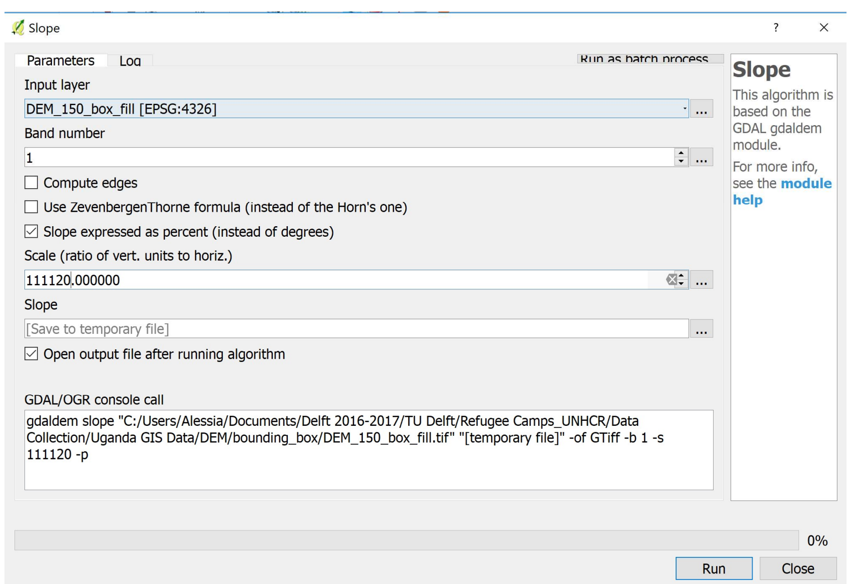


Figure 59. Slope GDAL tool on QGIS 2.14.12

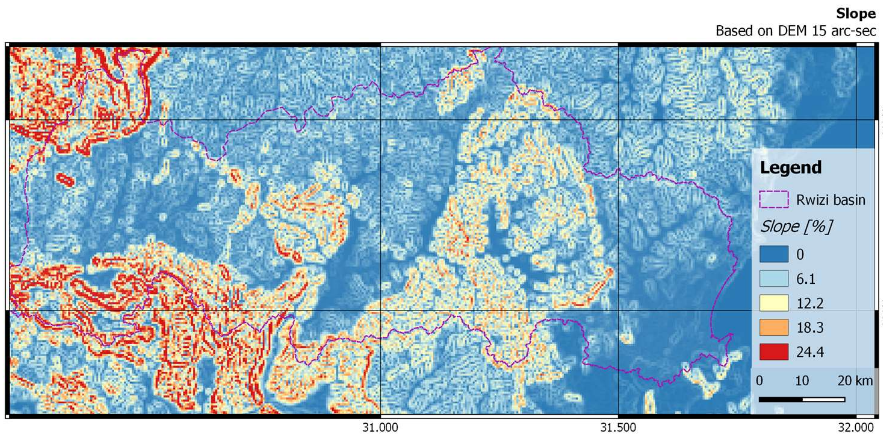


Figure 60. Slope map for Rwizi basin

Attribute 2: Total faecal emission for assessing SW hazards

The faecal production was computed according to the human and livestock emission. The human faecal emission for Africa was extracted from UNEP, 2016 and the animal faecal emission from FAO, 2003a (Table 54).

Table 54. Faecal coliform emission rate

	10^{10} CFU/cap/year
Human	170
Cattle	2555
Pig	657
Chicken	15
Goat	821
Sheep	821

By using raster calculator tool in QGIS 2.14.12, the emission rate of livestock and human was multiplied respectively by the spatial distribution of cattle, pig, chicken, goat and sheep (FAO, 2010) and the spatial distribution of population (WorldPop, 2010). The raster obtained by the sum of the human and livestock fecal emission was used for computing the fecal coliform emission in the area that drains toward the investigated location. This was delineated in one part of the algorithm.

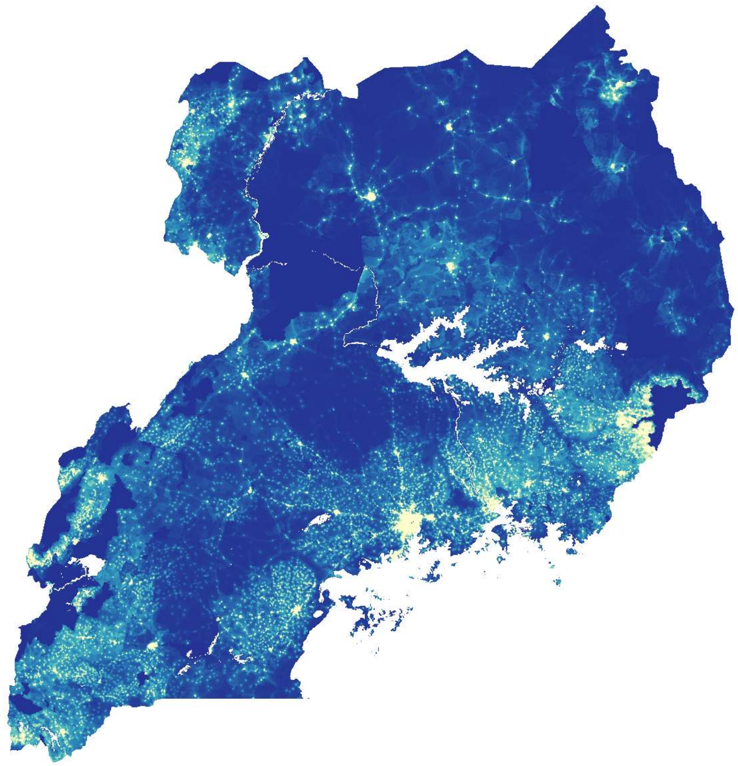


Figure 61. Spatial population distribution retrieved from (WorldPop, 2010)

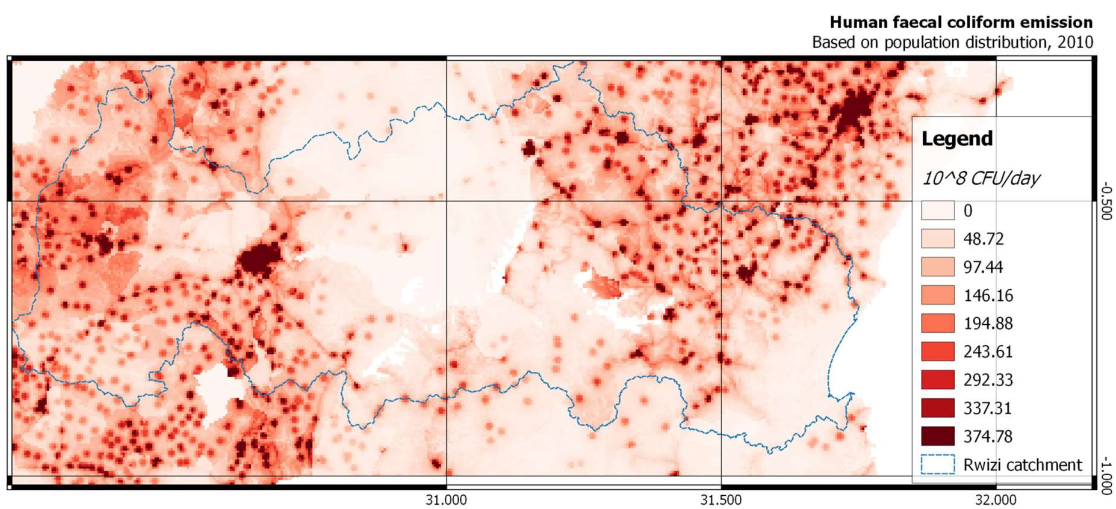


Figure 62. Human faecal coliform emission

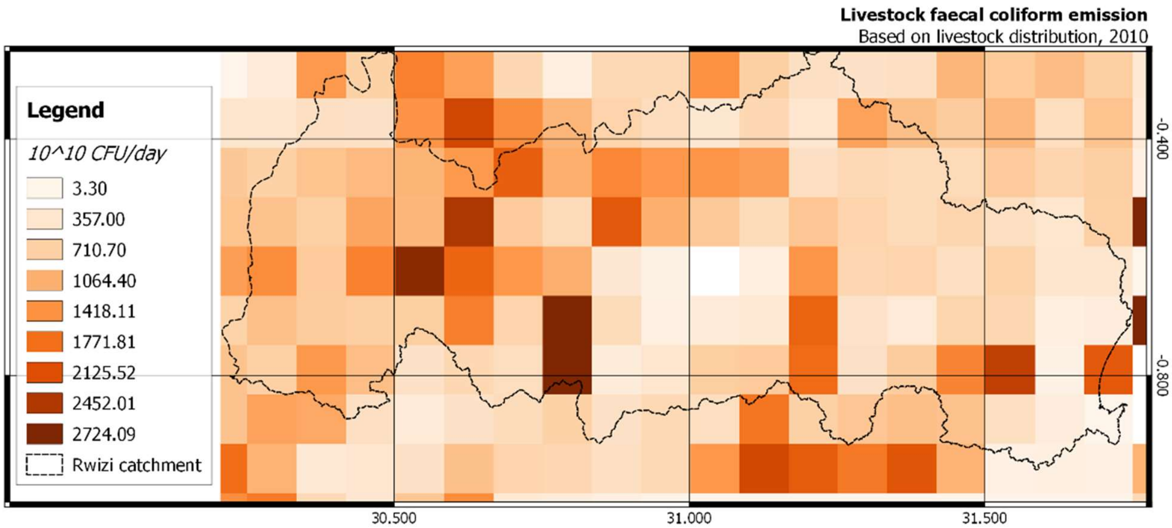


Figure 63. Livestock faecal coliform emission

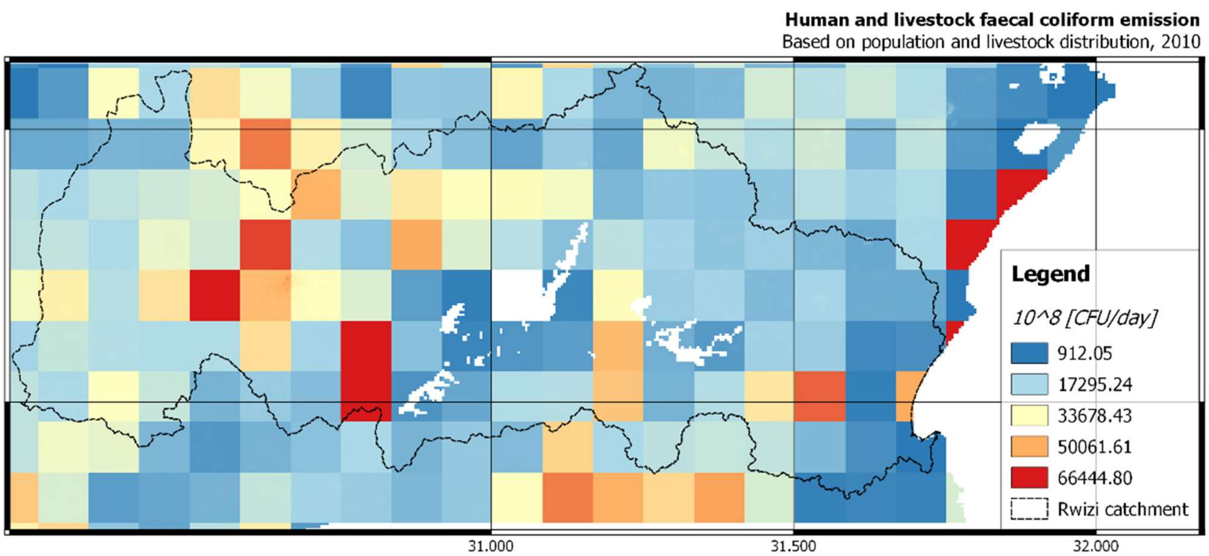


Figure 64. Human and livestock faecal coliform emission

Attribute 3: Topographic distance to the highest pollution load

From GIS the flow distance to the highest pollution load source inside the watershed was computed for each location (Figure 65). Sites with the highest faecal coliform production were identified from the map resulted in the previous analysis. Table 55 shows the results.

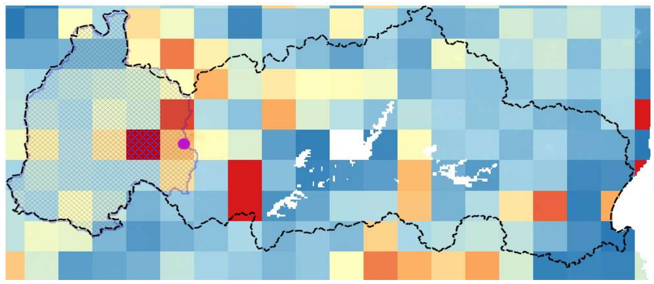


Figure 65. Identification of the site with the highest faecal production (purple square) inside one of the analysed watershed.

