Improving the integration of environmental considerations in planning for industrial development locations using Spatial Multi Criteria Evaluation

A case study in: Huye and Kigali districts, Rwanda

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May 2021

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Thesis submitted to the Faculty of Geo-Information Science and Earth Observation (ITC) of the University of Twente in partial fulfilment of the requirements for the degree of Master of Science in Spatial Engineering.

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ABSTRACT

Many African developing countries have been struggling to adequately address the environmental impacts of new industrial development locations in spatial planning practices next to the consideration of economic and social impacts. Especially in countries facing challenges with data availability and cross-sectoral coordination among institutions, the integration of environmental impacts during the planning processes can be lacking. The adaptation of strategic spatial planning methods conform to Strategic Environmental Assessment (SEA) guidelines may improve the consideration of environmental impacts during the spatial planning and decision-making processes for industrial development locations.

On that note, this study examines the development of such a method for countries where SEA is recently introduced. It applies the Spatial Multi-Criteria Evaluation (SMCE) to integrate environmental considerations: into planning practices for industrial park locations and complementary to plans that guide regional planning of industrial activities in Rwanda. First, the study reviewed the consideration of environmental issues in these planning practices. Then, based on a case study conducted in the Huye and Kigali districts, a method was developed to assess the suitability of locations for industrial development considering information about flood issues. Last, this study showed the contribution of this information to planning practices by illustrating how to assist planners in identifying potential industrial development locations and evaluating the information against designated industrial development locations.

As a result, this study developed a participative approach that considers flood issues to inform spatial planning about: more sustainable alternative options in regard to the location, shape or size of industrial development, or potential flood mitigation measures. To this extent, the assessment of flood issues in this research illustrated the potential of the SMCE method to implement SEA in a context characterised by data scarcity and difficulties with cross-sectoral coordination; thereby, introducing a method that can help to avoid environmental impacts that emerge from industrial development.

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I am also grateful to my friends and family who supported me during the thesis period and occasionally took my mind away from this work. I have great memories of the adventures with the kayak association Euros, my colleagues in *Umudugudu wa Bukinanyana* house, AIESEC and my roommates at Huize Pennylane and later Huize Saffier. They gave me a lot of energy, and I simply enjoyed it.

Finally, I would like to thank the department of Urban and Regional Planning at the Ministry of Infrastructure in Rwanda for the warm welcome and support throughout the field study. With special notice, I would like to thank Mr Edward Kyazze, Mrs Immaculate Rugema, Mr Sam Kabagamb and Mr Eugene Maridadi for their help and guidance in collecting data and scheduling interviews. *Murakoze!*

PREFACE

On a day in spring, I was walking near Twente airport. There was a sign standing next to a pond explaining the contribution of the airport's development to floods downstream in Hengelo. The pond was created years after the development of the airport to retain water, and; consequently, to relieve the floods in Hengelo. This struck me, as it captured the motivation of my thesis: too often, we repair environmental impacts afterwards while we may have been able to prevent the impacts from development strategically.

With a healthy Dutch bias, I went to Rwanda to find out how spatial planning can be applied strategically and effectively to avoid (irreversible) environmental impacts. Although this is a large topic to comprehend, I got the opportunity to explore different aspects of this topic. In this context, I investigated: how the environment is considered in the decision-making of industrial development plans in Rwanda; developed a method that can embed information about environmental issues in plan-making for industrial development locations; and explored how to adapt such method to the requirements of planners, decision-makers and other practitioners to make the method more useful in practice. This master thesis elaborated only on the development of the method. However, I am happy I got the opportunity to advance in the two other aspects as well.

In particular, the interdisciplinarity and the complexity of this topic appealed to me because finding (part of) a solution to a big, complex and interconnected puzzle is something I enjoy, but also something I am good at. This study is an example of such an interdisciplinary and complex topic. It combined many different disciplines such as water management, environmental modelling, spatial planning, urbanisation and decision-making into a multi-stakeholder environment characterised by opposing perspectives on how to plan for industrial development locations.

This broad interest in many disciplines also showed in my attitude towards this research. For me, the topic had to be about more than working in a model's reality. For this reason, this study incorporated the role of policy and plan-making, stakeholder dynamics and the consideration of the environment in Rwandan spatial planning practices as an attempt to bridge the gap between the model's reality and society. This attitude allowed me to understand the underlying societal problems that determine whether a method is useful in the spatial planning and governance context.

From time to time, the thesis research has been challenging as it required 'new' non-technical skills involving the acquisition of interviewees, the capability to differentiate between practice and the documented reality, the analysis of policy and plans in a larger legislative framework and the conduction of interviews. Furthermore, I was challenged by scepticism towards the necessity of including environment when planning for industrial development, and thus the necessity of my research. I sometimes got the impression that Strategic Environmental Assessment is only considered in decision-making due to its inclusion in law, and not as an approach to improve the environment. This was voiced multiple times by statements indicating that there are more relevant topics than the environment when planning for industrial development. Then again, proving the necessity to include the environment was one of my driving motivations.

To conclude, with this thesis in front of you, I hope to advocate a more environmental oriented approach towards spatial planning in general. On that note, Í hope to have produced a valuable read.

Yours sincerely,
Anne Mossink

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DEFINTIONS

Environmental Impact Assessment	The process of identifying, predicting, evaluating and mitigating the biophysical, social, and other relevant effects of project proposals prior to major decisions being taken and commitments made (IAIA, 2009).
Flash floods	Floods from overtopping streams or rivers occurring locally in small upstream areas when intense rainfall falls within a short period of time (Van Westen, Alkema, Damen, Kerle, & Kingma, 2011).
National Strategic Action Plan	A tool applied to strategically plan industrial activities while coordinating horizontally between districts and vertically between ministries, national governmental institutions and districts (ITC & UN-Habitat, 2019).
Natural marsh	A type of wetland composed mainly of grasses and reeds (Hayes, 2017), and administered as natural vegetation having a high ecological value.
Quickflow	A measure for disruptive water (in m^3) that runs off quickly during or after a storm. Disruptive waters are characterised by flooding, biodiversity loss, soil erosion, soil loss and poor water quality (NISR, 2019).
Riverrine floods	Floods from overtopping rivers as a result of persistent rain during several days over a large area (Van Westen et al., 2011).
SEA-objective	Set the aims that should be considered to effectively assess the environmental and sustainability impact of a proposed policy, plan or program (Scott & Marsden, 2003).
Spatial Development Framework	A strategic planning method that addresses gaps in spatial urban and regional planning by developing a better understanding of the spatial structure of urban settlements and the roles and inter-linkages of these settlements in a territory (Spaliviero, Boerboom, Gibert, Spaliviero, & Bajaj, 2019).
Strategic Environmental Assessment	A systematic process for evaluating the environmental consequences of proposed policy, plan or programme initiatives in order to ensure they are fully included and addressed at the earliest appropriate stage of decision-making on par with economic and social considerations (Sadler & Verheem, 1996).
Water hindrance	Local inundations or overland flows caused by the inability of a location to infiltrate or drain water during an intense shower (Ministerie van Infrastructuur en Milieu, 2018).
Wetland	Umbrella term for areas of marsh, fen, peat and/or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water less than six meters deep at low tide (Ministry of Environment, 2019b).

ABBREVIATIONS

DDS	District Development Strategies
EDPRS2	Economic Development and Poverty Reduction Strategy
EIA	Environmental Impact Assessment
ITC	University of Twente's Faculty of Geo-Information Science and Earth Observation
MINICOM	Ministry of Trade and Industry
MININFRA	Ministry of Infrastructure
MoF	Matrix of Functions
NSAP	National Strategic Action Plan
NST1	National Strategy for Transformation
NUP	National Urbanisation Policy
REMA	Rwanda Environment Management Authority
RLMUA	Rwanda Land Management and Use Authority
SDF	Spatial Development Framework
SEA	Strategic Environmental Assessment
SEZ	Special Economic Zone
SMCE	Spatial Multi Criteria Evaluation

1. INTRODUCTION

In many African developing countries, the conservation of the physical environment is challenged by industrial development. The encroachment of new urban and industrial development towards natural areas puts direct and indirect pressures on ecosystems (Burak, Lwasa, Masundire, Parnell, & Seto, 2017) and cause negative environmental and social impacts (UNIDO, The World Bank, & GIZ, 2017). As places grow, but tend to fail to address the consequences of this growth, they generate more pollution and waste, destruct natural habitats and environmental services, reduce flood protection (Roberts, 2014) and deplete surrounding natural resources (Spaliviero et al., 2019). Correspondingly, a vital question in Africa is whether urban development can help raise living standards without degrading its ecosystems on which life depends (Turok & McGranahan, 2013).

According to Roberts (2014), cities can promote sustainability and foster environmental performance when urban planning integrates environmental considerations. However, to achieve this, more integrated planning approaches, rather than traditional ones, are required to address the causes and effects of development (Roberts, 2014). Considering industrial development; spatial planning systems have been struggling to adequately address environmental impacts from industry thus far (Jones et al., 2005; Ruiz, Romero, Pérez, & Fernández, 2012). For this reason, the planning of industrial development locations would benefit from strategic methods that are able to integrate environmental information. Adapting these methods to Strategic Environmental Assessment (SEA) guidelines may provide such integration in the planning and decision-making of industrial development locations.

1.1. Background

In many countries, new industrial areas are planned to stimulate industrialisation as it is believed that industrialisation is an engine of economic growth (Roberts, 2014; Szirmai, 2012; Turok & McGranahan, 2013). Also in Africa, the economic growth that has taken place since the 1990s derives mainly from the development of the urban-based industrial sector (Kessides, 2005). As countries seek to enhance economic growth through urbanisation and industrialisation, a pressing need to balance this economic goal with environmental and social goals exists (UNIDO et al., 2017).

An effective instrument to promote industrialisation is the development of sustainable industrial parks as they serve as a catalyst in facilitating the development of industrial plots (UNIDO, 2019). An emerging trend affecting this development of industrial parks is the increasing emphasis to combine green growth strategies with spatial planning activities (UNIDO, 2019). Similarly, there is a growing attention for eco-industrial parks designed to improve the environmental performance of industrial complexes through relieving environmental pressure in and near the location of the park's development (Heeres, Vermeulen, & de Walle, 2004). Accordingly, the consideration of the environment has become a vital component in the process of establishing new park locations (UNIDO, 2019). This is particularly important because the selection of a location will determine the park's integration in the environment and the environmental impact from the park's future operations (Fernández & Ruiz, 2009). Strategic spatial planning methods may improve the inclusion of environmental considerations in this selection process.

Another way to promote industrialisation and economic growth is by encouraging urbanisation (Turok & McGranahan, 2013). A National Urbanisation Policy (NUP) aims to plan and manage urbanisation by enabling urban and economic growth that improves ecological sustainability, human well-being and shared prosperity (Turok & Parnell, 2009). However, in the past, NUPs in Africa had trouble to address all challenges of urbanisation. Correspondingly, it is difficult to find any African governments with a NUP that has all-encompassing objectives, and that is systematically implemented in practice (Turok, 2015).

A method able to guide the implementation of NUPs in spatial planning practices is the Spatial Development Framework (SDF). The SDF is a strategic planning method that addresses gaps in spatial planning by developing a better understanding of the spatial structure of urban settlements and the roles and inter-linkages of these settlements in a territory (Spaliviero et al., 2019). It was first applied between 2011 and 2013 to support the reconstruction of the Darfur region in Sudan after its armed conflict (Spaliviero et al., 2015). Later, it was further improved and applied to complement the implementation of an NUP in Rwanda (Boerboom, Gibert, Spaliviero, & Spaliviero, 2015), and specified to locate industrial activities and investments regionally (ITC & UN-Habitat, 2019). Besides, the framework had some other applications, including Myanmar in 2016, which showed the possibility to support planning on an environmental basis (Spaliviero et al., 2019). An SDF's application is followed by a Strategic Action Plan (e.g. the NSAP of Rwanda) to translate the SDF's findings into recommendations about investments and development actions (Spaliviero et al., 2019).