Table 55. Attribute values for vulnerability of the SW source

Location	Flow distance to the site with the highest faecal production load [m]
A	13821
B	26102
C	80247

Attribute 4: Total faecal emission for assessing GW hazards

Data inputs are the same of the one used for computing Attribute 2. However, the faecal coliform load that is liable to endanger the water quality of the aquifer are the one emitted in the all aquifer boundary (especially in the areas where recharge rate occurs most). However, local data on aquifer boundary were not available. Hence, the total pollution load production was computed only in the intersection of the catchment boundary with the aquifer boundary. This area was identified using global groundwater data (WHYMAP, 2006).

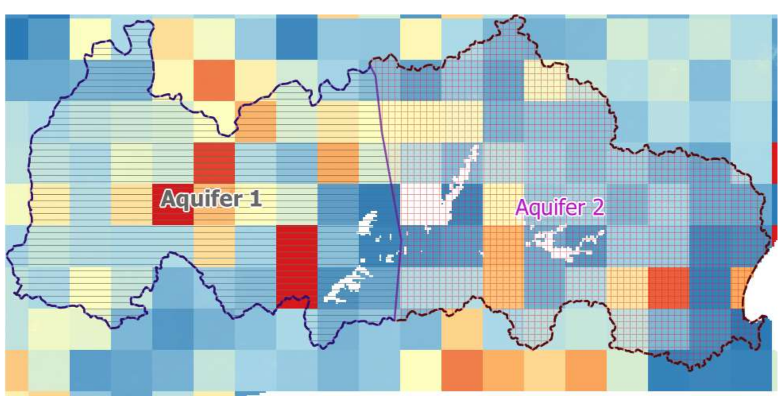


Figure 66. Intersection of aquifers' boundaries and Rwizi basin, overlaid on the faecal coliform production map

Attribute 5: Groundwater table depth

The map of the groundwater table depth was obtained from static water level measurements made in different points of the catchment and at a different times of a year (Figure 67). This introduce a significant error in assessing the spatial distribution of water level. However, no time series of groundwater table measures were available. The used data were partially provided by UNHCR, thanks to a borehole campaign in Nakivale refugee settlement carried out in September 2018. Other water level measurements were provided by the Victoria Water Resource Management Zone. The linear interpolation of the data resulted in the map showed in Figure 68.

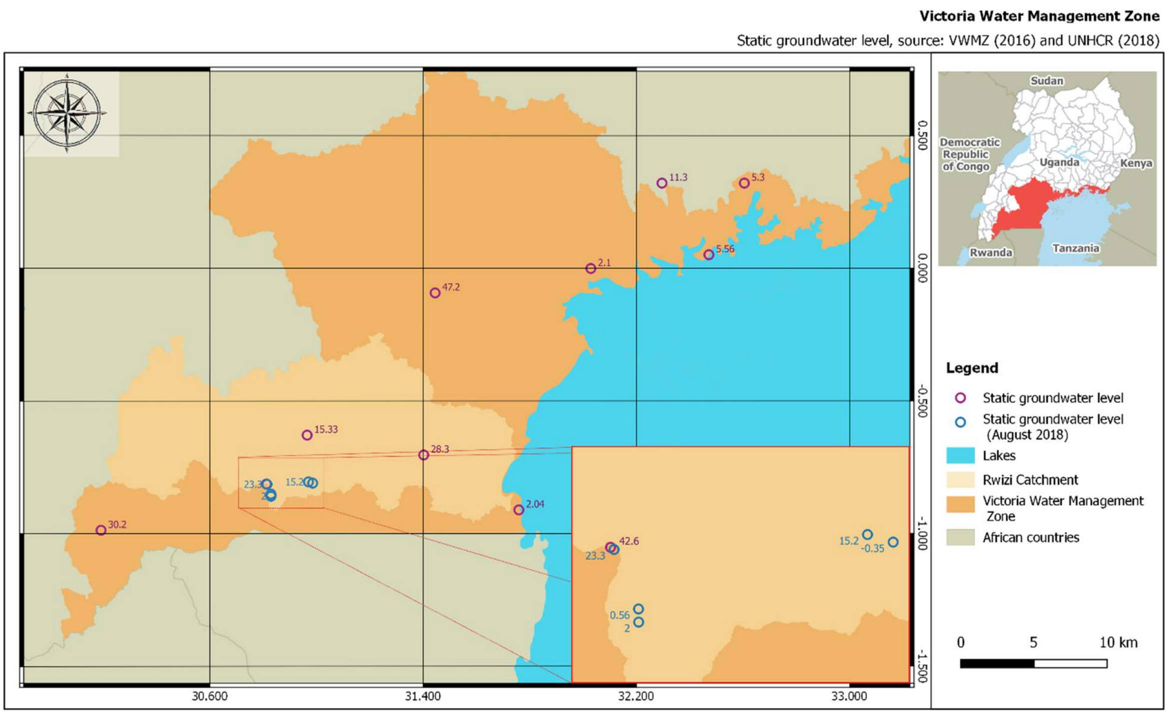


Figure 67. Available measurements of groundwater table level

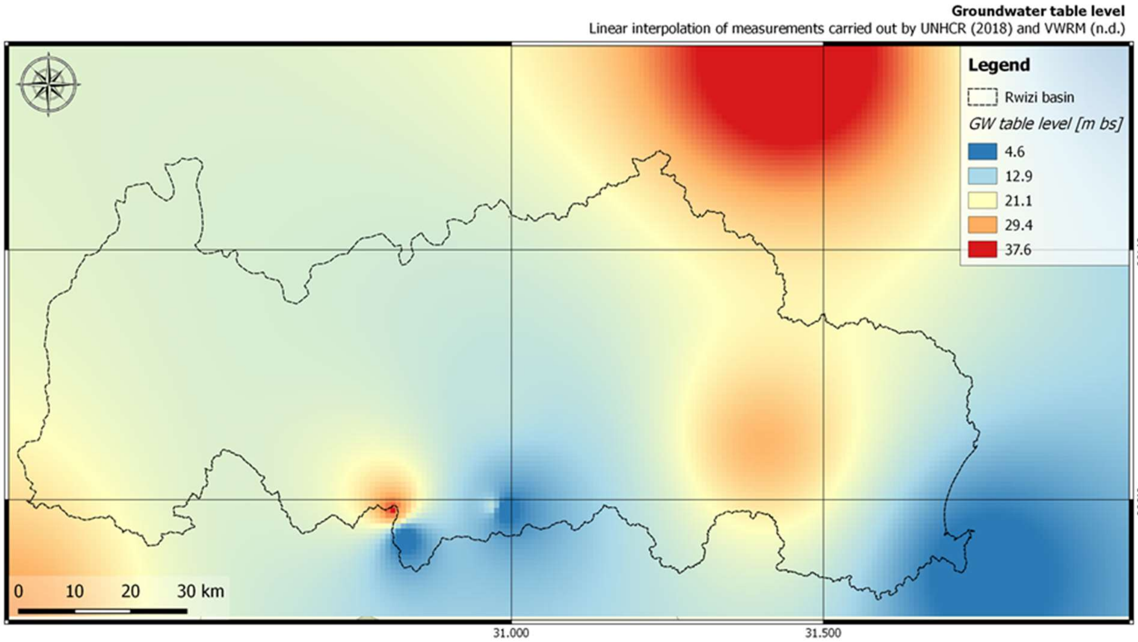


Figure 68. Groundwater table depth from linear interpolation process

Attribute 6: Range size TSS

Data on the source water quality were gather from the National Water Resource Assessment by (Ministry of Water and Environment (MWE), 2013). The report provides information on the max and min values of different water quality parameters over a year. The only parameter value available for all three investigated locations was the max and minimum concentration of the total suspended solid (TSS). Variation of the TSS effects the aluminum dosage in the coagulation and flocculation process.

The selected proxy attribute was the width of the TSS range in each location, expressed by the equation:

$$range\ width_{TSS} = Max_{TSS} - Min_{TSS}\ [\frac{mg}{liter}]$$

Location	Name water source	District	TSS (mg/l)			
			mean	max	min	Range width
A	River Rwizi	Mbarara	71.3	125	24	101
B	Lake Nakivali	Isingiro	74.44	145	26	119
C	Lake Kijanebalola	Rakai	76.9	4	195	191

Attribute 7: Iron concentration

To assess raw groundwater quality, the total iron concentration [mg/liter] was selected as attribute. High total iron concentration has been observed in many water production points from shallow aquifer. This is one of the main reason of their abandonment if no treatment is applied. The spatial concentration of Iron in the aquifer was provided by Arup, 2014 and it is shown in Figure 69.

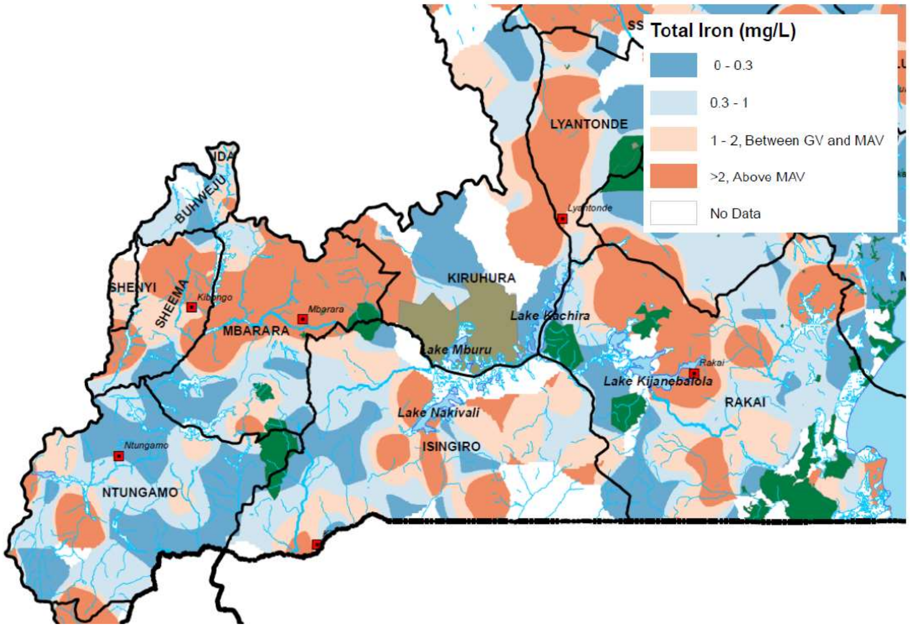


Figure 69. Map of the total iron concentration in South-western Uganda (Arup, 2014)

Attribute 8: Topographic distance to town

Water supplied from rainwater harvesting technique should be mainly used for cooking and washing if no water treatment is applied. However, common is the use of this water for drinking purpose in the visited refugee settlements. Many are the proxy attributes that could be used to assess the direct exposure of people to polluted harvested rainwater. For the sake of simplicity, only the *minimum topographic distance to towns* was used in this application. The input data (shapefile location of main towns) was gather from UBOS, 2016.

Attribute 9: Number of children affected by Malaria

Malaria risk in Uganda is well documented. This indicator was, hence, used for estimating the risk of water-borne diseases. Data concerning the number of children affected by Malaria at regional level were taken from (Uganda Bureau of Statistics, 2016).