Although plans for industrial park development, NUPs and Strategic Action Plans derived from the SDF provide the possibility to include environmental considerations in spatial planning, neither does consistently implement SEA. Consequently, they do not benefit from SEA's abilities to enhance environmental protection and promote more sustainable industrial planning and decision-making. By following a structured approach, SEA can analyse and evaluate the potentially significant effects of these policies and plans on the environment, supporting more informed decision-making (Sadler et al., 2011). In particular, a benefit of SEA for industrial park plans and industry-oriented Strategic Action Plans is the integration of environmental considerations early and throughout the entire planning process, as this will avoid decision-making without fully including the environmental consequences of industrial development (CEA, 2006; Walker, Spaling, & Sinclair, 2016).

With these benefits in mind, among other reasons, there has been an increasing interest in SEA (Dalal-Clayton & Sadler, 1999) that has led to the introduction of new SEA legislation worldwide (Netherlands commission for environmental assessment, n.d.). However, because SEA was often implemented based on an Euro-centric view (Walker et al., 2016), experiences in developing countries show an enduring challenge to adapt SEA to the conditions, needs and requirements of developing countries (Abaza, Bisset, & Sadler, 2004; Azcarate & Balfors, 2009; Walker et al., 2016). Future SEA implementations could address these challenges.

1.2. Problem statement

Strategies to integrate environmental considerations are not always applied in the decision-making process of industrial development. The focus of planning approaches on the economic dimension (Rodriquez-Pose, 2010) tends to ignore the alternative ways places can grow, and has unintended consequences of urban growth (e.g. depletion of surrounding natural resources and environmental impact) (Spaliviero et al., 2019). Moreover, Burak et al., (2017) state that although governmental authorities have the potential to contribute to ecological governance in Africa, though given Africa's economic challenges, much of the current focus is on opportunities that urbanisation can deliver for structural economic transformation.

Strategic spatial planning methods can potentially play a role in addressing this unbalance between the consideration of economic effects and the consideration of social and environmental effects in industrial planning (UNIDO et al., 2017). However, in developing countries characterised by insufficient human and financial resources, insufficient data (e.g. not timely, unreliable and inaccurate) and difficulties in institutional coordination amongst different levels of government, the implementation of planning practices is rather challenging (Spaliviero et al., 2019). The SDF-method was developed to address these challenges in developing countries (Spaliviero et al., 2019), but did not address the need to explore and simultaneously integrate information about multiple environmental, social and economic impacts. Consequently, a method such as the SDF tends to focus on a single aspect, and therefore, the challenge of integrating many subjects when making plans using such a method remains. Hence, there is a need to adapt spatial planning methods in developing countries to strengthen the integration of environmental considerations into spatial planning for industrial development locations next to social and economic considerations. These planning tools should not only address the needs of the institutional framework as bounded by legislation, but should also address place needs and help to understand how places and territories are changing (Harrison, Galland, & Tewdwr-jones, 2020).

Equally, this economic focus is found in the Rwandese National Strategic Action Plan (NSAP) of the SDF that implements the NUP of Rwanda. This plan aims to: "improve the territory of Rwanda, which is the basis for successful and equitable economic and social transformation" (ITC & UN-Habitat, 2019), and can be used to locate industrial activities and other investments to streamline industrial development planning on a regional level (ITC & UN-Habitat, 2019). Moreover, the SDF-method and NSAP have been adopted by one ministry, whereas NUP literature (Turok, 2006) and SEA guidelines (Sadler et al., 2011; Therivel, 2004) stress the importance of involving multiple stakeholders representing a number of disciplines and sectors to get a more comprehensive understanding of a decision problem. On top of that, on a local planning level in Rwanda, planning for industrial park locations can be improved as SEA is absent and current feasibility studies are described as superficial (UNIDO, 2016).

In this context, driven by a high need for economic transformation to a middle-income country, Rwanda aims to stimulate industrialisation by planning new industrial areas (The Republic of Rwanda, 2017). To guide achieving this, Rwanda plans to increase the share of the industrial sector to 26% of its Gross Domestic Product (GDP), mainly through the promotion of industrial parks (The Republic of Rwanda, 2012). These parks function to promote the development of the non-agricultural sector, attract investments and create new off-farm employment (MINICOM, 2010, 2018).

However, the industrial activities in Rwanda along with other interrelated drivers of increased economic development, add pressure to environmental resources such as wetlands, rivers and lakes, among others, depleting the natural wealth of these already strained ecosystems (MINICOM, 2011; Ministry of Environment, 2019b). In the last years, the magnitude and incidence of floods have increased due to the increased use and exploitation of wetlands and the transformation of land to unsustainable land-uses (Nabahungu, 2012; NISR, 2019), including the development of industry (Ministry of Environment, 2018b). The chances are that this will lead to irreversible natural damages and high rehabilitation costs in the future. Consequently, the protection of wetlands against industrial expansion became a more prevalent topic in national politics (Ministry of Environment, 2019b).

To deal with the degradation of wetlands and flood enhancement in Rwanda, rehabilitation and protection programmes for rivers, lakes and swamps are recommended (Ministry of Environment, 2019b; Nabahungu, 2012; NISR, 2019; Twagiramungu, 2006), because if not properly planned and managed, economic pressures will likely lead to further encroachment to these wetlands (Ministry of Environment, 2019b). However, management is complex since the precise impact of urban processes such as industrialisation on wetlands and floods in wetlands is not well known. This is illustrated by a lack of information about the essential functions and processes of wetlands and their benefits and costs to its different users (Turner et al., 2000), which is also evident among policy-makers (Nabahungu, 2012). Be that as it may, industrialisation can facilitate sustainable socio-economic growth, if combined with a green growth strategy that integrates environmental considerations (Government of Rwanda & GGGI, 2015; Turok & McGranahan, 2013; UNIDO et al., 2017).

Because spatial planning processes and methods in developing countries do not always adequately consider environmental impacts, a method that embeds environmental information to assess the suitability of locations for industrial development may help prevent irreversible environmental damages and costs in the future. However, for a method to be successfully implemented in developing counties, it should be able to deal with data scarcity and challenges in institutional coordination. Moreover, it should follow SEA guidelines to ensure that the environmental impact from industrial development is fully included in plan-making. While adhering to these requirements, this research aims to develop a method that can inform industrial planning practices about the environmental pitfalls and potentials of locations, thus promoting more sustainable plans for industrial development. To limit the scope of this research, the method is developed and tested using a case study on flood issues as floods are an important issue in Rwanda.

1.3. Research objectives and questions

1.3.1. Main objective

The purpose of this study is: To develop a method that uses information about environmental issues to assess the suitability of industrial development locations in plan-making that is guided by industrialisation policies or the NSAP.

1.3.2. Sub-objectives

To address the main objective, this research is divided into three parts. The first part examines the consideration of environmental issues in Rwanda's industrial planning practices to understand the spatial planning context to which the method should be able to contribute. These practices involve planning the industrial park locations mentioned in industrialisation policies and planning industrial activities using the SDF's NSAP. The second part aims to develop a method that determines the suitability of locations for new industrial development based on information about environmental issues. A case study considering flood issues in the Huye and Kigali districts serves to design and demonstrate this method. The third part tests the use of the information provided by the method by assessing its contribution to assist planners in locating industrial parks and by comparing the information with designated industrial development locations. Hence, the following sub-objectives and research questions are established:

Sub-objective 1: To determine the consideration of environmental issues in the spatial planning of industrial parks and the planning of industrial activities using the NSAP.

1.1 How do industrialisation policies and the NSAP that guide spatial planning of industrial development locations include the consideration of environmental issues?
1.2 What is the role of environmental policy in locating industrial development?

1.3 Which key environmental issues are caused by industrial development?

Sub-objective 2: To determine the suitability of industrial development locations considering flood issues according to different stakeholder perspectives.

2.1 Which flood issues determine suitable locations for industrial development?
2.2 Which objectives can be formulated to address these issues?
2.3 Which criteria, indicators and spatial data measure the performance of locations against these objectives?
2.4 What is the spatial performance of locations according to each objective?

2.5 Which visions describe distinctive stakeholder perspectives on where to locate industrial sites?
2.6 Where are the suitable locations for industrial development according to these visions?

Sub-objective 3: To assess the contribution of the information about the suitability of industrial development locations in comparison to planning practices for industrial park locations and the NSAP.

3.1 How can information about the suitability of industrial development locations assists planners and decision-makers in identifying locations for industrial development?
3.2 How suitable are the designated industrial park locations and the industrial areas zoned in the NSAP for development according to the different visions on flood issues?

1.4. Organisation of the thesis

This thesis consists of six chapters. Chapter 1, the introduction, describes the background of industrial development planning with respect to considering environmental impacts. This is followed by justifying the necessity for planning methods that include the environment, and by the research objectives and questions. Chapter 2, the literature review, discusses the key concepts relevant to the study, including strategic industrial development planning, SEA and flood issues. Then chapter 3 describes the study area and the research methodology used to answer the research questions. Subsequently, chapter 4 presents the results after applying the methodology. In view of existing literature, chapter 5 interprets these results, discusses the developed spatial planning method and discusses the implications of implementing the method into planning practices for industrial parks and planning industrial activities using the NSAP. Finally, chapter 6 presents the conclusions and recommends future research.

2. LITERATURE REVIEW

This chapter explains different concepts related to strategic spatial planning practices of industrial development locations considering flood issues. First, it provides an understanding of what makes industrial development planning complex and introduces the Spatial Multi Criteria Evaluation (SMCE) as a method to address this complexity (Section 2.1). Then, Section 2.2 describes SEA as an approach to support decision-making in spatial planning practices. This is followed by explaining the concept of flood issues to describe different types of flood events (Section 2.3). Last, Section 2.4 elaborates on the case study by describing the policy background of industrial spatial planning in Rwanda.

2.1. The complexity of industrial development planning

Planning industrial development locations is guided by multiple policies and plans. The variety of policies and the many different interests including those from different departments and levels of government, NGO's, community representatives, among other stakeholders, makes these planning practices complex (Jones et al., 2005; Turok & Parnell, 2009), especially when dealing with data scarcity (Pavlickova & Vyskupova, 2015) and unstructured planning systems (Sadler et al., 2011). Within government alone, various departments of local and national government serve different interests, have distinctive bureaucratic practices and diverse responsibilities (Turok & Parnell, 2009), generally with distinct views on how and where industry is best developed.

As more and more factors get included in the planning process of industries, the practices become increasingly difficult to manage. For a long time, the proximity to markets, basic infrastructures and the availability of qualified manpower were the main considerations when planning industrial locations (Fernández & Ruiz, 2009). But for industrial planning to be sustainable a location must consider a wider range of factors, and therefore encompass multiple social, economic and environmental impacts (Ruiz et al., 2012).

Strategic planning can deal with the complexity if the planning processes are adaptive to dynamic circumstances and a changing planning context, and can easily incorporate new information and knowledge (Albrechts, 2015). Strategic planning is defined as a set of concepts, procedures and tools tailored to the circumstances at hand (Albrechts, 2015). The planning tasks require the ability to analyse and combine different data sets and intelligence, often from different sources (Harrison et al., 2020). As such, strategic planning methods should coordinate and align the policies and investments of different parts of government (Turok & Parnell, 2009) and help to collectively prepare for new plans (Harrison et al., 2020). The SDF and SEA accommodate the strategic planning process, respectively by guiding implementation and promoting sustainability in policies and plans.

2.1.1. Spatial Multi-Criteria Evaluation

The SMCE method can assist decision-makers in structuring complex decision problems, and in designing, evaluating and selecting a number of alternative decisions (Malczewski, 2006). The method divides a problem into small understandable parts that can be analysed individually (Malczewski, 1999). These parts are represented by measurable evaluation criteria that can vary across space (Malczewski, 1999); as such, a spatial distinction between locations can be made. The alternatives are evaluated based on the criterion's values and judgments about the criteria's importance (Malczewski, 2006). The latter is a strength of SMCE since valuing criteria allows expressing perspectives from multiple individuals (Malczewski, 2006).

The SMCE method has several applications to assist decision-making. Spaliviero et al. (2019) implemented SMCE as part of the SDF to assess and evaluate the progress of human settlements using criteria based on relevant policies and laws. Moreover, Ruiz et al. (2012) applied a predefined SMCE model to distinguish different zones according to their suitability for industrial development, enabling the model to locate potential industrial areas or to evaluate existing areas. SMCE can also be applied in the field of flood risk analysis as is demonstrated by Karlsson, Kalantari, Mörtberg, Olofsson, & Lyon (2017), Kourgialas & Karatzas (2011), Prawiranegara (2014) and Wang, Li, Tang, & Zeng (2011). Most importantly, the SMCE method could provide information during the SEA (Choi & Lee, 2016; Thérivel, 2004).

Considering flood risk modelling, SMCE is helpful in situations characterised by data scarcity (Wang et al., 2011). In these situations, quantitative models that use numerical expressions to describe hydraulic or hydrologic relationships are less applicable as they need high-quality data and require complicated calculations (Wang et al., 2011). Instead, qualitative approaches that depend on expert opinions are more suited. These qualitative approaches may become semi-quantitative in nature when they assign weighted values to describe the importance of criteria (Castellanos & Van Westen, 2007; Wang et al., 2011).

2.1.2. Sequencing activities of the decision-making process

A planning process, such as planning new industrial development locations using SMCE, involves a sequence of activities that affect the quality of the process, and thus of the decision-making itself (Zucca, Sharifi, & Fabbri, 2008). This sequence starts with recognising and defining the decision problem and understanding the system in which the problem is rooted. It ends with a recommendation for a decision (Sharifi, Van den Toorn, Rico, & Emmanuel, 2002).

Keeney (1992) (as cited in Zucca et al., 2008) distinguishes between a value-focussed approach and an alternative-focussed approach to organise these activities. A value focussed approach first specifies values and criteria that are used to test a decision. Then, using these predefined values and criteria, new feasible alternatives are developed to decide from (Keeney, 1992 as cited in Zucca et al., 2008). This order implies that the alternatives serve to achieve the values and criteria specified for a decision situation (Zucca et al., 2008). In contrast, the alternative-focussed approach develops alternatives independent of the decision values and criteria. It starts with developing alternative options and then proceeds with specifying the values and criteria (Keeney, 1992 as cited in Zucca et al., 2008). This approach is better suited when a decision problem starts with a predefined number of alternatives (Zucca et al., 2008).

2.2. Strategic Environmental Assessment

A way to stimulate strategic thinking about the environment in the planning process is implementing Strategic Environmental Assessment (SEA). SEA has been defined as: "a systematic process for evaluating the environmental consequences of proposed policy, plan or programme initiatives in order to ensure they are fully included and addressed at the earliest appropriate stage of decision-making on par with economic and social considerations (Sadler & Verheem, 1996). In Rwanda, it became law in 2018, stating: "Every policy, strategy, plan and programme must undergo a Strategic Environmental Assessment" (Ministry of Environment, 2018a); thereafter, SEA regulation has been under development (Nieuwenhuis, 2019). Its execution was put under the supervision of the Rwanda Environment Management Authority (REMA) (REMA, n.d.).

Sadler et al. (2011) set spatial planning processes and SEA apart by the obligation of SEA to identify and quantify potentially significant and adverse environmental impacts, which would generally be underrepresented or ignored. To acquire the information about these environmental impacts, an exploration of alternatives to achieve a policy, plan or program should be present (Sadler et al., 2011). This exploration assesses for each alternative how the environment is expected to change, and accordingly, provides advice on how the environmental changes of a policy, plan or program are best managed (Abaza et al., 2004). Subsequently, it prompts the integration of mitigation measures that avoid, minimise or compensate negative environmental impacts or optimise positive impacts in such policy, plan or program (Abaza et al., 2004; Thérivel, 2004). In this way, SEA aims to make policies, plans or programmes as sustainable as possible.

SEA is very much alike to Environmental Impact Assessment (EIA). However, whereas EIA applies to site-specific projects that normally involve one activity, SEA is implemented to assess larger policies, plans or programs (Thérivel & Partidário, 1996). Consequently, SEA is suited to deal with cumulative impacts from multiple projects (Thérivel, 2004), such as: additive effects, that may occur when impacts are individually minor, but collectively and over time, may prove to be major; and induced impacts that arise when one project stimulates other developments with unaccounted environmental impacts (Thérivel & Partidário, 1996). When commenced before projects, the assessment of the cumulative impacts from policy, plans or programs, and the implementation of mitigation measures accordingly, influences future smaller projects. To put it differently, SEA studies could trickle down sustainability principles from SEA policies to plans, which in turn may influence programmes, and finally, project-level EIA (Thérivel, 2004).

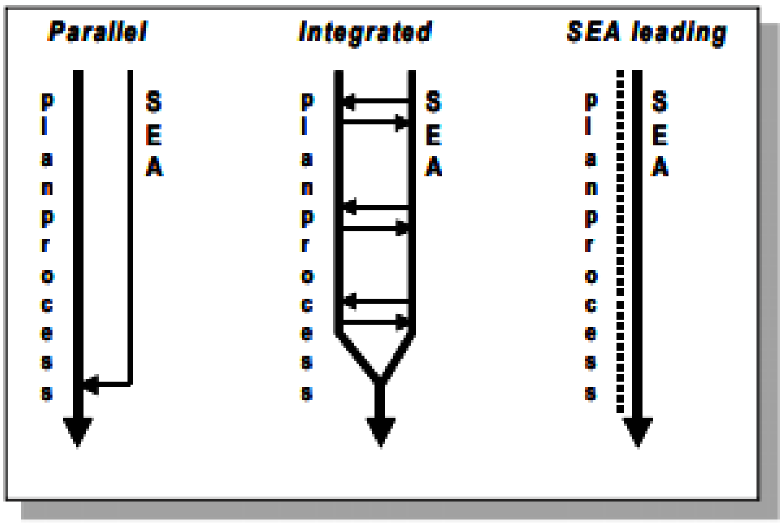


Figure 1: Applications of SEA into the planning process for policies, plans and programmes (adopted from CEA, 2006).

Although SEA encompasses a sequence of systematically organised components, that are linked to the stages of policy, plan or program making (Figure 2) (Thérivel & Partidário, 1996); each SEA normally implements a different approach adapted to the circumstances of the planning context at hand (Hildén, 1999, as cited in Azcarate & Balfors, 2009; Torrieri & Batà, 2017). In the basis, SEA: can be applied as a stand-alone parallel process to the making of a policy, plan or program; can be integrated into the planning process to provide input throughout its various stages; or can represent the planning process altogether, which sometimes occurs when planning processes are weak or absent (Figure 1) (CEA, 2006). To perform these activities, no specific methods or techniques exists; thereupon, multiple methods and techniques can be applied throughout the SEA process (Torrieri & Batà, 2017). In the same fashion, the SEA approach can differ in its level of public participation (Walker et al., 2016), its duration or its comprehensiveness (e.g. environmentally focussed or sustainability focussed) (Thérivel, 2004). Regarding the latter, a sustainability focussed approach would include socio-economic issues, whereas an environmentally focussed approach would restrain to environmental issues.

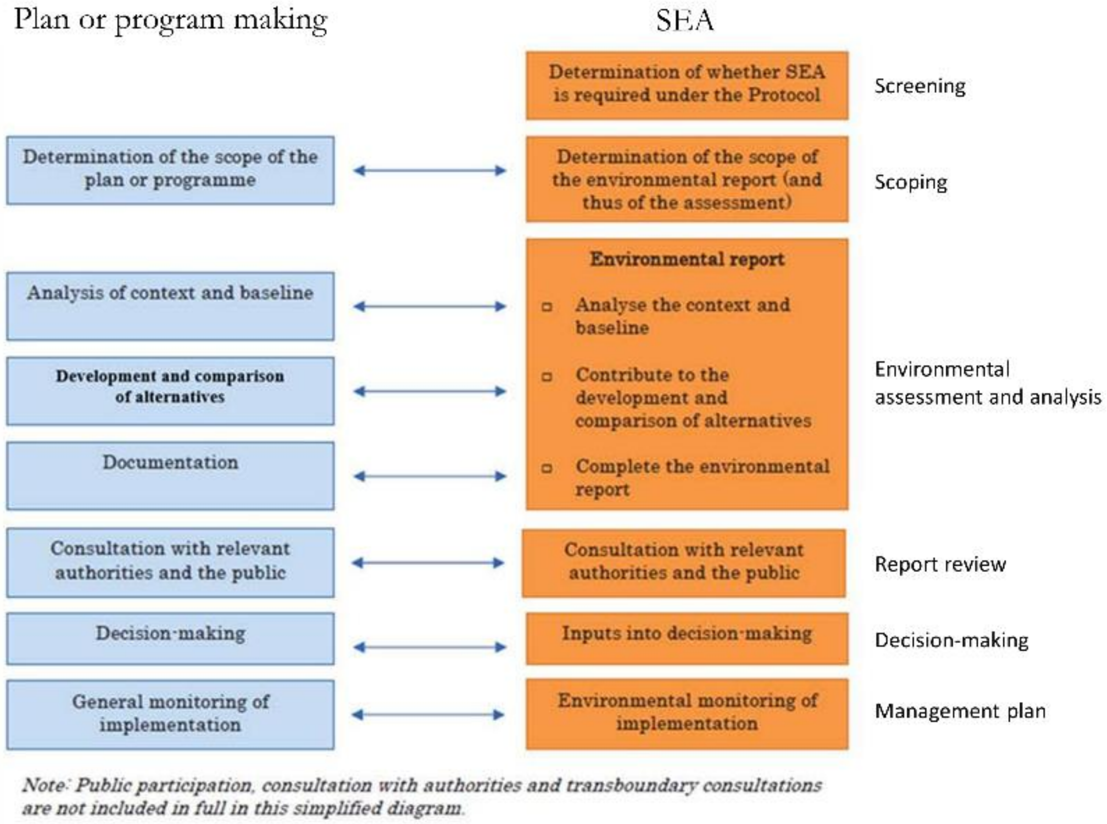


Figure 2: Logical links between plan- and programme- making processes and SEA components (adopted from UNECE, 2007).

As illustrated by Figure 2, SEA includes the components: (1) Screening, to decide whether SEA is required to evaluate the planning process; (2) Scoping, to establish what to include in the SEA; (3) Environmental assessment and analysis; (4) Report review; (5) Decision-making; and (6) Management plan, describing the implementation of a plan, and the strategy to monitor impacts from plan implementation (Nilsson, Björklund, Finnveden, & Johansson, 2005; Scott & Marsden, 2003). Since this study is limited to the development of a method for the assessment of more suitable alternatives for industrial locations, and not the entire plan-making process, the components scoping and assessment apply to this research and are therefore further elaborated below:

Steps for scoping (deciding what to include in SEA) (Scott & Marsden, 2003):

1. Institutional context and decision scope: Determine key elements of the plan assessed.
2. Issue coverage: Determine the environmental issues to be assessed, to what range and to which detail.
3. Institutional context and decision scope: Collect and report on relevant international, regional and local plans, objectives and environmental standards that may impact the plan.
4. List environmental SEA-objectives (or themes) and their corresponding indicators and targets against which the impacts of a plan will be evaluated.
5. Formulate alternatives to achieve the plan.

Steps for environmental assessment and analysis (Scott & Marsden, 2003):

1. Establish an understanding of the existing conditions and future trends (baseline environment).
2. Predict the impact of the plan and its alternatives to the environment.
3. Evaluate the impacts' significance.
4. Establish mitigation measures to the impacts.
5. Select the preferred alternative to a plan.