Table 56. Number of children affected by malaria

Districts in Rwizi basin	% of Districts within the Rwizi basin	Region	% children affected by Malaria (RDT [4] test)	Number of children
Buhweju	35%	Ankole	11.3	361
Sheema	80%	Ankole	11.3	361
Buhenyi	11%	Ankole	11.3	361
Mbarara	71%	Ankole	11.3	361
Ntungamo	9%	Ankole	11.3	361
Isingiro	46%	Ankole	11.3	361
Kiruhura	30%	Ankole	11.3	361
Lyantonde	25%	South Central	16.1	575
Lwengo	48%	South Central	16.1	575

[4] RDT= Rapid Diagnostic Test SD Bioline

Rakai	63%	South Central	16.1	575

High reliability of raw water quantity

Attribute 10: Sustainable yield of water

The sustainable yield was computed as the ratio of the total water demand in the catchment to the sum of the 30% of the GW recharge and the runoff Equation 4. The latter were estimated applying the water balance model for each cell in which the watershed was divided (see Appendix 0). The water demand was instead computed both for refugees and host community (see Appendix H) considering a projection of the water consumption over the next 15 years. Specific components of the water demand value used in the attribute computation are shown in Table 57.

$$Sust_{Yield} = \frac{Tot\ water\ demand}{Catchment\ yield + 0.30 * Recharge_{GW}}$$

Equation 4

Table 57. Water Demand parameters considered in the estimation of the sustainable yield

Users		Water demand
Host community	*Current*	Agriculture
		Livestock
		Industrial
		Aquaculture
	Projected	Domestic (projected population over 15 years)
		Water gap (government target – current water demand)
Refugees	*Proj.*	Domestic
		Agriculture
		Livestock

Attribute 11: High reliability of surface water source

The volume of shortage from surface water was computed comparing the daily water extraction with the available volume of water in the water body (Equation 5). The latter was retrieved as daily time series of discharge (for the river) and water level (for the lake) from gauge stations. Concerning the river, the gauge station is located after the current water extraction points. Therefore, considering the total water demand in the computation of the reliability will led to double counting as the current water demand is already met (with the term "water demand" we refer to the ratio of water currently used on total population). Therefore, the future daily water extraction was computed considering the projected water demand both of host community and refugees and, the water gap (difference between the current water demand of the host community and the target of 20 l/person/day set by the government). In the computation of the water available from the lake, the approximation of rectangular reservoir was adopted. The volume was, hence, computed as the product of the monthly average water level of the lake and the surface (constant value).

$$\text{Volume of shortage} \begin{cases} 0 & \text{If } (we)_{SW} < avb_{SW} \\ (we)_{SW} - avb_{SW} & \text{If } (we)_{SW} > avb_{SW} \end{cases}$$

Equation 5

Where:

we_{SW} :future daily water extraction from surface water [m3/day];

avb_{SW} :available volume of water in the analyzed water body (river discharge (m3/day) or lake storage(m3));

Providing to the decision makers only the information of water shortage can be misleading. Therefore, to facilitate the preference elicitation, the volume of shortage was divided by the amount of future water extraction (Equation 6).

$$Shortage_{SW} = \frac{Volume\ of\ shortage_{SW}}{water\ extraction\ from\ SW}$$

Equation 6

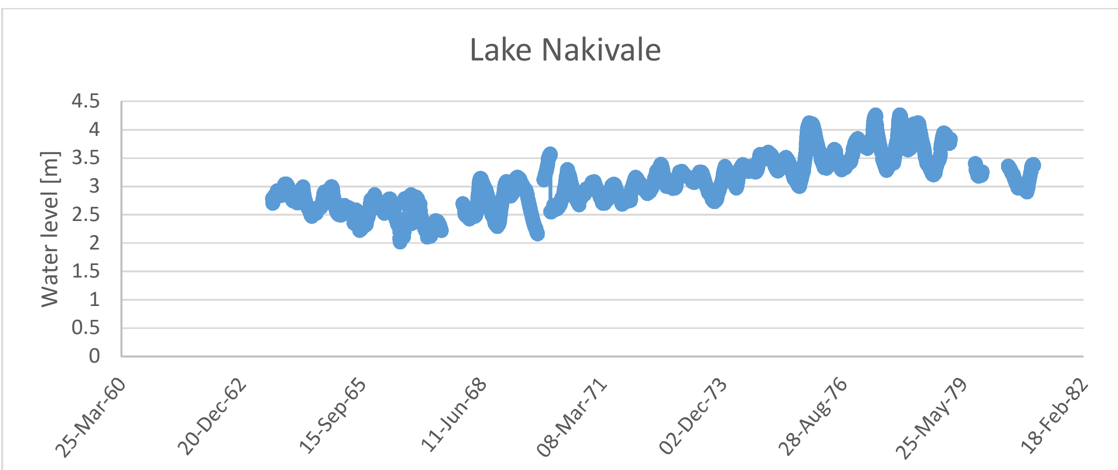


Figure 70. Daily time series of water level of lake Nakivale over 20 years (Sept 1963 - Oct 1979)

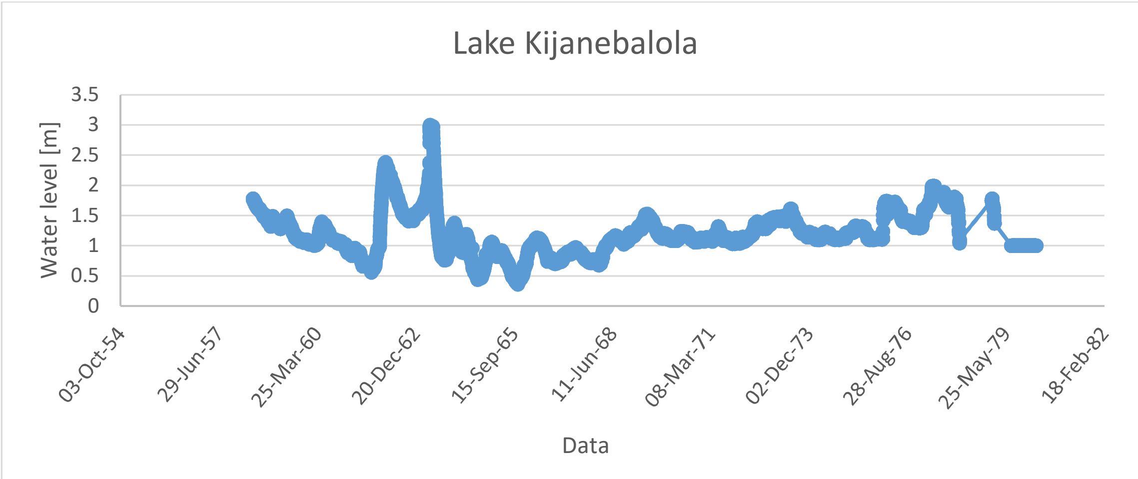


Figure 71. Daily time series of water level of lake Kijanebalola over 20 years (Jan 1958 - March 1980)

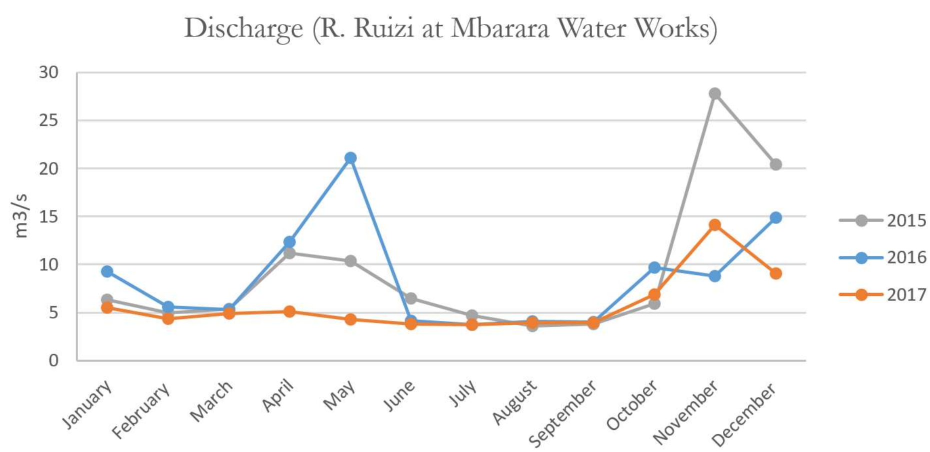


Figure 72. monthly average discharge value of Rwizi river elaborated from daily discharge time series

Table 58. Surface area of the lakes Nakivali and Kijanebalola

Lake	Area GIS [km2]
Nakivali	26.7
Kijanebalola	38.33

Attribute 12: High reliability of rainwater source

Same equation of attribute 13 was applied to RW source (Equation 7). The water volume collected from rainwater harvesting system was assessed considering a roof area equal to the 40% of the refugee camp size. This percentage was selected estimating the number of institutions and offices from which water could be collected. The volume of shortage was estimated comparing daily precipitation data with the amount of supplied water that rely on the RW harvesting system. In computing the shortage for the day *n+1* we are not considering possible storage from the rainwater collection occurred in day *n*. This could be corrected by introducing storage measures and computing the shortage at monthly scale.

$$Shortage_{RW} = \frac{Volume\ of\ shortage_{RW}}{water\ collecetd\ from\ RW\ harvesting\ system}$$

Equation 7

High acceptance and integration of refugees in the host community

Attribute 13: NDVI

Time series of MODIS NDVI data can be used to quantify vegetation coverage. A strong correlation between NDVI and vegetation coverage has been established comparing the NDVI map with the land use map.

NDVI values in satellite image are scaled between 0 and 1, representing bare soil (0) and 100% cover (1). The NDVI was retrieved as NetCDF file ("*MOD13A1 MODIS/Terra Vegetation Indices 16-Day L3 Global 500m SIN Grid V006* [Data set]. NASA EOSDIS LP DAAC. doi: 10.5067/MODIS/MOD13A1.006"). This was downloaded from AppEEARS (website: https://lpdaacsvc.cr.usgs.gov/appeears/task/area). The data was extracted only for the location in analysis by inserting a polygon vector file of the catchment. The final subset comprehends data from October 2013 to October 2018 for NDVI product with a pixel resolution of 250 x 250 m using the global coordinate system WGS84. Among them the most recent data were selected for the analysis.

The programming algorithm extracts spatial coordinates of the buffer area and use them to mask the NDVI dataset, in order to compute the average of NDVI values only over the location in analysis.

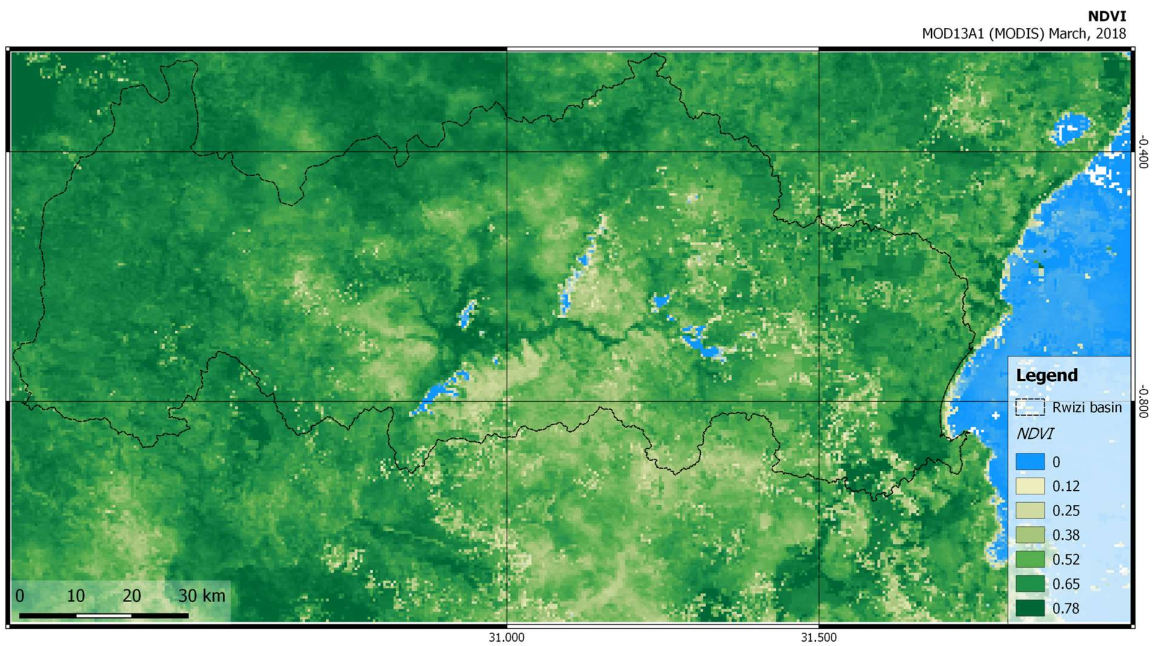


Figure 73. NDVI map for Rwizi catchment retrieved from MOD13A1

Attribute 14: Topographic distance to protected areas

A shapefile layer with the ESA areas for the south-west of Uganda was gathered from VWRM. The distance to ESA areas is computed by the programming algorithm in the sub-module Acceptance. The algorithm assess the distance between the point shapefile (investigated location) to the closest ESA area.