The assessment could make use of diverse methods to provide information. In the field, many of these methods comprise qualitative assessment methods (Choi & Lee, 2016). Nonetheless, quantitative assessment methods (e.g. modelling, scenario analysis, GIS tools, (S)MCE, and cost-benefit analysis) which predict cumulative and future impacts are useful as well (Choi & Lee, 2016; Thérivel, 2004).

Altogether an SEA study should meet several requirements. It should be an integrated concept; that is, SEA is initiated early to inform the planning process and is integrated throughout the various stages of the planning process (See Figure 1), while incorporating environmental, social and economic considerations (Walker et al., 2016). Second, SEA should give adequate consideration to alternatives (Walker et al., 2016) that are applied proactively to achieve a future vision, not only in reaction to planning practices (Thérivel, 2004). Third, SEA should be inclusive in the sense that SEA assesses a wide range of potential issues, including cumulative effects (Walker et al., 2016). Fourth, it should promote participation by inviting diverse stakeholder groups throughout the process (Thérivel, 2004; Walker et al., 2016). Last, SEA should be transparent and have accountable governance achieved through well-documented reporting of the SEA process (Walker et al., 2016).

In developing countries such as Rwanda, there has been an increasing interest in SEA. However, experiences with the process have been limited (Abaza et al., 2004; Azcarate & Balfors, 2009), and the form and scope appropriate for SEA in developing countries has been open to debate (Dalal-Clayton & Sadler, 1999, as cited in Abaza et al., 2004). In fact, past experiences show the challenge to ensure that SEA is adapted to the conditions, needs and requirements of developing countries (Abaza et al., 2004; Azcarate & Balfors, 2009). Moreover, the availability of adequate data, the clarity of planning goals and the reservations towards local stakeholder involvement have been obstacles for implementing SEA properly (Azcarate & Balfors, 2009). This study deals with these challenges by demonstrating an example of implementing SEA following the scoping and assessment steps of the well-established Irish SEA guidelines; described in Scott & Marsden (2003).

2.3. Flood issues

Conducting a complete SEA study takes time and resources (Thérivel, 2004). Therefore, this study was limited to identify and assess the impacts of new industrial plans on flood issues only.

Flood issues in this study are defined as problems caused by a flood event. Each flood event has different dimensions in time and space (Bloschl & Sivapalan, 1995) determined by the geographical conditions of the area, the duration and intensity of a shower, and the size and location of the rain. Van Westen et al. (2011) classifies two events; Riverine floods that result from persistent rain during several days over a large area and flash floods that occur locally in smaller upstream areas when intense rainfall falls within a short period of time. A third event distinguished in this study is water hindrance. Water hindrance can be local inundations or overland flows caused by the inability of a location to infiltrate or drain water during an intense shower (Ministerie van Infrastructuur en Milieu, 2018). Whereas riverine and flash floods apply to events that overtop river and streams (Van Westen et al., 2011), water hindrance is not limited to these geographical conditions. For example, overland flow can apply to grass fields, urban construction sites, unpaved rural roads or other surfaces where the infiltration in the soil is insufficient to deal with intense rainfall (Hayashi, 2014; Horton, 1945).

The severity of a flood issue is dependent on the magnitude, the occurrence and the impact of a flood event (NISR, 2019; Van Westen et al., 2011; Wang et al., 2011). Several parameters describe the magnitude of a flood event: water depth, flow velocity, impulse (the amount of movement of the water mass), duration, rising time and amount of sedimentation (Van Westen et al., 2011). The possible impact of the event is expressed by the vulnerability of different assets to floods (Wang et al., 2011).

2.4. Policy background of industrial spatial planning in Rwanda

Planning industrial development in Rwanda is guided by multiple policies and plans. These policies and plans can relate to the industry itself but also to the location of investments or the supporting infrastructure. The National Industry Policy and Special Economic Zone (SEZ) policies steer the development of industrial parks intending to concentrate industrial activities (MINICOM, 2010). Outside these parks, industrial units can be developed as well. The NSAP of the SDF, which implements the NUP of Rwanda, facilitates this type of development on a regional level. The NSAP introduces a tool to strategically plan the location of investments in economic development projects geared towards the development of (agro-)industry and the (service) functions that support such industry (ITC & UN-Habitat, 2019).

2.4.1. Vision 2020 and NST1

These policies and plans are part of the path to achieve sustainable growth and economic transformation in Rwanda. This path is laid in the vision 2020/2050, the visions' implementation through the National Strategy for Transformation (NST1) and the predecessor of NST1; the Economic Development and Poverty Reduction Strategy (EDPRS2) (The Republic of Rwanda, 2017). The NST1 is structured around economic, social and transformational governance pillars, which are implemented through District Development Strategies (DDS) and Sector Strategic Plans (The Republic of Rwanda, 2017) (Figure 3) Likewise, the goals mentioned in the National Industrial Policy (MINICOM, 2010) and the NUP (Ministry of Infrastructure, 2015) are those stipulated from vision 2020/2050 and the NST1. The economic pillar of NST1 covers the objectives: 'to promote industrial development' , 'to sustainably exploit natural resources and protect the environment' and 'to promote sustainable management of the environment and natural resources to transition Rwanda towards a green economy' (The Republic of Rwanda, 2017).

Within the planning framework to implement vision 2020 and NST1, environment and climate change are considered as cross-cutting areas that will be embedded within Sector Strategic Plans and DDS (Ministry of Environment, 2019b). Correspondingly, NST1 states that the focus of environment and climate change is to improve cross-sectoral coordination that ensures a smooth implementation of environmental policies and regulations (The Republic of Rwanda, 2017).

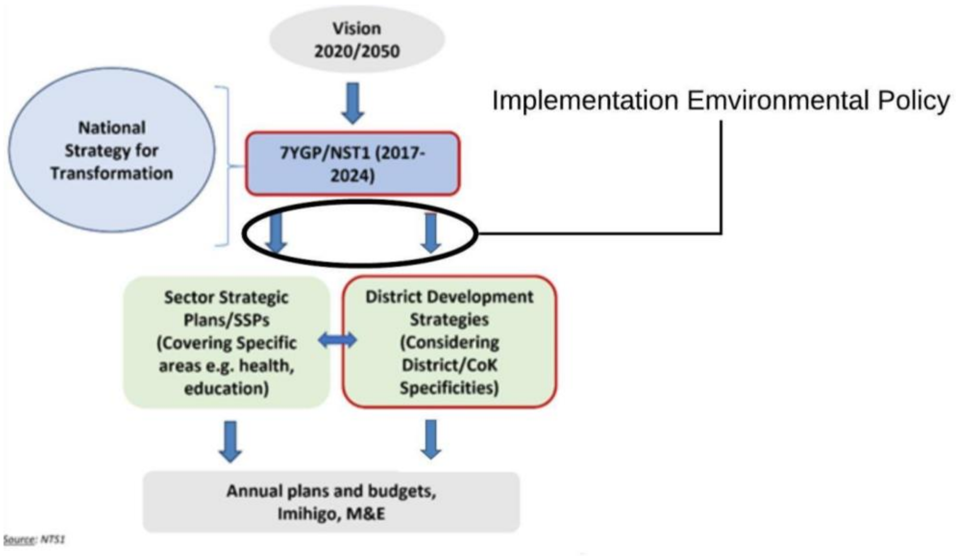


Figure 3: Planning framework for implementation vision 2020/2050 and NST1 (adopted from ITC & UN-Habitat, 2019).

2.4.2. National Industry Policy

A strategy applied in Rwanda to promote industrialisation and boost economic growth is the development of industrial parks. These parks aim to promote economic growth because they can: attract investments, utilise economies of scale, address key business constraints, offer quality infrastructure, centralise waste management, facilitate more clustered business development and enable healthy business environments (MINICOM, 2010). For these reasons, the Ministry of Trade and Industry (MINICOM) determined 11 industrial park locations across Rwanda based on the National Industrial Policy and the SEZ policies (UNIDO, 2016). These parks can facilitate heavy industry, but also IT, agro-industry, construction companies, light manufacturing, among others (UNIDO, 2016). The parks' investments are driven by foreign capital, local industrial demands and the relocation of industries from the Gikondo wetlands (UNIDO, 2016).

2.4.3. The NSAP of the SDF; implementing the National Urbanisation Policy

Another strategy to promote industrialisation in Rwanda is by encouraging urbanisation. To guide this urbanisation, the Rwandese Ministry of Infrastructure (MINIFRA) developed a NUP. This NUP aims to ensure effective urban management by addressing the cross-sectoral aspects of urban development and governance; including planning for the needs of industrial development (Ministry of Infrastructure, 2015). The logic of such NUP is that economic investments go where it would be most cost-effective and that a NUP can articulate a shared vision, establishing relevant standards and norms applicable to the entire country (Turok & Parnell, 2009). Moreover, it can encourage collaboration across municipal boundaries (Turok & Parnell, 2009). For those reasons, NUPs promote well-coordinated urban development, and therefore Rwanda's NUP is considered to be an opportunity for socio-economic growth (Ministry of Infrastructure, 2015). To effectively tackle the challenges from urbanisation, the NUP promotes strategic methods such as the SDF to guide the decision-making process (Ministry of Infrastructure, 2015).

2.4.3.1. Spatial Development Framework

The SDF-method for Rwanda is intended as an instrument to facilitate the implementation of the NUP (ITC & UN-Habitat, 2019). It assists decision-making in countries with weak planning systems by addressing gaps in urban planning where; insufficient human and financial resources, insufficient data and information, and challenges in institutional coordination lead to poor implementation of approved policies and action plans (Spaliviero et al., 2019). It does this by providing a shared spatial understanding of the roles and interlinkages of the settlements in Rwanda. Concretely, the SDF-method: analyses Rwanda's system of (linked) settlements; subsequently evaluates the spatial structure obtained from the analysis against development criteria or policies; and accordingly, develops a Strategic Action Plan to formulate strategic spatial planning recommendations or development actions (Spaliviero et al., 2019).

The SDF-method in Rwanda has two phases (Figure 4). Phase A establishes the spatial structure of Rwanda based on the Matrix of Functions (MoF), consultative workshops and the Spatial Multi Criteria Evaluation (SMCE) (Spaliviero et al., 2019). Phase B, develops the Strategic Action Plan of Rwanda to identify priority investments for industrial development (ITC & UN-Habitat, 2019).

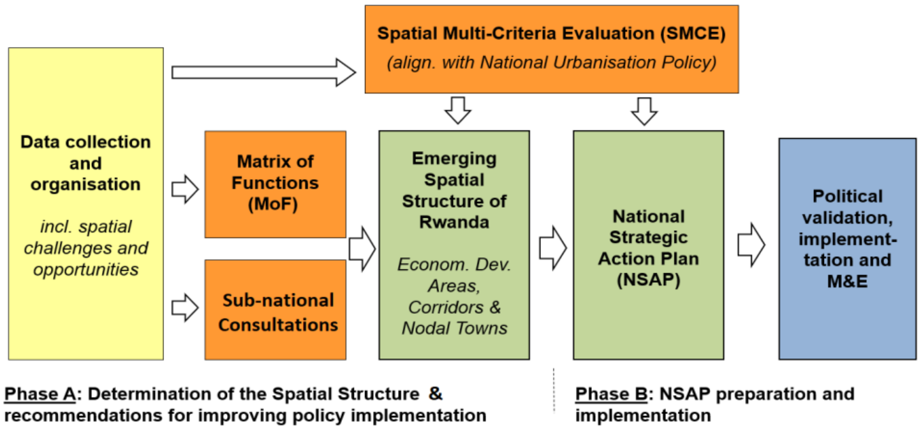


Figure 4: Flowchart of the SDF methodology of Rwanda (adopted from ITC & UN-Habitat, 2019).

The first methodology, the MoF, is based on the functional integration approach as described in Rondinelli (1985). This approach argues that more widespread economic development can be facilitated by stimulating an integrated system of settlement growth centres of different sizes and functional characteristics (Rondinelli, 1985). It assumes that promoting more widespread economic growth and development will provide greater benefits for people living in economically lagging regions such as rural areas. Adopted in the SDF's MoF, it categorises existing settlements hierarchically on the availability or absence of key functions (e.g. economic, financial, health, security, etc.) (Figure 5) (Boerboom, Gibert, & Spaliviero, 2016).