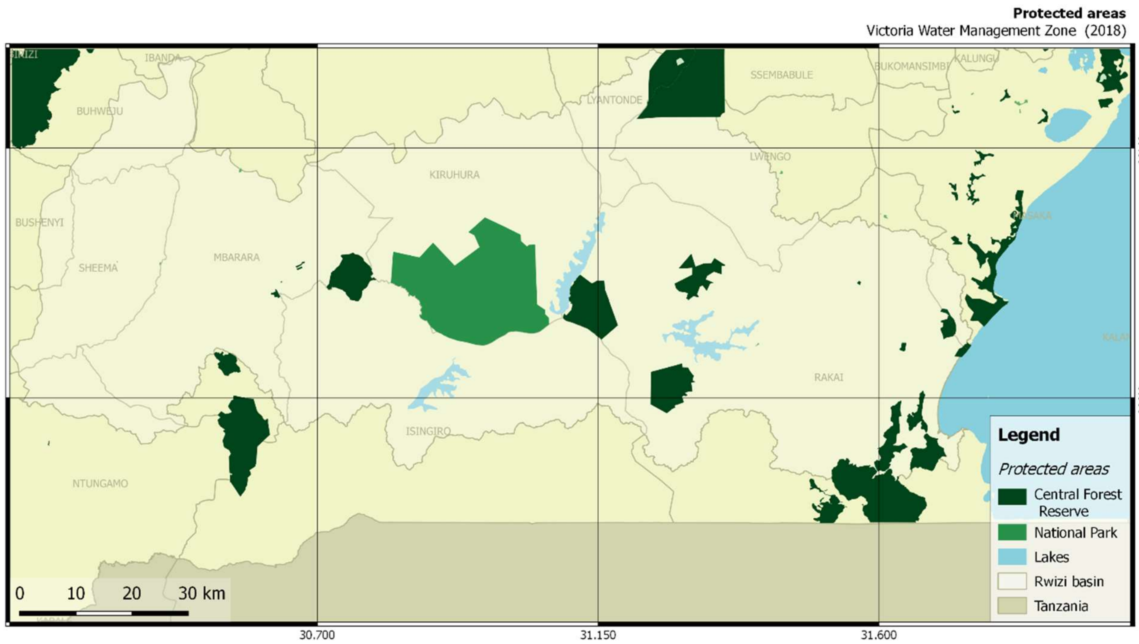


Figure 74. Protected areas in catchment Rwizi (VWMZ)

Attribute 15: Reciprocal of access to safe water

Uganda - Water Atlas website (http://wateruganda.com/index.php/reports/district/79) provides the percentage of access to safe water per each sub-county (Figure 75 and, Figure 76) with the exception of the once supplied by the National Water and Sewerage Cooperative (NWSC). In order to fill these gaps and increase the detail of the analysis, field data were used. The water supply for domestic purpose in Mbarara district was provided by the NWSC, while the population distribution per district by Ministry of Water and Environment (MWE), 2013 (Table 59). Access to safe water in existing refugee camps is instead not assessed by the government. National statistic usually does not include in the assessment refugee camps. Therefore, to include Nakivale refugee settlement in the study, field data were integrated (Table 60). The ratio of the total water extracted to the expected water demand (computed multiply the current population to 20 l/person/day) gave us an estimation of the access to safe water in the settlement. Final results are shown in Figure 77.

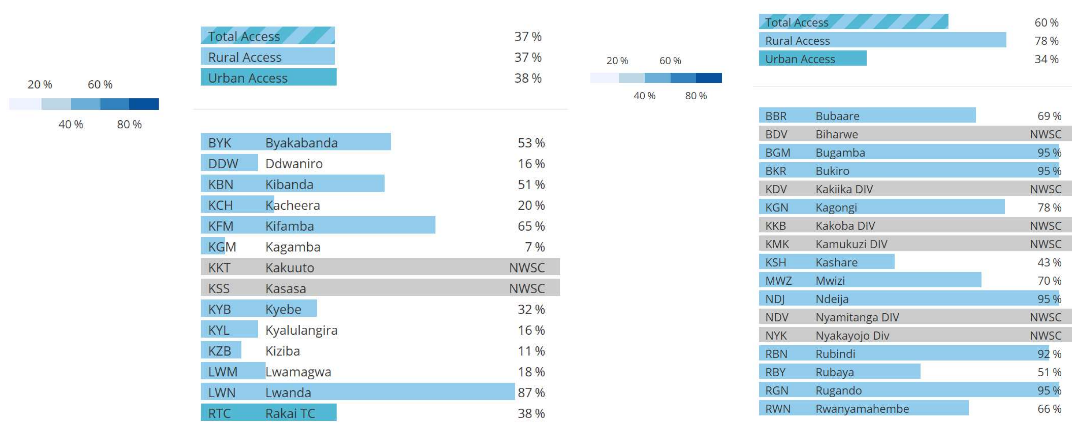


Figure 75. Access to safe water respectively in Rakai and Mbarara districts

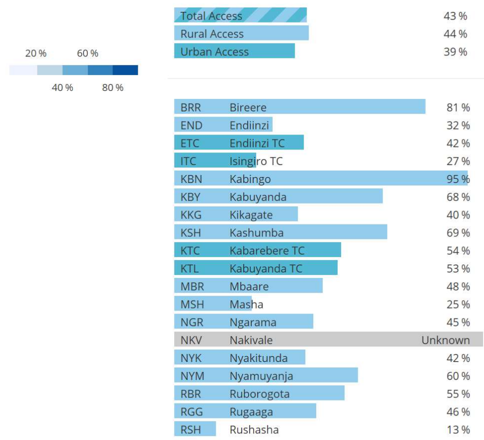


Figure 76. Access to safe water in Isingiro district

Table 59. Computation of safe water access in Mbarara town

Population 2014	195016	
Water demand	30	[l/p/day]
Tot water demand	5850480.00	[l/day]
Domestic water sold	5540556.48	[l/day]
Percentage coverage	95%	

Table 60. Computation of safe water access in Nakivale Settlement

Population 2018[5]	86211	
Water demand (UNHCR standard)	20	l/person/day
Tot water demand	1724220	l/day
Water distributed	1460000	l/day
% safe water access	85%	

[5] Refugee population can strongly vary over the life-time of a refugee settlement. The used population value was assessed by Nsamizi (UNHCR WASH implementing partner). However, higher is the estimation provided in June by UNHCR (90872 refugees).

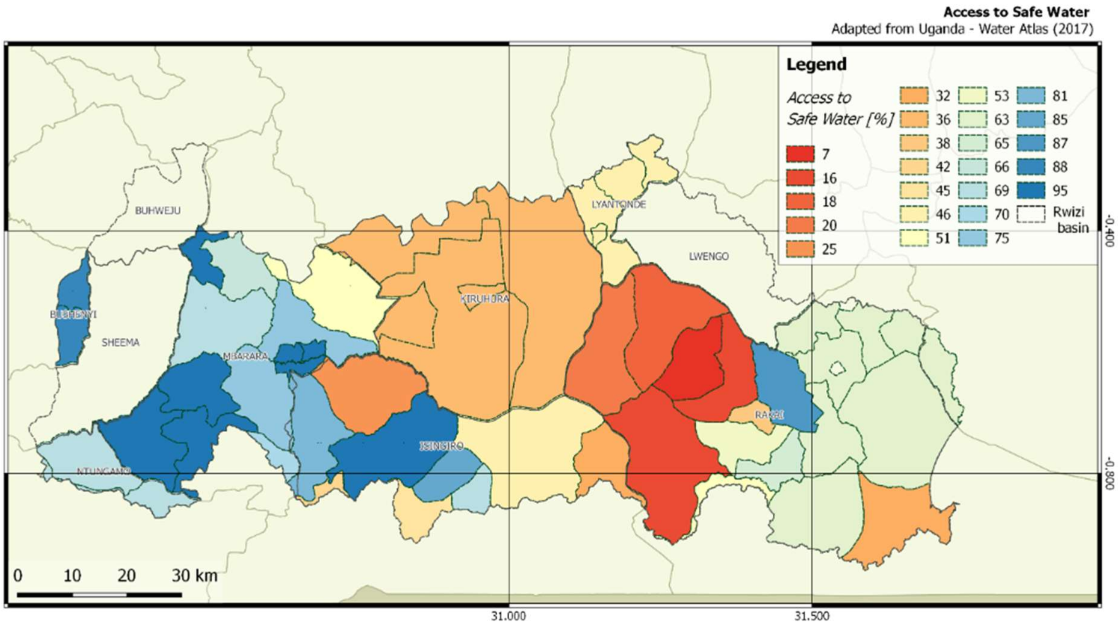


Figure 77. Map of access to safe water in Rwizi catchment

Low cost

In the application, no information concerning the planning phase and preference of stakeholders on them are known. Therefore, the objective low cost was estimated according to the cost items that most affect the cost after carrying out a cost analysis of different water supply system in Uganda.

Attribute 16 and 17: Minimize cost of the water supply from groundwater and surface water

The investment cost of the water supply system was assessed differently based on the used water source. When groundwater source is used, the investment cost of the water supply system includes the cost for extraction, treatment, transmission and distribution (Equation 8). The latter referrers to the cost of reservoirs and pipe network to transport the water at the taps. When surface water source is used, the investment cost includes the cost for extraction, treatment, transmission and distribution (Equation 9). The transmission line transports water from the DWTP to the reservoir located in the supplied village. This cost could negatively affect the economic sustainability of the water supply system if the water body is located far from the supplied villages.

$$Inv\ Cost_{GW} = Cost_{installation\ GW} + Cost_{distribution}$$

Equation 8

$$Inv\ Cost_{SW} = Cost_{installation\ SW} + Cost_{distribution} + Cost_{trasmission}$$

Equation 9

- **Installation cost for groundwater sourcing**

In the estimation of extraction and treatment costs from groundwater source, various bill of quantities (BOQ) of recent water supply systems in Uganda were analyzed with the aim of identifying the items that most affect the overall cost.

This approach was adopted because there is no detailed information or preferences on the planning of the future refugee settlement to be able to compute in detail each item cost. All the analyzed BOQ refers to solar power supply system. In Uganda, the more recent power supply systems are, indeed, solar or hybrid. Given the low number of generators recently used in refugee camps, it was not possible to identify a relation between the hydraulic power and generator costs.

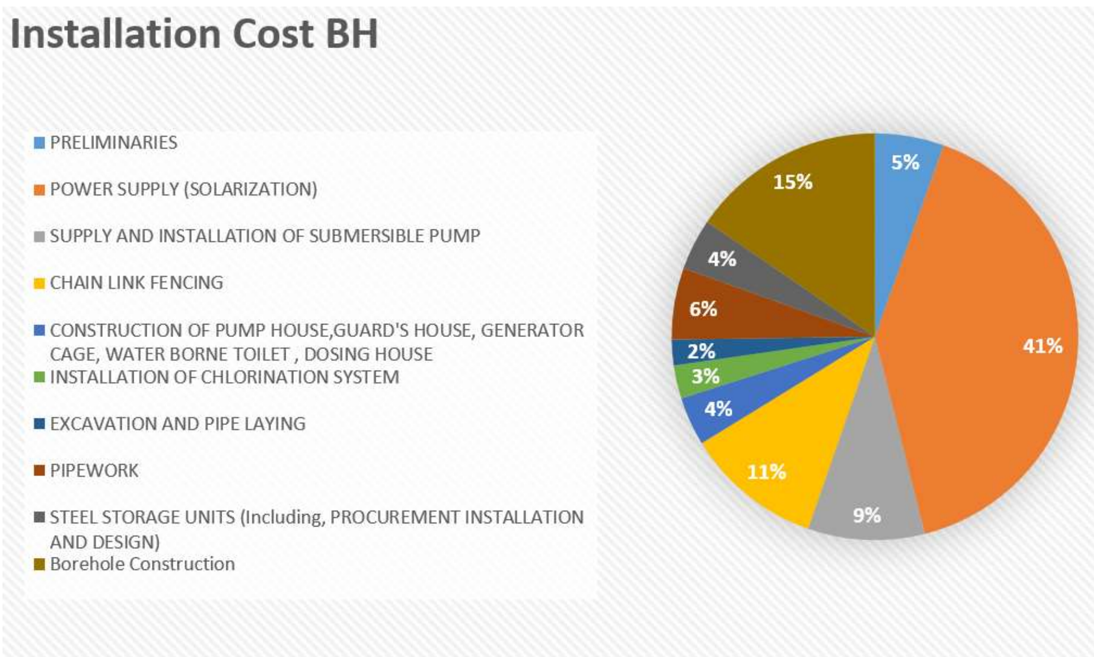


Figure 78. Analysis of borehole installation cost items

The results of the cost analysis are shown in Figure 78. The cost of the power supply system is far higher than the other costs. The second highest cost is the borehole construction. According to the result, the installation cost for borehole was, hence, computed as sum of the power supply system cost and the borehole construction (Equation 10).

$$Cost_{installation\ GW} = Cost_{PS} + Cost_{BH}$$

Equation 10

Where:

$Cost_{PS}$ = cost of the power supply system;

$Cost_{BH}$ = cost of the borehole construction;

The cost of the power supply system depends by the total head [m] (level of the reservoir – static groundwater table) and the yield [m3/day]. A set of data concerning the cost of the pump was provided by W.Water Works which is one of the main suppliers of pumping systems for water projects in Ugandan refugee camps (Table 61). The regression method was applied to identify the relation among total head, yield and pump cost. If the level of the reservoir is known, this relation could be used for the cost estimation (Table 62).