Second, a preliminary MoF is discussed in consultative workshops with stakeholders such as national, regional, and local authorities, technical and financial partners, among others, to make recommendations for each settlement on the potential activities to be developed (Boerboom et al., 2016).

Third, the SMCE assesses the performance of settlements in relation to the policy pillars as defined in the NUP of Rwanda, i.e. 'Coordination' (institutional capacity and governance), 'Densification' (spatial issues), 'Conviviality' (social issues) and 'Economic growth' (productivity and economic issues) (Spaliviero et al., 2019). This evaluation aligned to (sub-)objectives of the NUP, and established criteria according to national standards and norms (Spaliviero et al., 2019).

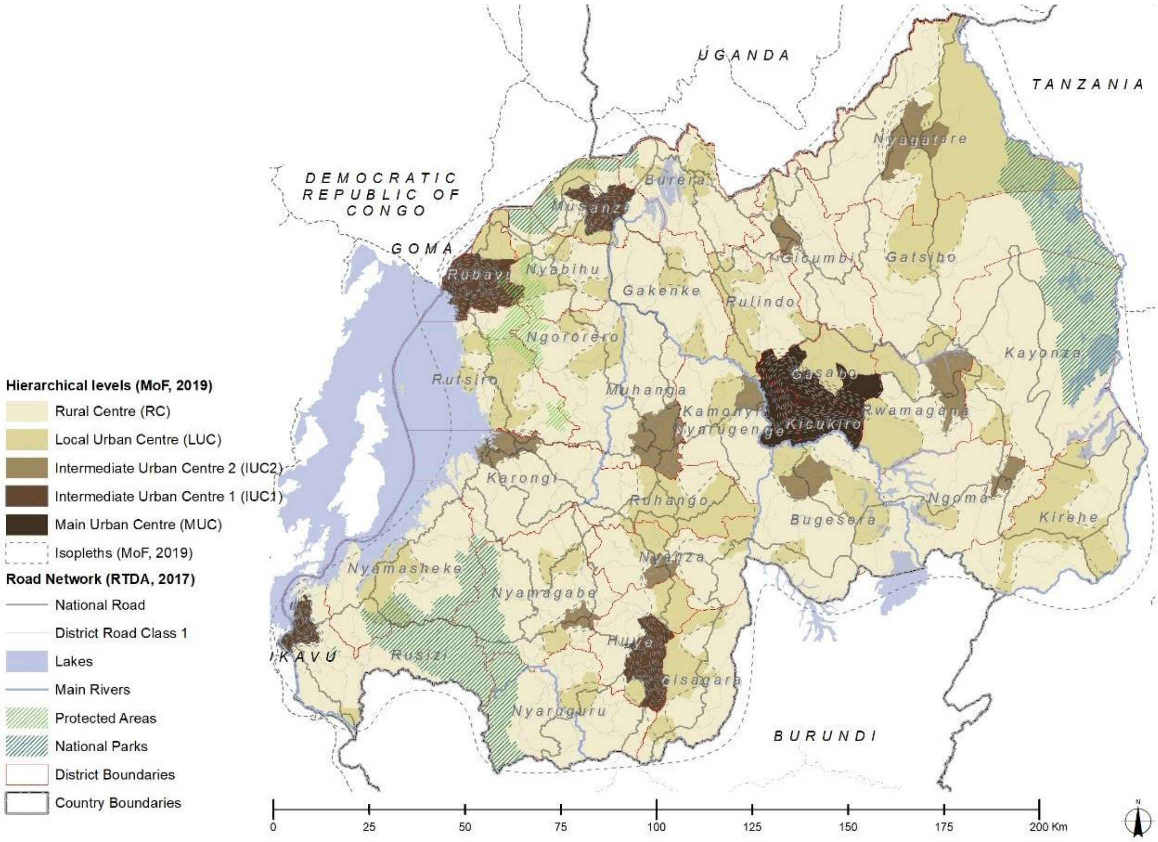


Figure 5: Spatial distribution of the five hierarchical categories of existing settlements in Rwanda; July 2019 (adopted from ITC & UN-Habitat, 2019).

Phase B formulated an industry-oriented Strategic Action Plan for Rwanda (i.e. NSAP). This NSAP is a tool applied to strategically plan industrial activities while coordinating horizontally between districts and vertically between ministries, national governmental institutions and districts (ITC & UN-Habitat, 2019). It aims to support regional economic development by aligning spatial planning among DDS and the NST1 and by providing better distributed budgeting: maximising the benefits of industrial investments. In other words, the NSAP aims to avoid that districts propose similar industrial development projects and stimulates complementary planning on the potentialities of other districts (ITC & UN-Habitat, 2019).

In the NSAP, Economic Specialisation Areas (Table 1) were obtained from analysing the MoF regarding industrial and manufacturing functions (ITC & UN-Habitat, 2019). The areas (Section 3.2; Figure 7) show how industry manifests itself in a territory. It is intended to use these areas to allocate strategic interventions proposed in the NST1 (non-spatially), review manufacturing and industrial activities mentioned in DDS and recommend supporting functions (i.e. transport infrastructure and services, electricity, schooling, market provision, etc.) (ITC & UN-Habitat, 2019).

Table 1: Description of industry & production based Economic Specialisation Areas (adopted from ITC & UN-Habitat, 2019).

Agriculture Production and Agro-Processing area	Include **Rural Centres** (RC) widespread across the sloping mountains or plains. Population living in this area mainly rely on agriculture and basic agro-processing industries.
Agro-Industry area	Include those **Rural Centres (RC)** and **Local Urban Centres (LUC)** located along main axes of transportation and at the road junctions of national roads. Better transportation infrastructure allows the presence of more **economic establishments and agro-industries.**
Industry, Trade and Logistic area	Include **Intermediate Urban Centres** (IUC 1,2) considered the second level of urban and socio-economic development, allowing the **presence of more industrial and trade establishments.**

3. METHODOLOGY

This chapter describes the methodology used to develop a method that integrates environmental considerations into spatial planning practices for industrial development locations. The chapter starts by introducing the research approaches (Section 3.1), which is followed by a description of the study area (Section 3.2). Then this chapter commences with describing the methodology steps that answer the research questions (summarised in Figure 6). The first of these steps (Sections 3.3 & 3.4) aimed to understand the context in which the new method ought to be applied. This includes reviewing the consideration of environment in policies and plans, the identification of environmental issues and constraining this study to flood issues. The outcome served to shape the case study; thus, providing boundaries and direction to the method's application. Subsequently, the next Section (3.5) describes the development of the method, elaborating on: identifying flood issues, the representation of these issues in the criteria tree, collecting and processing data, developing visions that reflect different stakeholders' perspectives and developing suitability maps that reflect these visions. Then, to assess the contribution of the method, Section 3.6 presents a possible approach that applies these suitability maps to assist planners with identifying suitable industrial development locations considering flood issues. Moreover, this section describes evaluating the industrial parks and the NSAP's Economic Specialisation Areas using these suitability maps. Finally, Section 3.7 describes the interview strategy conducted in support of this study.

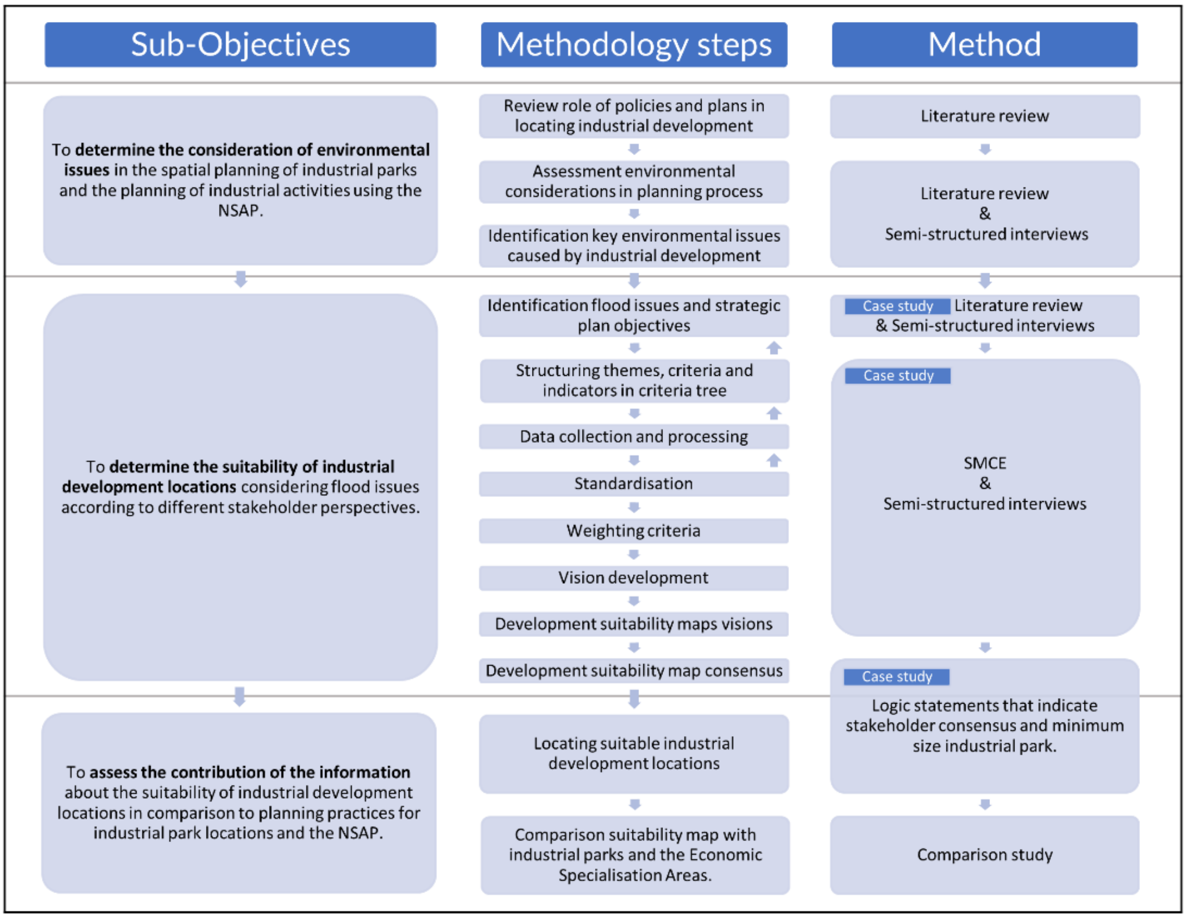


Figure 6: Methodology steps and methods applied in this research.

3.1. Research approach

In this research, a case study approach was applied to develop the method, and to test if the method can be applied to identify suitable locations for new industrial development based on environmental issues. The benefit of a case study is that it can obtain more in-depth knowledge on a contemporary phenomenon and that it gains insights into real-life events (Yin, 2003); in this case: how to include environment when planning industrial development locations, and the difference between including or not including environment through spatial planning methods that use SEA guidelines. The essence of a case study is its attempt to illuminate decisions on why they were taken, how they were implemented and with what results (Schramm, 1971). For those reasons, a case study is fit for an assessment on a method that influences the choice for an industrial development site.

According to Yin (2003), a case study is used to cover the contextual conditions that might be pertinent to a phenomenon that is studied. In this case, SEA legislation, data scarcity and challenges in institutional coordination set the conditions for method development. These conditions determine if a method can properly assess the environmental impacts of new industrial development. Moreover, this study tested the method in respect to the context provided by planning industrial development locations in Rwanda using industrialisation policies or the NSAP. Thereupon, it allows for reflection on these two spatial planning practices. Understanding this context, and how the method is rooted in this, is key for making adequate generalisations, especially since it is difficult to provide for external validation or reproduce a case study (van Tulder, 2012).