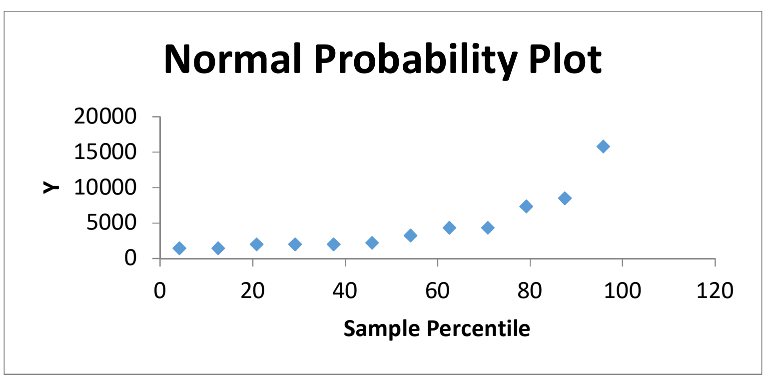
Table 61. Item costs of the solar power supply system for different projects in Uganda (W.Water Works, 2017)

Total Head [m]	*Abstraction rate [m3/day]*	*Abstraction rate [m3/h]*	*Cost Solar PV/WP Grid [euro]*	*PV /WP (watt (peak)) GRID*	*Cost Pump [euro]*	*Hydropower pump power [kW]*
209	540	45	46376	58000	15795	VSP 46-24, 37KW motor
120	72	3	7665.54	10540	4360	VSP 8-37,5.5KW
148	180	7.5	21649.1	32760	8515	VSP 30-21,18.5KW
102	60	2.5	7185.5	9880	4360	VSP 8-37, 5.5KW
136	40	1.67	7665.4	10540	7350	VSP 17-27, 15 KW
171	42	1.75	9572.7	14040	3265	VSP 5-44,4 KW
80	28	1.167	1818.18	2500	1479.54	4HS 05/08 Multipower
65	28	1.167	1454.54	2000	1480	4 HS 05/08 Multipower
105	12	0.5	2000	2750	2215	VSP 2-33,1.5KW
22	28	1.167	727.27	1000	2000	4HS 08/05 Multipower
55	28	1.167	1454.5	2000	2000	4 HS 08/05 Multipower
57	28	1.167	1455	2000	2000	4 HS 08/05 Multipower

Table 62. Regression analysis for total head, yield and pump cost (in the normal probability plot the y is the predicted value)

	Coefficients
Intercept	244.39
X Variable 1	23.32
X Variable 2	20.51

Regression Statistics	
Multiple R	0.95
R Square	0.91
Adjusted R Square	0.89
Standard Error	1411.66
Observations	12



In the application in analysis, no information on the location of the reservoir and its capacity were available at this decision phase. Therefore, the power supply cost were estimated through a polynomial relation of the power supply system cost and the yield. This relation was identified using data extracted from different BOQs, which are reported in Table 63. The polynomial relation was identified plotting the cost of different power supply systems against the capacity (Figure 79).

Table 63. Items' costs of the power supply system extracted from different BOQ related to water scheme is BidiBidi refugee settlement. The item cost underlined in yellow was used for identify a polynomial relation with the yield.

	AMOUNT (UGX)					
YIELDS	*3 to 5m3/h*	*5 to 8m3/h*	*8 to 10m3/h*	*10 to 15m3/h*	*15 to 20m3/h*	*25 m3/h*
PRELIMINARIES	19500000	19500000	19500000	19500000	19500000	19500000
POWER SUPPLY (SOLARIZATION)	71435200	72713200	110249400	110249400	178905800	319564200
SUPPLY AND INSTALLATION OF SUBMERSIBLE PUMP	13114000	16367000	23610000	23079000	47239000	74196800
CHAIN LINK FENCING	12758400	20613600	27563600	37353600	52041600	81488600
CONSTRUCTION OF PUMP HOUSE,GUARD'S HOUSE, GENERATOR CAGE, WATER BORNE TOILET , DOSING HOUSE	10863800	10863800	10863800	10863800	10863800	28089965.71
INSTALLATION OF CHLORINATION SYSTEM	14360000	6860000	6860000	6860000	6860000	14360000
EXCAVATION AND PIPE LAYING	2595500	2595500	2595500	2595500	2595500	30416070.4
PIPEWORK	5013000	5006700	5013000	5014000	5019000	96140000

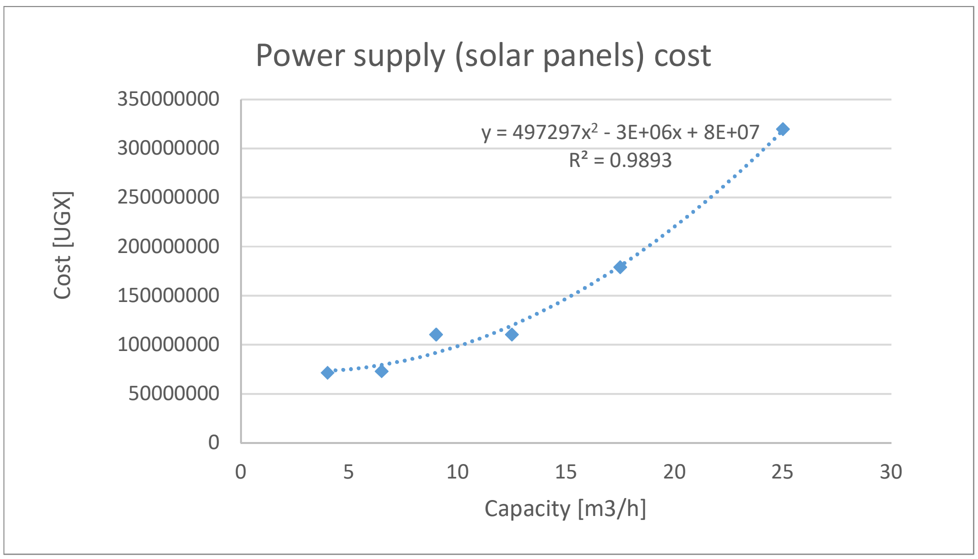


Figure 79. Polynomial relation between the capacity and the power supply cost (using solar panels)

For the estimation of the borehole construction cost, the costs incurred during the borehole campaign carried out in Nakivale by UNHCR were used (Table 64). A polynomial relation between the static water depth and the borehole construction cost was identified (Figure 80).

Table 64. Borehole construction costs in the borehole campaign carried out in Nakivale refugee settlement in August 2008

Name	***Drilling Depth [m]***	***Static Water Depth [m bgl]***	***Cost [UGX]***	***INFO***
Bururuma n.69415	123	-0.35	60390000	Preliminaries and General, Hydrogeological and Geophysical Surveys, Bprehole construction
Kyakashana 2 n.69423	125.4	2	59012000	
Kityaza n.69424	151	15.2	64765000	
Kyakasana 1 n.69422	91.7	0.56	49275000	
Isingiro HQ 69425	131.5	23.3	56615000	

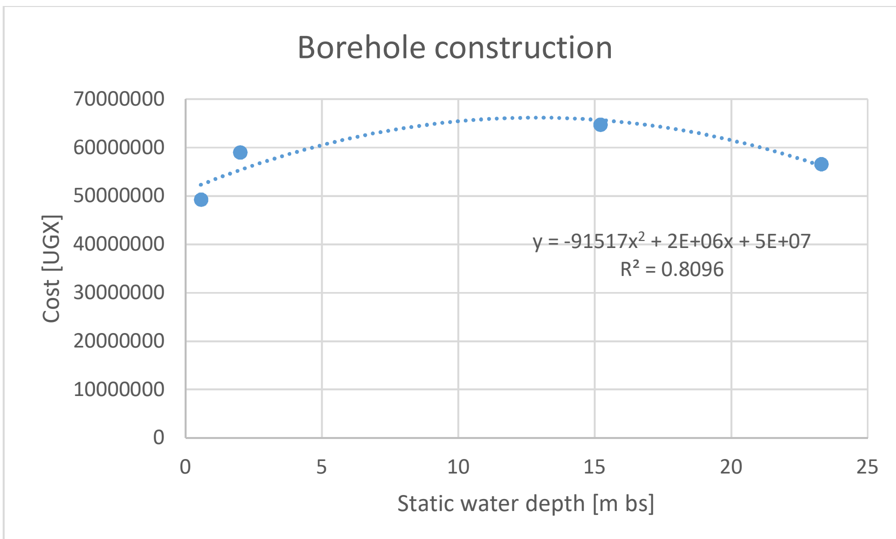


Figure 80. Polynomial correlation between the static water depth and the borehole construction cost

Total investment cost was estimated by the sum of power supply system cost and borehole construction cost. This results in including capacity and the GW static water depth parameters in the assessment. Both are variables of the decision model. The former depends on number of newly arrived refugees allocated in the investigated site and the percentage of groundwater use. The latter depends on the location investigated.

- **Installation cost for surface water sourcing**

The procedure above described was also applied for identifying the item cost that most affect the total investment cost of surface water supply systems. According to the cost analysis of different water system projects in Uganda, the drinking water treatment plant (DWTP) cost represents the 79% of the overall cost (Figure 81). According to this result, the installation cost was estimated using the cost of the DWTP in Kyaka extracted from the detailed design report (IOM, 2016) (Table 65).

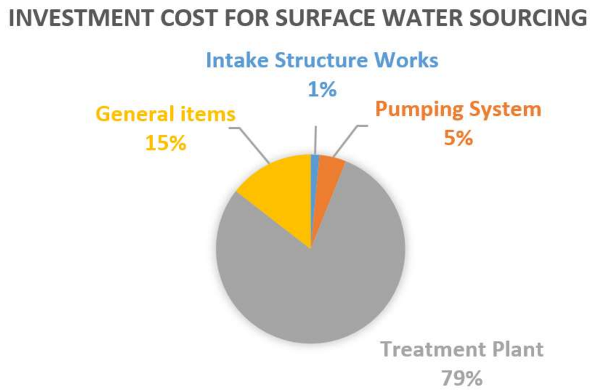


Figure 81. Analysis of the water supply system items cost with raw water extracted from surface water source

Table 65. Capital cost of the water supply system in Kyaka (Capacity: 1450 m3/day)

Item	***Description***	***Cost [UGX]***
Intake Structure Works		36,012,096
Pumping System	Raw Water Pumping Mains, Pump House	109,977,129
Treatment Plant	Treatment plant site-works, Aerators -2No, Flocculator & Rapid Mixing Chamber, Sedimentation Tank, Rapid Gravity Filters, Clear Water Tank, Chemical House, Sludge Drying Bed and Channel, Laboratory and Workshop	1,904,783,953
General	General items, Day works, method related charges	347,904,500

The investment cost of the DWTP was evaluated through the Cost-to-Capacity method. This method is an order-of-magnitude cost estimation tool that uses historical costs and capacity in order to develop current cost estimates for an entire facility (Baumann, 2014). The estimated cost is indicated by the Association for the Advancement of Cost Engineering ("AACE") International as a preliminary estimation based on limited information. The basic concept of the method is that the investment costs of facilities of a similar technology but with different sizes, vary nonlinearly. In specific, cost is a function of size raised to an exponent or scale factor (Equation 11).

$$\frac{\$_1}{\$_2} = \left(\frac{Q_1}{Q_2}\right)^x$$

Equation 11

$\$_2$: Unknown Investment cost of Plant 2, with capacity $Q2$

$\$_1$: Known Investment cost of Plant 1, with capacity $Q1$

$Q2$: Known Capacity of Plant 2

$Q1$: Known Capacity of Plant 1

x: Scale factor for technology of Plant 2 and 1

The scale factor in Equation 11 accounts for the nonlinear relationship and introduces the concept of economies of scale where, as a facility becomes larger, the incremental cost is reduced for each additional unit of capacity (Baumann, 2014). A scale factor of less than 1 indicates that economies of scale exist and the incremental cost of the next added unit of capacity will be cheaper than the previous unit of capacity. A scale factor equal to 1 represents a linear incremental cost.