Besides the case study approach, this methodology complies with the scoping and assessments steps described by the Irish SEA guidelines (See Section 2.2). These well-established guidelines were chosen to avoid the potential gaps inherent to novel SEA regulations. Moreover, since no socio-economic issues were considered, an environmentally-focused SEA approach was conducted (See Section 2.2).

3.2. Study area

The suitability of industrial development locations was examined in the City of Kigali, which covers the districts Nyarugenge, Gasabo and Kicukiro and the district Huye. These districts were selected for the case study as they are promoted for urban development (Ministry of Infrastructure, 2015), and industrial parks (MINICOM, 2018). Currently, Kigali accommodates half of the urbanisation in Rwanda, and therefore offers a large amount of off-farm employment in industry. Huye, is a secondary-city facing a prospect of rapid urbanisation in the near future, and therefore strategies to stimulate employment in industry are under exploration (Ministry of Infrastructure, 2015). Considering these districts, allowed to investigate the difference between the largely urbanised city of Kigali and the more rural city of Huye.

Figure 7 shows the industrial sites: industrial park Huye (52ha.), Masoro (490ha.) in Gasabo district and Gahanga (41ha.) in Kicukiro district, and the Economic Specialisation Areas as defined by the NSAP. According to the Economic Specialisation Areas, Kigali, except for the North-East, is suitable for the development of all types of industry since all these types manifest themselves in the area. In the North-East, however, only the development of agricultural production and processing, and agro-industry are advised. In Huye, whereas industry, trade and logistics areas are preferably located in the centre of the district, agro-industry is recommended in most of the area and agricultural production and processing in the entire area.

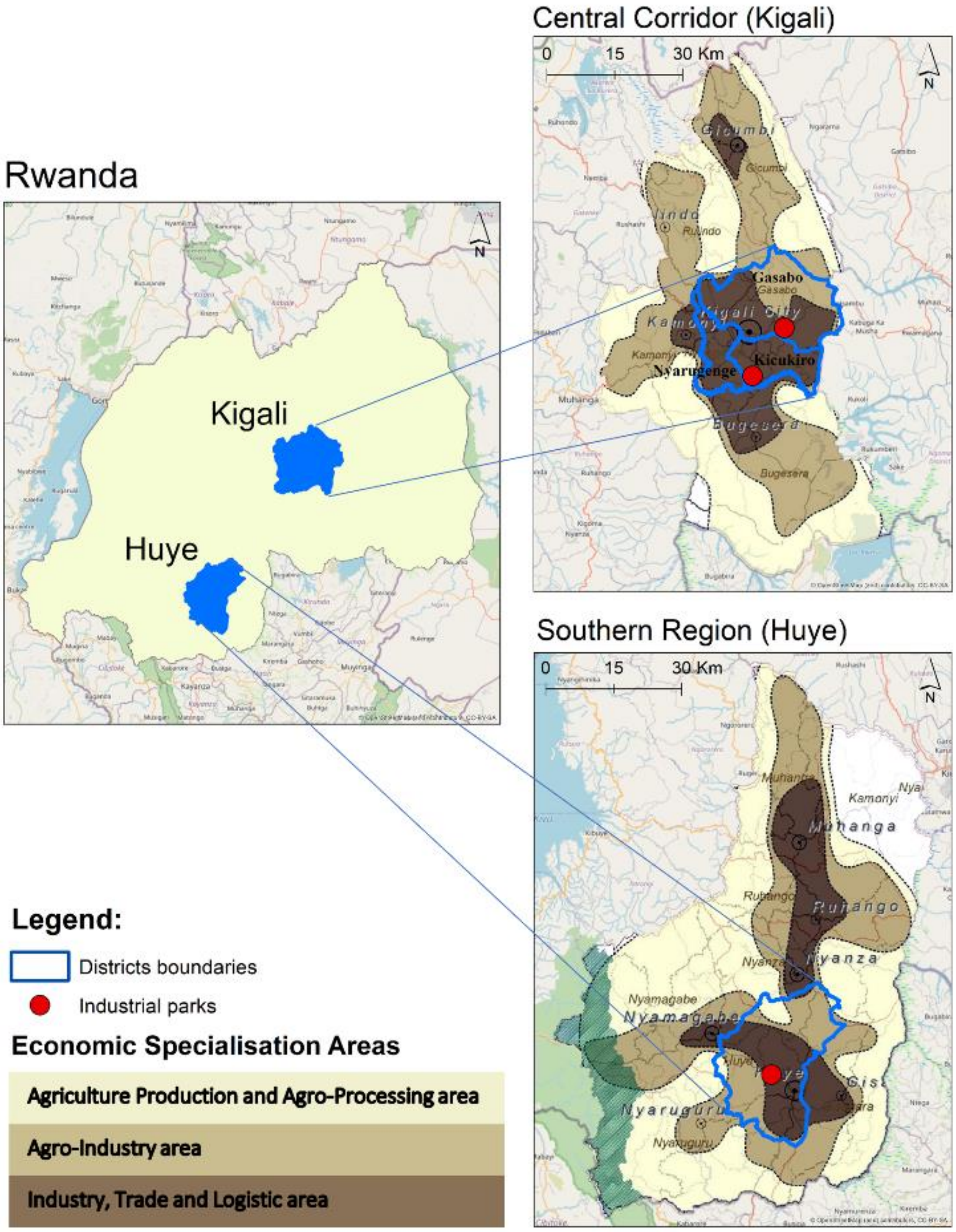


Figure 7: Industrial sites and Economic Specialisation Areas (NSAP) in Kigali and Huye.

Regarding floods, the districts in Huye and Kigali are similar. Both recognise floods as a problem (City of Kigali, 2017; Huye district, 2018; Ministry of Environment, 2018c; NISR, 2019), are covered with a large amount of wetlands and rivers and have a similar altitude and relief (MIDIMAR, 2015). A hydrological difference is that Kigali is surrounded by major wetlands, while Huye is located at the beginning of many streams (Figure 8), causing different types of floods.

Environmental issues apply to a different spatial scale than planning for industrial development. For instance, water issues do not oblige to administrative boundaries defined by districts. Instead, they apply to catchment areas (Figure 8), which can be distinguished in four catchment types based on size; ranging from Level1 (big) to Level4 (small) (Nieuwenhuis, 2019). Therefore, to adequately address flood issues, plans or programs on a district level should consider their flood effect on a catchment level, and coordination among institutions is required. Especially considering that two catchments have a catchment plan; Upper Nyaburongo (Level1) and Nyabugogo (Level2).

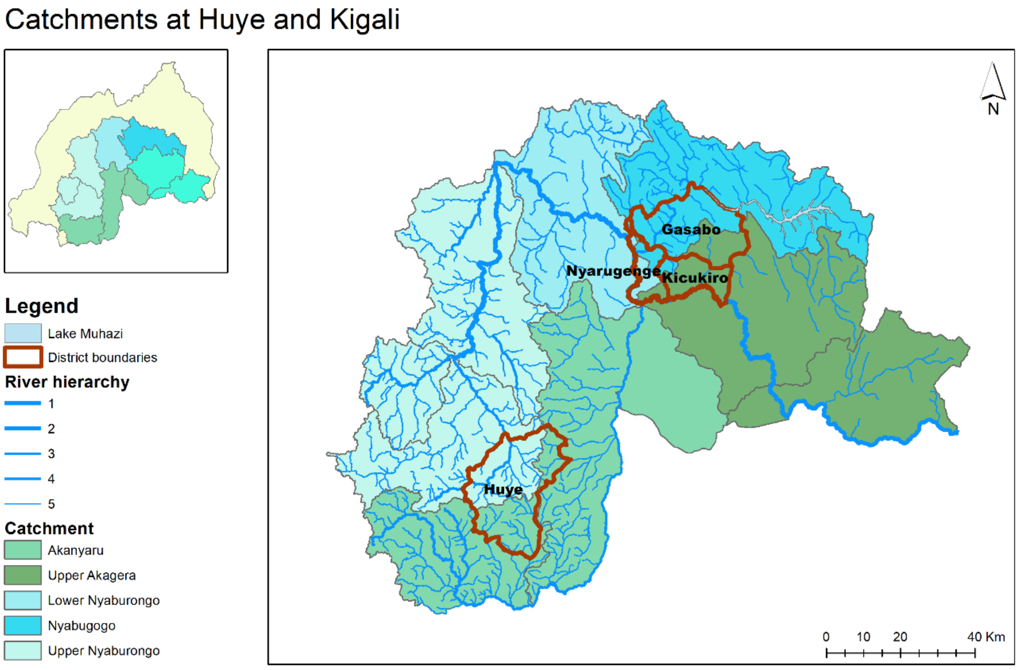


Figure 8: Overlay of the districts on Level2-catchments.

3.3. Review of industrial development planning practices on environmental considerations

In preparation for the case study and following the first steps of scoping (See Section 2.2), the institutional context was examined to determine the consideration of environmental information in Rwanda's industrial spatial planning practices and to describe the spatial planning context in which the new method will be applied. This review examined industrialisation policies that currently guide planning industrial parks, and the NSAP that ought to assists future planning for industrial activities. Moreover, it included examining other relevant policies, plans and strategies that influence planning new locations for industrial development.

The industrialisation policies and the NSAP were selected because they were developed for distinct ministries; therefore, they have a different scope, implement different methods and consequently deliver unique results. The industrial policy and SEZ-policies were analysed on their purpose, characteristics and objectives to examine their role in planning industrial park locations. Similarly, the NSAP, the SDF and underlying policies (e.g. vision 2020, NST1 and NUP) were analysed on their role in the development of the Economic Specialisation Areas, and planning industrial activities accordingly. Furthermore, the consideration of the environment was examined in both of these planning practices to identify potential planning gaps in addressing the environmental impacts from new locations for industrial development parks or activities.

This study also analysed other policies, plans and strategies to assess whether and how they include environmental considerations in planning new industrial development locations, expanding the understanding of Rwanda's spatial planning context. These documents included district development strategies (DDS) (Gasabo district, 2018; Huye district, 2018; Kicukiro district, 2018; Nyarugenge district, 2018), the Rwanda National Land Use planning guidelines (RLMUA, 2017), the City of Kigali master plan (City of Kigali, 2017), catchment plans (Ministry of Environment, 2018b, 2018c), environmental law (Ministry of Environment, 2018a) and the National Environment and Climate Change Policy (Ministry of Environment, 2019b). A more in-depth investigation was done to the regulations and the application of SEA, because for an SEA to be successful, it needs to be adapted to the situation and the decision-making context (Hildén, 1999, as cited in Azcarate & Balfors, 2009).

The documents described above were screened on their environmental considerations by selecting paragraphs and (sub-)objectives that mention: environment, ecology, wetlands, forest or environmental issues such as degradation, erosion, pollution, among others. This study strengthened this policy review by conducting semi-structured interviews with government officials that reflected on the inclusion of the environment in existing industrial planning practices.

3.4. Analysis of environmental issues

As prescribed by the scoping steps of SEA (See Section 2.2) the environmental issues that should be assessed in spatial planning for industrial development were determined. A preliminary exploration of key environmental issues was made based upon the screening of policies for environmental considerations (See Section 3.3). This exploration was complemented using a combination of primary data from semi-structured interviews and secondary data from reports, policies and plans. The latter included: the National Policy for Water Resources Management (Ministry of Natural Resources, 2011), the National Roadmap for Green Secondary City Development (Government of Rwanda & GGGI, 2015), advisory reports on natural resources and climate change vulnerability (REMA, 2019a; SHER Ingénieurs-Conseils s.a., 2014; Twagiramungu, 2006), and national forest policies (Ministry of Lands and Forestry, 2017, 2018).

As an example to illustrate SEA implementation, this research restrained to investigating environmental issues in relation to the degradation of wetlands, including drought, sedimentation, pollution, erosion and flood issues. Statements about these issues were collected, listed and grouped using the interviews, reports, policies and plans mentioned above, and additional reports and newspaper articles. Based on the availability of spatial data and the issues' importance, the case study was further limited to flood issues (See Section 3.5.1).