As there are few recent surface water treatment plant in refugee camps in Uganda, it was not possible to collect cost information concerning other DWTPs. Therefore in the estimation of the cost, the scale factor was considered equal to 1 (Equation 12).

$$\$_2 = \left(\frac{\$_1}{Q_1}\right) * Q_2 = 1{,}313{,}644 * Q_2$$

Equation 12

- **Transmission line cost**

In case raw surface water is extracted, the investment cost is computed also considering the cost of the transmission line. This was because usually borehole campaign are carried out inside the settlement itself and, even if boreholes will be constructed outside the settlement, we do not know yet the sites at high potential yield. In case raw surface water is used, the distance of the water body to the settlement can be key to assess the economic suitability of the water scheme. This was computed considering the distance of the water body to the boundary of the settlement (as the location of the reservoir is not yet known) and an optimal velocity (1 m/s) in the pipes for computing their diameters.

The design velocity in the pipe system should be a maximum of 1.5 m/s and a minimum of 0.6 m/s. According to this range, the value of 1 m/second was used to estimate the diameter of the pipe according to the flow (Equation 13).

$$D_{pipe} = \sqrt[2]{\frac{Area_{pipe} * 4}{\pi}}$$

Equation 13

Where:

D_{pipe}: Diameter of the pipe [m]

$Area_{pipe}$: Area pipe $\left(\frac{flow}{v}\right)$ [m²]

$flow$: outflow from the DWTP $\left(\frac{Extracted_{SW}}{86400}\right)$ [m³/s]

$Extracted_{SW}$: amount of water extracted from the surface water body [m³/d]

Applying the power relation between diameter and unit cost per meter (Figure 73), the cost of the transmission line was estimated using Equation 14.

Table 66. Installation and pipe Unit cost per meter with respect to different diameters (detailed design report of Kyaka, 2017)

Pipe characteristics	[UGX/m]
HDPE OD 40 PN6	3,518
HDPE OD 50 PN6	4,149
HDPE OD 63 PN6	6,404
HDPE OD 75 PN6	8,840
HDPE OD 90 PN6	12,718
uPVC OD 110 PN10	26,965

uPVC OD 160 PN10	37,816

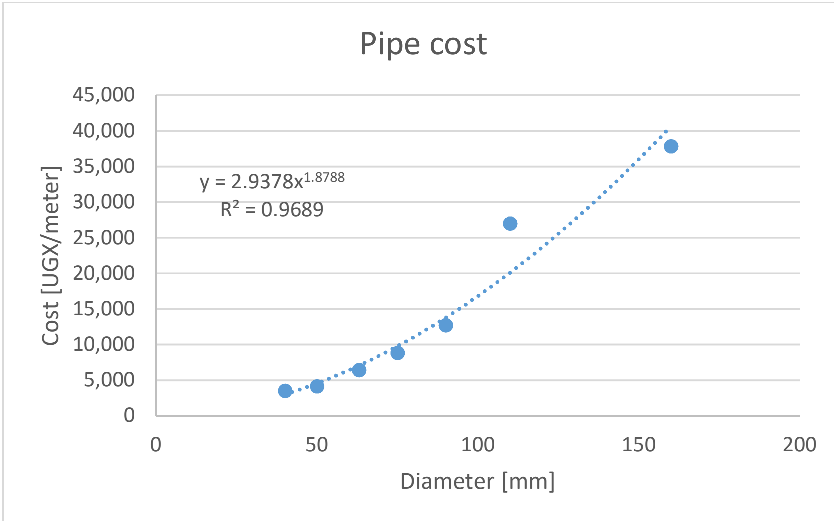


Figure 82. Power relation between diameter and installation and pipe unit cost per meter

$$Cost_{trasmission} = Cost_{meter\ of\ pipe} * d$$

Equation 14

d: minimum distance of the water body to the boundary of the potential settlement;

$Cost_{meter\ of\ pipe}$: unit cost of the pipe per meter [UGX/m]

- **Distribution cost**

The distribution cost mainly depends by the slope. If the slope is less than 2% a water tower is needed to guarantee a gravitational flow in the pipe. Contrary, a simple steel tank can be built.

In the application, the average slope in the buffer area is computed. If this was less than 2%, the linear equation in Figure 83 is used. Opposing, the equation in Figure 84 is used. Both equations were obtained by extracting cost data from various BOQ.

Table 67. Cost of pressed panel tanks and towers

Capacity [m3]	Cost [UGX]	Source
10	46787000	from BOQ Bidibidi (OCEA, Adjumani, Ofua)
20	75166000	
40	1.1E+08	
60	1.29E+08	
80	1.66E+08	
100	1.87E+08	
120	2.19E+08	
150	2.57E+08	

Table 68. Cost of pressed steel tanks

Capacity [m3]	Cost [UGX]	Source
150	131834500	Omugo
10	14794500	BH1 bidibidi

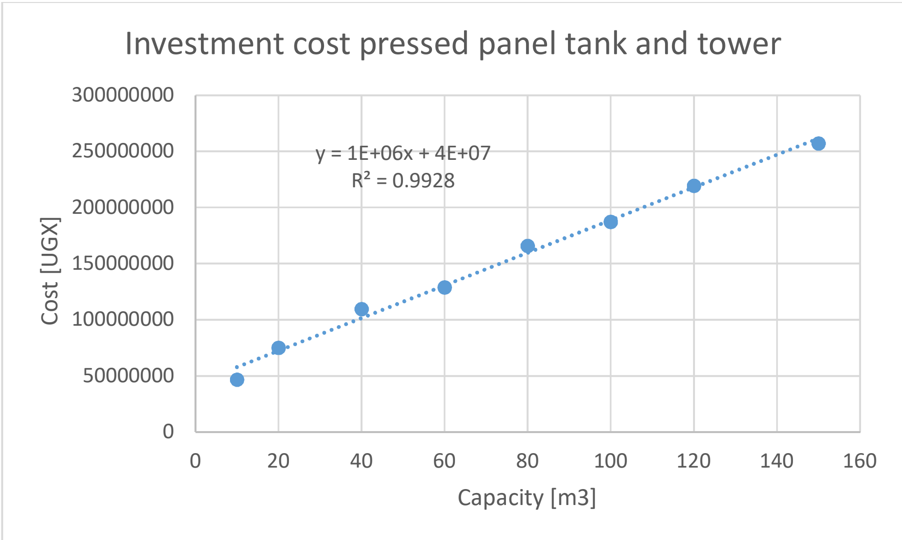


Figure 83. Pressed panel tank and tower: Cost vs Capacity with linear trend line

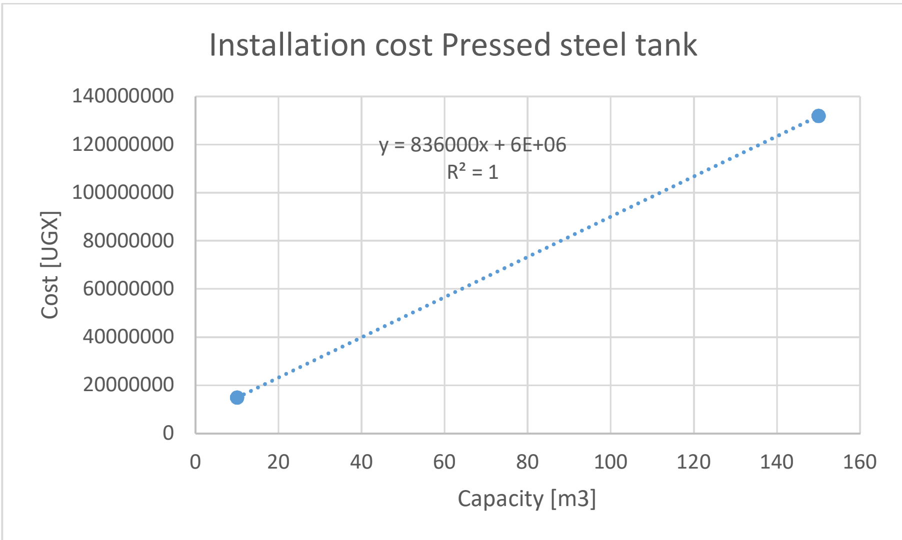


Figure 84. Pressed steel tank: Cost vs Capacity with linear trend line

Attribute 18: Minimize cost of the water supply from rainwater

Before to compute the cost of the rainwater harvesting (RWH) system is important to assess the suitability of the site for such techniques. According to (Ammar, Riksen, Ouessar, & Ritsema, 2016), indicators frequently used for assessing the potentiality of rainwater harvesting in different locations are:

- Mean annual precipitation
- Curve number
- Slope

For most RWH techniques, rainfall (distribution and rain intensity over the year), soil type (texture and saturated hydraulic conductivity), and slope are the basic criteria that determine the technical suitability of a location. Soil type and land cover are considered through the curve number. The former is important because it will, to some extent, determine water intake rates (absorption) and water storage in the soil. While the land cover considers possible interception losses and retention rates which consequently decrease the volume of runoff (Boniface, Mahoo, & Mkiramwinyi, 2015). Slope is also considered an important criterion as the rapid runoff response from steep slopes consequently results in non-availability of water, even if average rainfall remains quite high (de Winnaar, Jewitt, & Horan, 2007).

In assessing the suitability level of different sites, rankings for each criteria were adopted.

Table 69. Suitability ranking of RWH techniques according to slope

Slope min (%)	Slope max (%)	Value	Description
0.0	3.5	5	optimally suitable
3.5	8.7	4	highly suitable
8.7	17.6	3	moderate suitable
17.6	32.5	2	marginally suitable
32.5	57.7	1	marginally suitable
57.7		0	not suitable

The classification in Table 69 is suggested by (Boniface et al., 2015). According to (FAO, 2003b) slopes of 5% are suitable for ponds, slopes of 10% are suitable for percolation tanks, and slopes of 15% are suitable for check dams.

Table 70. Suitability ranking of RWH techniques according to mean annual precipitation

min [mm/year]	max [mm/year]	Value	Description
100	200	0	not suitable
200	300	1	marginally suitable
300	400	2	moderate suitable
400	600	3	highly suitable
600		4	optimally suitable

Also for the mean annual precipitation, the values suggested by (Boniface et al., 2015) were adopted (Table 70). Finally, for the curve number, Ammar, Riksen, Ouessar, & Ritsema, 2016, suggests the classification reported in Table 71

Table 71. Suitability ranking of RWH techniques according to the CN

CN min	CN max	Value	Description
80	90	8	Medium suitability
70	80	9	Very high suitability
60	70	4	Suitable
50	60	3	Low suitability
	50	1	very low suitability

With an overall score greater than 5, the location was considered suitable and the installation cost of roof harvesting system was computed according to the data provided by Nsamizi (UNHCR WASH implementing partner in Nakivale and Oruchinga refugee settlements). The overall cost highly depends by the cost of the water tank (Figure 85). As we can see from Table 72, the unit cost of the tank increase with the capacity. This is mainly because transportation cost becomes higher. The equation used in the computation is reported in Figure 86.