3.5. Suitability mapping for industrial development considering flood issues

This research adopted a case study approach to develop and demonstrate a method that informs planners about the whereabouts of industrial development locations that avoid, nor enhance, flood issues. To this end, the methodology steps described in this section aimed to produce suitability maps that depict the spatial performance of a location for new industrial development, while incorporating different stakeholder perspectives.

3.5.1. Identification of flood issues and strategic plan objectives related to floods

First, the case study proceeded with the identification of issues by adding additional and more detailed statements about flood issues. Moreover, strategic plan objectives, which were mentioned in policies and plans to improve a flood problem (ODPM, 2003, as cited in Therivel, 2004), were collected. A wide range of different flood issues and strategic plan objectives was considered to avoid issues being forgotten, because SEA has the obligation to identify potentially significant environmental impacts, which would generally be underrepresented or ignored (Sadler et al., 2011). As such, this study considered issues related to riverine floods, flash floods and water hindrance (See Section 2.3). These flood issues and strategic plan objectives were collected from reports, policy, plans, newspapers and a series of semi-structured interviews with experts (e.g. NGO and government officials from various institutions). This combination of primary and secondary data strengthened the understanding of these issues as they were listed.

This study considered two possible implications of developing new industrial locations to flood issues (Figure 9). First, industrial development affects and is affected by flood issues at the industrial location itself, for instance, when industry is located in or near wetlands. In that case, industrial development should avoid those places likely subjected to floods or water hindrance. At the same time, new industrial development also increases flood issues elsewhere, downstream of its location. In that situation, locating industrial development should avoid changes that lead to enhanced floods downstream.

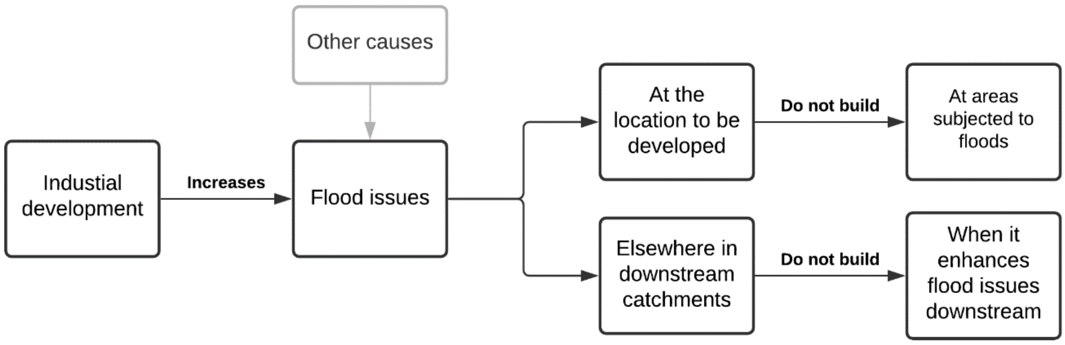


Figure 9: Implication of industrial development to flood issues.

3.5.2. Spatial multi-criteria evaluation

After the identification of flood issues, this study demonstrated the Spatial Multi-Criteria Evaluation method (SMCE). This method complies well with the SDF methodology (See Figure 4) and is appropriate for SEA studies (Thérivel, 2004). Thereupon, the SMCE can evaluate the performance of key themes against existing development policies as intended by the SDF (Boerboom et al., 2015); and at the same time assess environmental impacts following SEA guidelines (Thérivel, 2004). For this reason, the SMCE may be an appropriate method to integrate environmental considerations into the planning practices for industrial park locations or the planning of industrial activities using the NSAP from the SDF.

Besides, this study aims to demonstrate other benefits of the SMCE to industrial spatial planning practices. First of all, SMCE allows co-design and decision-making among stakeholders with different views by facilitating to achieve a mutual understanding of the situation and transparency in decision-making (Thérivel, 2004). Second, it can give an impression of cumulative environmental effects combining a wide range of indicators (Thérivel, 2004). Third, it can manipulate large amounts of datasets relatively easily (Thérivel, 2004).

The SMCE applied a value-focussed approach as demonstrated by Zucca et al., (2008) (See Section 2.1.2) to organise its activities. This order ensured that flood issues are addressed in the early stages of planning through the development of criteria before alternative industrial development locations are developed. As such, the case study maintained a broad strategic scope, whereas this scope would be limited when working with a set number of alternatives from the start.

The SMCE was conducted in ILWIS 3.8.6[1] software, which was also used to perform the SMCE in the SDF. Another advantage is that the software is open source and that it has a built-in spatial multi-criteria tool, which is convenient in situations characterised by low financial and human resources.

Conducting SMCE is typified by the challenge of embedding meaningful criteria that depict environmental issues and by providing accurate data to measure these criteria. To address these limitations, the focus of this study was on what was possible. In other words, this study explores a wide selection of promising criteria and data to overcome difficulties in data availability and finding relevant criteria.

3.5.2.1. Establishing the criteria tree

As a first step of the SMCE, the flood issues were translated into SEA-objectives, criteria and indicators to form a criteria tree. First, to select the key flood issues, the issues and strategic plan objectives collected were filtered based on their spatial implication and the strength of their causation with industrial development. Second, the selected key issues were compiled into overarching themes; each theme represented by a single SEA-objective. These SEA-objectives set the aims against which the effect of new industrial locations on flood issues can be evaluated (Scott & Marsden, 2003) (See scoping steps SEA; Section 2.2). Third, criteria were specified that indicate to what extend SEA-objectives are achieved at a location. Thereby, criteria provide the evidence upon which a decision can be based (Eastman, Jin, Kyem, & Toledano, 1995). These criteria consisted of constraints and factors. The constraints indicate absolute thresholds, which cannot be compensated by the (good) performance of other criteria, whereas the factors can be compensated by other factors. Besides, these factors show a degree of suitability by assessing the extent to which that factor is relatively favourable or unfavourable. Finally, for each criterion, a corresponding indicator to track its achievement was defined (Thérivel, 2004). This process resulted in a first concept of the tree that served as a framework for further spatial data collection.

The process of developing a criteria tree was an iterative process (Thérivel, 2004) that adapted based on proceeding insights from literature and interviews with experts in the field, the availability of spatial data to measure indicators and the choices made in the selection process. When indicators change, criteria and SEA-objectives were reformulated to achieve alignment within the criteria tree, and vice versa alterations to criteria influenced indicators and guided further spatial data collection.

A couple of considerations guided the formulation of the tree, the SEA-objectives (i.e. themes) and criteria. First, a thought-out selection of SEA-objectives and criteria is crucial because their inclusion or exclusion can greatly influence the results when evaluating an industrial location. On the one hand, the set

[1] https://52north.org/software/software-projects/ilwis/

of evaluation criteria should be complete to ensure that all aspects of a decision problem are encompassed (Malczewski & Rinner, 2015); on the other hand, the number of criteria should be kept to a minimum to reduce the complexity of the evaluation process (Keeney & Raiffa, 1993 as cited in Malczewski & Rinner, 2015). To add, according to Karlsson et al., (2017), the number of elements in the SMCE should not be more than seven because it exceeds the human capacity for processing information. Second, the formulation of SEA-objectives and criteria should point out the potential impact caused by industrial development clearly. Hence, the following reasoning was used: Which locations are more suitable for new industrial development as they have a smaller impact on flood issues both at the location to be developed and the area downstream of the development? Conform to SEA, this reasoning centralises the source of a problem, or to put it differently: starts reasoning with the proposed change in mind; i.e. industrial development. Third, SEA criteria should ensure that the impact from development does not exceed limits beyond which irreversible damage may occur. This requires the identification of these limitations (Thérivel, 2004) and their translation into constraints. Last, Keeney & Raiffa, (1993) (as cited in Malczewski & Rinner, 2015) state that criteria should be operational to be used in analyses, non-redundant to avoid the problem of double counting and decomposable to simplify the process by splitting criteria into parts.

3.5.2.2. Spatial data collection and processing

Spatial data related to wetlands and floods were collected, listed, assessed on its quality (e.g. completeness, scale and year) and then matched with the criteria and indicators. These source data were obtained from governmental institutions, ministries, and open-source geoportals. The most recent datasets and data used by the Ministry of Infrastructure (MININFRA) were preferred.

Appendix V: Data processing & Standardisation of indicator maps describes the processing of source data to indicator maps (i.e. raster) that depict the spatial influence of the criteria at a resolution of 100x100m^2. This resolution was selected based on the size of industrial parks and the software's processing speed. This processing included the transformation to distance maps, the projection of values to a catchment scale, a frequency analysis to calculate the return period of rainfall, the SCS-method to describe the hydrologic properties of land-uses, the change of units to make indicators within the tree comparable and the separation of upstream catchments from downstream catchments to simulate river characteristics, among others. Depending on the procedure, pre-processing occurred in the software Arcgis 10.7.1, Excel or ILWIS 3.8.6.

3.5.2.3. Standardisation of indicator maps & Weighting of factors

After data processing, the indicator maps were standardised, and the factors specified under each SEA-objective (i.e. theme) were weighted. This resulted in a suitability map depicting the spatial performance of locations for new industrial development in respect to each flood issue theme (i.e. SEA-objective).

First, each indicator map was standardised to be able to compare factors with each other. The values in these indicator maps were transformed using value functions to normalised values on a scale of 0 to 100; of which the value 100 indicates a better performance. That is to say, a value closer to 100 is more suitable for industrial development. These value functions were established considering the literature and the input from experts, and could take a variety of linear and non-linear forms. However, in cases of doubt, a linear function was used. The standardisation of each indicator is substantiated in Appendix V: Data processing & Standardisation of indicator maps.

Second, the factors within the themes were weighted to indicate the importance of factors compared to each other, thus determining the factor's influence on the performance of a flood issue theme. These weights were assigned using different weighting schemes (e.g. direct weighting and ranking with expected values) and based upon literature and qualitative data from expert interviews. When no supporting evidence was found to justify the weights, equal weights were assumed.

3.5.3. Development of visions

This study drafted four visions and a consensus situation to determine alternatives for industrial development locations (See last scoping step SEA; Section 2.2). The incorporation of these visions aimed to illustrate decision-making among stakeholders with different views.

These visions were developed as follows: First, statements that illustrate stakeholder perspectives were collected from literature and stakeholder interviews. Second, these statements were reviewed against several topics for debate that cover various contrasting perspectives about what a suitable location for industrial development defines. Third, based on this review, visions that are significantly different from each other were formulated. As such, a framework for strategic planning was established that encompasses a wide range of opinions about the suitability of a location for industrial development in regard to flood issues. Thus, addressing standpoints in the debate about: how and how much industry impacts flood issues, what issues form the most significant thread and how this translates to the suitability of a location for potential development.

The visions were distinguished by prioritising the themes (i.e. SEA-objectives) that are most in concord with the description of a vision. The prioritized themes were emphasised by assigning them high weights in the criteria tree, using ranked weighting (i.e. expected values). Subsequently, this resulted in four composite index maps that describe the relative suitability of a location according to the visions, and a consensus index map that indicates the common ground among stakeholders. Each of these maps could be used to propose different alternatives for industrial development locations. It was assumed that development is certainly implemented. Therefore, this study did not compare; development with no development.

3.5.3.1. Perspectives on: the suitability of a location for industrial development considering flood issues

Below four topics for debate used to establish distinct visions are elaborated. These topics discuss different perspectives about what defines a suitable industrial development location that avoids, nor enhances, flood issues.

Topic 1: Compliance to legislation

Perspectives could argue that a strict compliance to legislation is sufficient to locate industrial development or they could express a need for a broader consideration of flood issues. The former would be limited to restrictions described in law or policy, while the latter would also include flood issues obtained from reports and stakeholders.

Topic 2: Spatial implication from industrial development

Another discussion relates to the spatial implication of new industrial development, as mentioned before in Figure 9: Implication of industrial development to flood issues. . It reasons that perspectives could prioritise either the local implication from new industrial development or its broad catchment-wide implication. Considering the former, development addresses flood issues at the development site itself. In contrast, the latter addresses the impacts of development on flood issues elsewhere, downstream of the location, and is concerned with the impact of constructing industry on the overall hydrologic regime in the entire catchment.