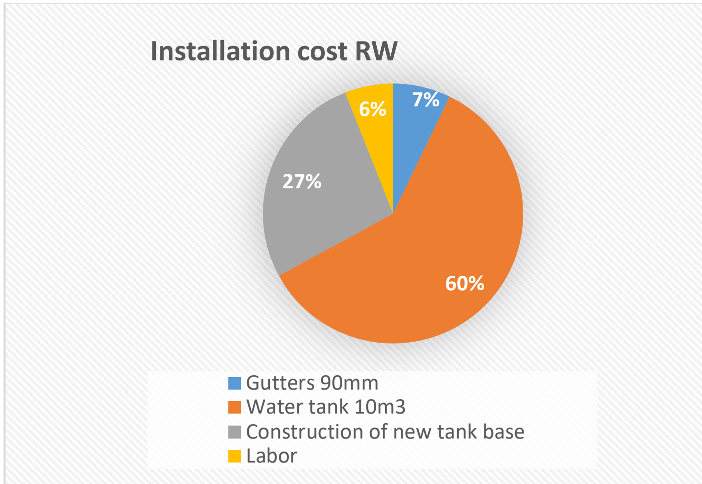


Figure 85. Analysis of the costs' items for roof RW harvesting system

Table 72. BOQ for roof rainwater harvesting system

ITEMS	UNIT	UNIT PRICE
Gutters 90mm	M	6,000
Water tank 5m^3	Pc	1,500,000
Water tank 10m^3	Pc	4,000,000
Construction of new tank base	Pc	1,800,000
Labor	-	400,000

Table 73. Costs of roof rainwater harvesting systems

Capacity [m3]	Cost [UGX]
5	3,706,000
10	6,206,000

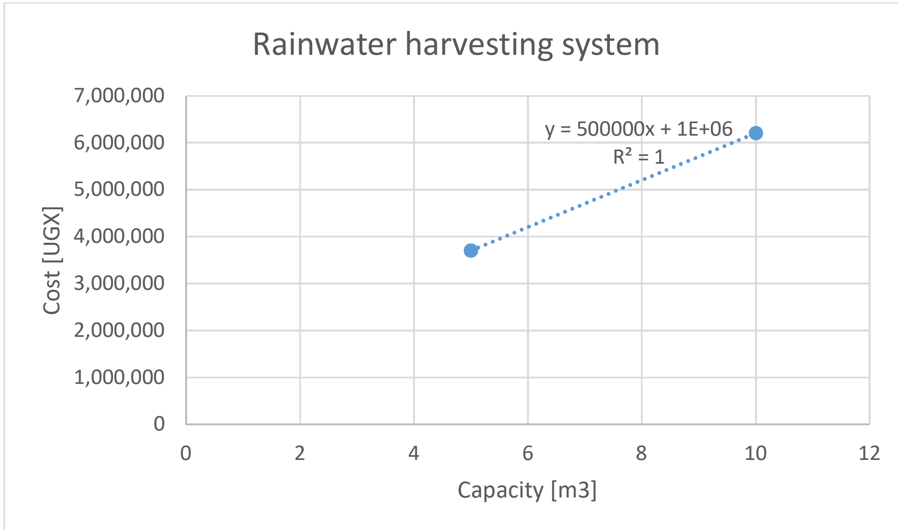


Figure 86. Roof rainwater harvesting system: Cost vs Capacity with linear trend line

Attribute 19: Minimize water trucking cost

For the computation of the water trucking cost, the refugees water demand and the current water gap were assessed. Their sum tell us the amount of water that need to be truck before that the water scheme is complete. Below the steps followed to compute the water trucking cost:

1. Estimate the water gap and refugee water demand;
$$Tot\ water\ to\ be\ truck = water\ gap + refugee\ water\ demand$$
2. Compute the distance to the closest water body;
3. Identify the cost per trip (Table 74) according to the distance to travel;
4. Compute the n. of trips per day as the ratio of the total water to be truck on the max truck capacity:
$$n. of\ trip = \frac{total\ water\ to\ be\ truck\ [\frac{l}{d}]}{20{,}000\ [l]}$$
5. Compute the n. of days in which the water need to be truck:
$$\text{Needed } period\ to\ complete\ the\ water\ sheme\ [days] = \begin{cases} 60 * GW\% + 100\ SW\% & If\ WD \geq 15\ \text{l/p/day} \\ 150 * GW\% + 250\ SW\% & If\ WD < 15\ \text{l/p/day} \end{cases}$$

   Where: *GW%* and *SW%* are respectively the percentage of water extracted from groundwater and surface water over the all water demand. The estimation of the n. days needed to complete the water scheme in case of groundwater source or surface water source was provided by UNHCR-Kampala.

Table 74. Water trucking: Cost per trip according to the travelled km (UNHCR-Kampala, 2018)

Capacity of water truck (Litres)	**Cost per trip (Uganda Shillings)**									
	0 -5 km	**5-10 km**	**10-15 km**	**15-20 km**	**20-25 km**	**25-30 km**	**30-35km**	**35-40 km**	**40-45km**	**45 -50km**
10,000	163666.7	178571.4	224285.7	226428.6	262142.9	265714.3	310000	315833.3	340833.3	341666.7

20,000	267250	281500	314750	318125	339125	343875	359125	367250	387500	387500

Capacity of water truck (Litres)	Cost per trip (Uganda Shillings)									
	50-55 km	55-60 km	60 - 65 km	65 - 70 km	70- 75 km	75-80 km	80 -85 km	85-90 km	90-95 km	95-100 Km
10,000	363333.3	365833.3	435000	435000	467500	467500	497500	500000	530000	542500
20,000	400625	400625	412500	415000	426875	426875	438750	440000	452500	460000

Attribute 20: Minimize operational and maintenance cost of groundwater supply

Analyzing various operational and maintenance (O&M) cost reports of water schemes in refugee camps in Uganda, the maintenance of the solar power supply system cost plays the major role in the overall cost (Figure 87).

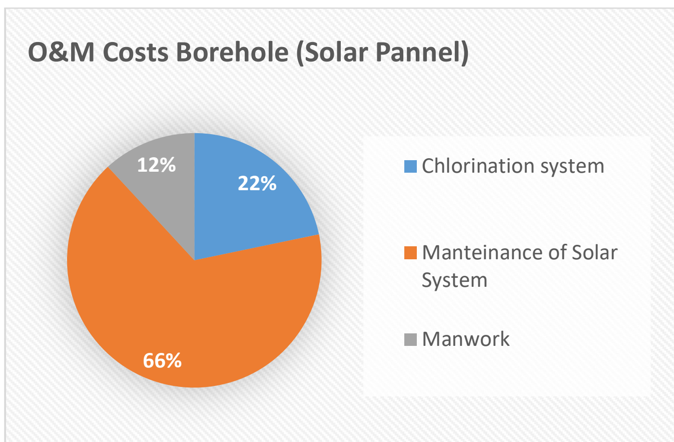


Figure 87. O&M costs analysis for water scheme based on GW extraction

Table 75. O&M costs of the solar panels systems in different boreholes located in Yumbe (UNHCR, 2018)

Manteinance solar panels system

Name	*Extraction [m3/day]*	*Power rating of the pump [kW]*	*Cost [UGX/year]*	*Detail cost*
Yumbe - Zone 3	56	7.5	2400000	Cleaning Panels
Yumbe - Reception- BH1	58	7.5	2400000	Cleaning Panels
Yumbe - Reception- BH2	36	5.5	2400000	Cleaning Panels
Yumbe - Reception- BH3	18	1.4	600000	Cleaning Panels
Yumbe - Lyete system	65	7.5	2400000	Cleaning Panels

Using the O&M cost of the power supply system in Yumbe district (Table 75), it was possible to identify a polynomial relation between the cost and the extraction rate (extraction rate per day in which only the solar power supply system is used. For example: the second hybrid system use the solar panels for 8 hours and for 3 hours the generator. The total extraction rate per day is 80 m3/day. Therefore, 58 m3/day are extracted from the solar panels system and the rest from the generator).

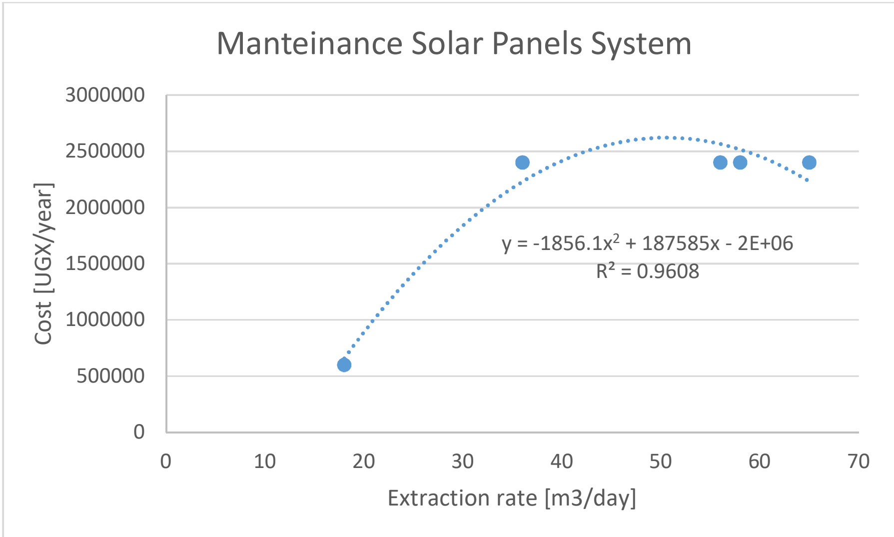


Figure 88. O&M costs of solar power system: Cost vs Extraction rate with polynomial trend line

In the estimation of the future O&M cost, it was considered a maximum extraction rate equal to 70 m3/day. This is because the relation identified in is valid only in the rage between 20 and 70 m3/day. In the application, the costs were computed according to the present value. The PV is the subtraction between the present values of cash outflows from the present values of cash inflows over a period of time (Costs & Worth, 2011).

The usual life span of water infrastructure is at least 15 to 20 years if designed to minimum standards (van der Helm, Bhai, Coloni, Koning, & de Bakker, 2017). Therefore, regardless of whether the camp is needed for refugee accommodation or not in the long-term, the infrastructure remains as a legacy for the benefit of local communities. In the computation a value of 15 years was used.

The equation related to equal cash outflows over the selected time period, is shown below.

$$PV = R * \frac{1-(1+i)^{-n}}{i}$$

Equation 15

R = net cash outflow expected to be paid in each period

i = discount rate

n = number of years during which the project is expected to operate

Attribute 21: Minimize operational and maintenance cost of surface water supply

Analyzing the O&M costs estimated by (IOM, 2016) for the new water scheme in Kyaka, we can see that the pumping cost prevails on the other items' costs (Figure 89).

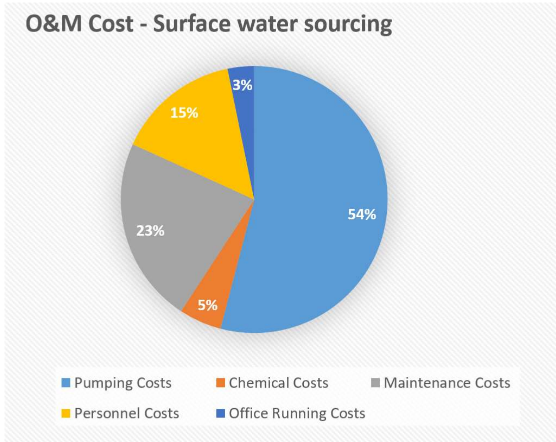


Figure 89. O&M cost analysis for Kyaka water scheme

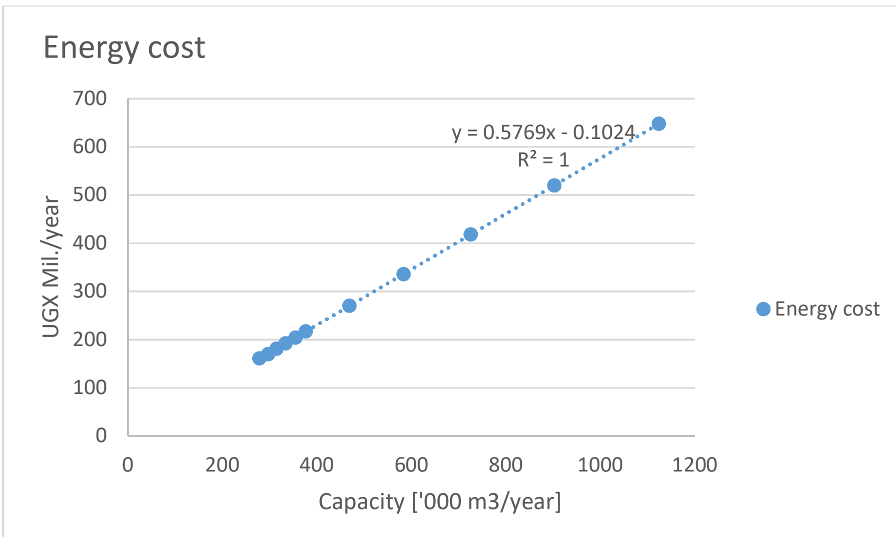


Figure 90. O&M cost of the energy system: Capacity vs Cost with linear trend line

According to the estimation of the energy cost for the Kyaka system, a linear relation between the capacity and the cost was identified Figure 90. Also in this case the present value was computed for a life time of the power supply system of 15 years.

Attribute 22: Slope to reduce soil failure

According to (UNHCR, 2007), ideally, a site should have a slope of 2%–4% for good drainage to protect building infrastructure, and not more than 10% to avoid erosion and the need for expensive earth-moving for roads and building construction. Sites on slopes steeper than 10% gradient are difficult to use and usually require complex and costly site preparations. The slope map previously created (see Attribute 1) was used to compute the average slope in the buffer area.

Attribute 23: Percentage of peat and Luvisoil to reduce soil failure

Problem of soil failure are mainly caused by the presence of organic matter in the soil or silt soils. These have frequently low strengths and minimal bearing capacity. In order to reduce soil failure and hence, minimize cost (e.g. sludge management cost), the percentage of peat and luvisoil has to be low. The soil map downloaded from the harmonized World soil database of FAO (http://www.fao.org/soils-portal/soil-survey/soil-maps-and-databases/harmonized-world-soil-database-v12/en/), was used to assess the percentage of peat and luvisoil in the buffer area.

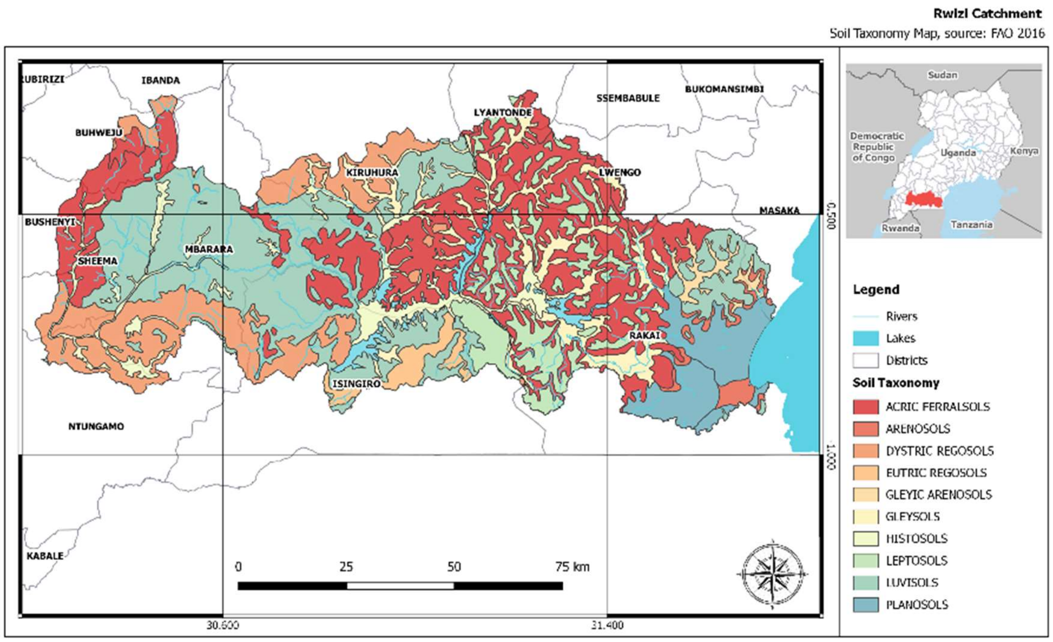
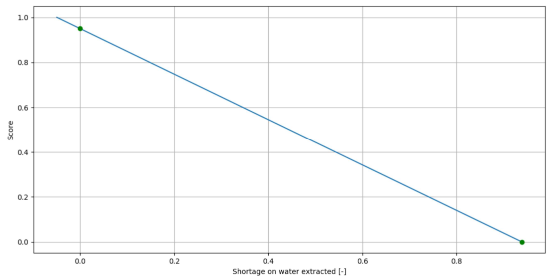
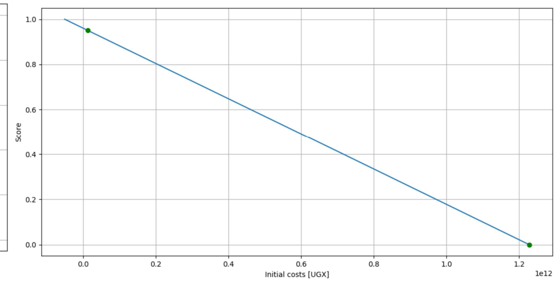
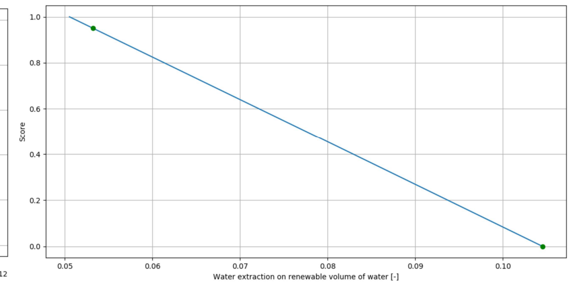


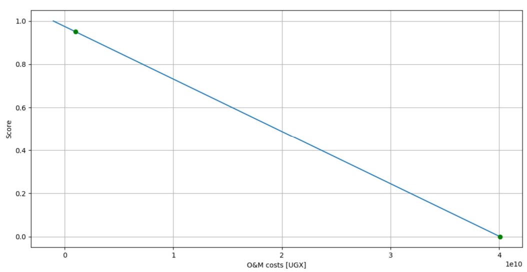
Figure 91. Soil Map for Rwizi Catchment

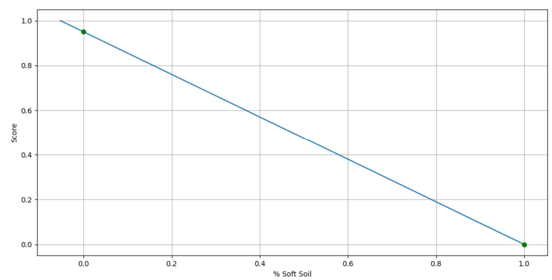
K. Value Functions

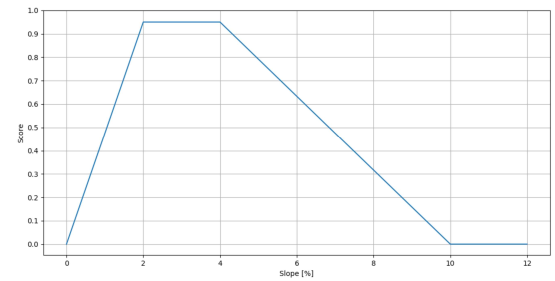


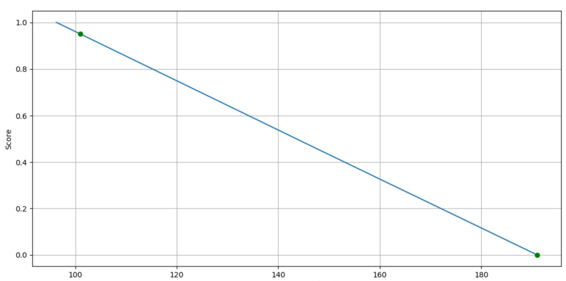


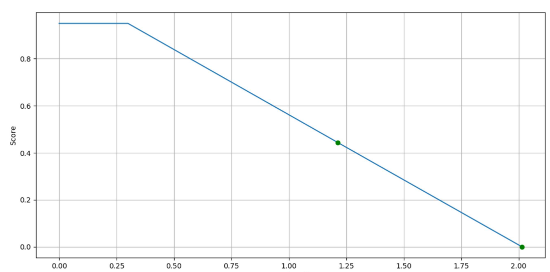


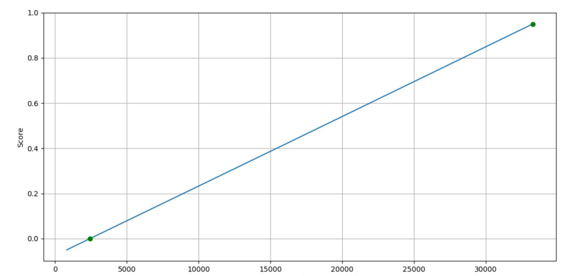


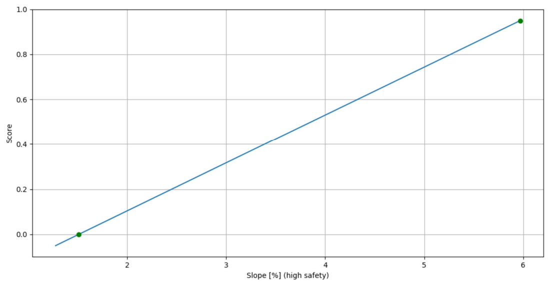


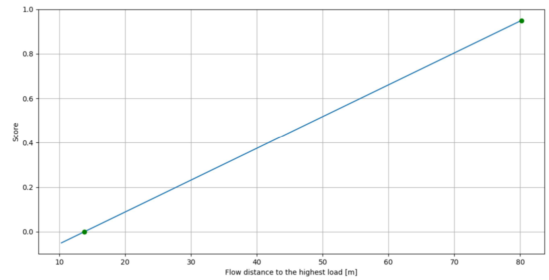









Score
1.0
0.8
0.6
0.4
0.2
0.0
2
3
4
5
6
Slope [%] (high safety)


Score
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10
20
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50
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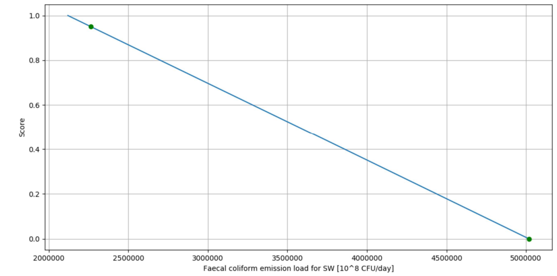
70
80
Flow distance to the highest load [m]


Score
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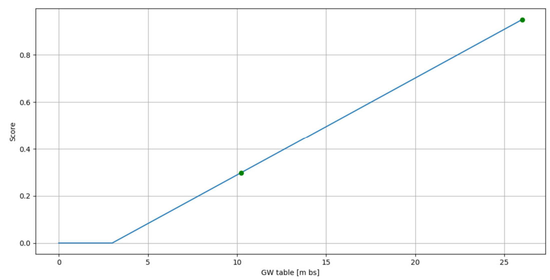
4500000
5000000
Faecal coliform emission load for SW [10^8 CFU/day]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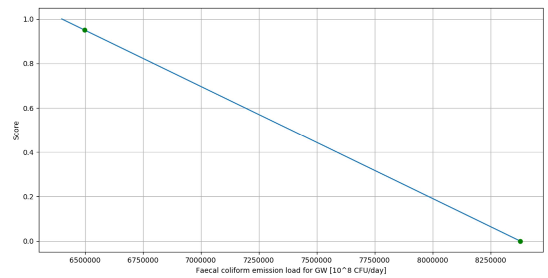
GW table [m bs]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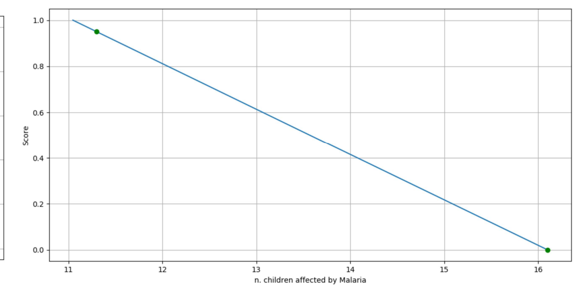
Faecal coliform emission load for GW [10^8 CFU/day]


Score
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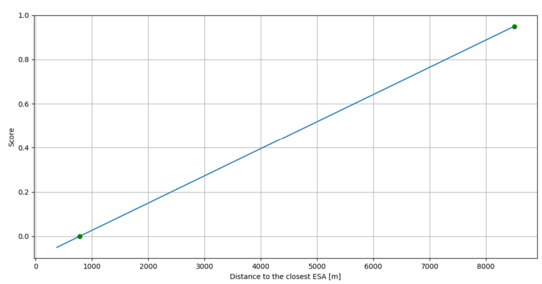
16
n. children affected by Malaria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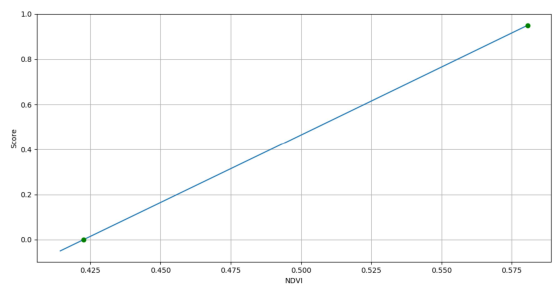
0.0
0
1000
2000
3000
4000
5000
6000
7000
8000
Distance to the closest ESA [m]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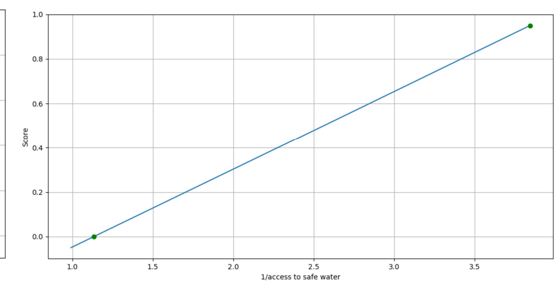
NDVI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0.4
0.2
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1.0
1.5
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2.5
3.0
3.5
1/access to safe water