Topic 3: Risk
Perspectives could emphasize avoiding group risk or individual risk. Individual risk is defined as the probability of an individual person at risk and group (or societal) risk as the probability of a population at risk (Jongejan, Jonkman, & Maaskant, 2010). In this study, individual risk refers to flood issues affecting one industry, while group risk relates to the exposure of multiple assets or stakeholders to flood issues.

Topic 4: Social, economic and environmental pillars of sustainability.
Perspectives could favour one of the social, economic or environmental pillars of sustainability. In essence, to achieve sustainability, decisions aim to address all of these pillars because they are mutually dependent on each other (Higgins, 2013). Nevertheless, in decision-making, the extent to which the plans' objectives should meet each of the pillars is debatable.

Within this topic, some sub-topics are distinguished. The first sub-topic encompasses a debate relating to water management based on the Cultural Theory (Thompson, Ellis, & Wildavsky, 1990). According to the Hierarchist's perspective in the Cultural Theory, water management is an integral part of spatial planning. As such, industries are located with the idea that flood waves can be controlled with solutions such as raising dykes, channelling or other discharge control systems. In contrast, the Egalitarian perspective argues that water would steer spatial planning, and that water needs space to flow freely. It strives to keep nature untouched to address flood issues effectively (Haasnoot, Middelkoop, Offermans, van Beek, & van Deursen, 2012; Middelkoop et al., 2004). The second sub-topic questions: who carries the costs from increased flood issues? To clarify, building an industrial complex in a flood risky area generates costs in the form of extra maintenance, mitigation measures and insurance, but would it also cover the potential cost from flood damages in communities nearby?

3.5.3.2. Consensus

The four visions' suitability maps were compiled, and a binary suitability map was calculated to simulate an occasion when consensus between stakeholders is achieved. Logic statements were applied to each map to rule if a location would exceed the suitability standard set by the consensus (See Eq. 1). To illustrate, if a location scored suitable according to three visions and unsuitable in the fourth vision, then the consensus was found to be unsuitable, while if all visions indicated suitable, the consensus was found suitable as well.

$$Y_{Consensus} = (X_{Vision1} > I) \wedge (X_{Vision2} > I) \wedge (X_{Vision3} > I) \wedge (X_{Vision4} > I) \quad \text{(Eq. 1)}$$

Where $Y_{Consensus}$ indicates if a grid cell is suitable (True) or unsuitable (False) according to the condition set by I. X is the index value of a grid cell at a designated location. I is the threshold indicating the suitability standard distinguishing between suitable and unsuitable and $\wedge$ is the logic symbol for "and". Four different suitability standards were tested (e.g. I=40, 50, 60 and 70). These were compiled into a single map to show the influence of changing the suitability standards.

3.6. Applying suitability maps to design and assess industrial development locations

After the SMCE, the suitability maps were applied to design potential alternative industrial park locations and to evaluate designated industrial development locations. These applications explored the potential contribution of the SMCE method and technology to current spatial planning practices. Moreover, they illustrated an approach that assists planners to locate industrial development based on flood issues.

In correspondence with the last scoping step of SEA (See Section 2.2) and to simulate spatial planning practices, possible suitable alternatives for industrial park locations were designed using the consensus map that shows areas with a suitability value (I) >60. Three industrial parks were proposed, alternatively to the existing parks. These parks were located in the same districts as the existing parks and had roughly the same sizes for adequate comparison. First, area numbering in Ilwis was applied on the consensus map to construct stand-alone, but horizontally and vertically connected areas. Second, the size of these areas was calculated and areas smaller than respectively 490ha. (Masoro), 41ha. (Gahanga) and 52ha. (Huye) were discarded. Third, in Arcmap, three potential industrial parks were drafted as polygons near the existing industrial parks. Fourth, statistics on the themes were collected using zonal statistics to compare the park designs with the existing parks and to investigate the flood issues more likely to occur in each park.

Last, this study conducted an ex-post evaluation for the industrial parks in Huye and Kigali and the NSAP's Economic Specialisation Areas. This evaluation reflected on the impact of designated industrial development plans on flood issues in comparison to the alternatives designed using the SMCE method (See assessment component SEA; Section 2.2); consequently, it aimed to identify potential improvements to the industrial plan. The industrial parks and areas were compared with five suitability maps representing four visions and consensus. On a local scale, industrial parks were analysed visually and using zonal statistics to see which park performs best for which vision and consensus. Regionally, a visual examination of the Economic Specialisation Areas investigated the SMCE method's contribution to guiding the placement of new industrial activities.

3.7. Interview strategy

Semi-structured interviews, as described in Fylan, (2005) and van Tulder, (2012), supported the analysis of environmental considerations in the prevalent planning practices and the development of the SMCE model. Due to its narrative form and the possibility to ask follow-up questions, this method allowed an in-depth examination of environmental considerations, flood issues and visions. Moreover, it explored vital info that otherwise would be missed. The disadvantages of semi-structured interviews are the difficulty of reproduction, the loss of external validation and the difficulty to come up with generalisations (van Tulder, 2012). However, these disadvantages were minimised since the interviews were conducted complementary to the literature review, increasing this research validity.

The interviews covered four topics (Table 2), addressing:

1. The consideration of the environment in spatial planning practices according to government officials.
2. The identification of environmental issues and the development of a criteria tree prototype for flood issues; consulting experts in environmental or water management.
3. Prototype review with stakeholders for vision creation, collecting perspectives on what defines a suitable location with respect to flood issues. These visions were drafted after the field study.
4. Case study validation, providing recommendations and improvements to strengthen the model as part of its ongoing development.

Besides discussing these topics, the interviews served to collect data. Appendix VII: Information sheet consent interview shows an overview of the session objectives, content, logistics and guiding questions that guided these interviews.

Table 2: List of participants and topics covered, with recorded interviews (Rec.) and non-recorded interviews (X).

		Topics			
Organisations	**Reference interviewee**	**Consideration environmental information**	**Environmental issues**	**Weighting & visions**	**Evaluation**
NGO	Participant: NGO1		Rec.		
Ministry of Environment	Participant: MoE1	X	X		
	Participant: MoE2		X	Rec.	Rec.
Rwanda Environmental Management Authority	Participant: REMA1	X	X	X	
	Participant: REMA2	X	X	X	Rec.
Rwanda Water Resource Board*	Participant: RWB1	X		X	Rec.
	Participant: RWB2		X		
City of Kigali, Environmental department	Participant: CoK1	X			
Huye district office	Participant: Huye1	Rec.			Rec.
Ministry of infrastructure	Participant: MININFRA1				Rec.
	Participant: MININFRA2				Rec.
	Participant: MININFRA3		X		
Rwanda Housing Authority	Participant: RHA1		X		
Rwanda Land-use authority	Participant: RLMUA1		X		
	Participant: RLMUA2	Rec.		Rec.	
Total		7	8	5	6

*Formerly a department of Rwanda Water and Forest Authority (RWFA)

In total, 18 interviews were conducted, sometimes covering multiple topics, with 15 different participants, representing 9 different organisations. 8 Interviews were recorded, as the interviewee did not always approve of being recorded. The group of participants consisted of an environmental NGO, which was contacted through an online inquiry and government officials from various institutions contacted after preliminary interviews with MININFRA and the Ministry of Environment. These participants were selected based on their background in either environment, SEA or SDF. Moreover, a wide selection of participants from different disciplines was strived for: to achieve inclusiveness of many parties conform to SEA (Jones et al., 2005) and to provide several distinctive perspectives for vision development. Last, since SEA should provide for active involvement and discussion opportunities throughout the entire decision-making process (Walker et al., 2016), the study aimed to involve interviewees throughout the whole case study, from identifying issues until creating visions. Consequently, this allowed interviewees to contribute at various stages of the criteria tree's ongoing development process.

4. RESULTS

This chapter describes the method developed to assess the suitability of industrial development locations using information on flood issues. First, to address Sub-objective 1, Section 4.1 describes the consideration of the environment in spatial planning practices for industrial development, providing an understanding of the planning context to which the method should contribute. This is followed by a description of the environmental issues (Section 4.2), which were reduced to a collection of key flood issues that relate to industrial development (Section 4.3.1). Based on this collection of flood issues, the SMCE method was developed, beginning with describing five SEA-objectives (Section 4.3.1.3) to establish a criteria tree (Sections 4.3.2). Next, the expression of stakeholder perspectives by means of four visions and consensus led to five suitability maps that illustrate different options to determine suitable locations for industrial development (Section 4.3.4) (See Sub-objective 2). Accordingly, to assess the contribution of the method's information (See Sub-objective 3), Section 4.4.1 demonstrates a five-step planning approach that uses these suitability maps to suggest better performing alternatives for industrial development locations in regard to flood issues. This chapter concludes by comparing these suitability maps with industrial parks (Section 4.4.2) and Economic Specialisation Areas (Section 4.4.3). This comparison showed that, when considering flood issues, industrial parks were not located at places valued as highly unsuitable and that Economic Specialisation Areas covered large parts of unsuitable land, especially in the North-West of Kigali.

4.1. Environmental considerations in spatial planning for industrial development locations

For industrial planning to be sustainable, a location must consider a wide range of factors representing multiple social, economic and environmental impacts (Ruiz et al., 2012). Thus policies and plans that guide planning industrial development locations ought to describe how the impacts on environment are considered.

Examining the interviews gave the impression that the consideration of environment in plans lacked. For instance, participant RWB1 stated that, most of the time, environmental components were not included in master plans and participant RLMUA2 addressed that data about environmentally sensitive areas is not always used to support decision-making. Instead, plans tended to focus on economic, agricultural and transport aspects (Participant: RWB1) and the benefits of industrial areas for job creation and socio-economic development (Participant: MoE2). Accordingly, the need for more comprehensive plans was expressed (Ministry of Environment, 2018b; Nabahungu, 2012) (Participant: RLMUA2) to include environmental aspects such as: land-use; the recurrent conflict between agriculture and environment (Participant: RLMUA2); stormwater planning (Participant: MoE1); the consequences of floods; and the multiple benefits of wetlands (Nabahungu, 2012), among others.

4.1.1. Plans that guide industrial development

Examining the National Industry Policy and SEZ policies that guided locating industrial parks showed that the feasibility studies were described as superficial (UNIDO, 2016) and lacking (Fiave, 2020), considerably due to the absence of robust market demand analysis and financial feasibility studies (UNIDO, 2016). Moreover, factors that determine the suitability of locations were missing (Fiave, 2020; Marete, 2020) (Participant: Huye1). Consequently, as of 2020, because difficulties in developing these areas exist (Fiave, 2020), only a few industries were developed in the zoned industrial parks (Participant: Huye1).

Despite the lack of studies, which suggests the absence of environmental considerations, Environmental Impact Assessments (EIA) were conducted, and law and policy constraints were applied for single industrial projects within the parks (Participant: CoK1; REMA2) (MINICOM, 2018). The EIA studies were performed after a site was selected to make local adaptations or to apply mitigation measures (Participants: CoK1; Huye1; REMA2). However, to assess industrial park locations on environmental impacts, a SEA should be conducted. The implementation of such SEA has been absent (MINICOM, 2010; UNIDO, 2016).[2]

Outside of the industrial parks, individual industrial units for light industry could be located using the land-use master plan (Participants: RLMUA1; REMA2). It is intended that every development plan is guided by this master plan (The Republic of Rwanda, 2012). It includes those rules set by the environmental law (Participant: RLMUA2), and adopted the planning guidelines for flood-prone areas, wetlands, rivers and lakes (RLMUA, 2017) (Participant: REMA2). However, the translation of the land-use master plan to DDS on a local district level has proven difficult (The Republic of Rwanda, 2012) (Participant: RLMUA2). By the same token, it was mentioned that land-use planning, including locating industries, could benefit from local input (Participant RLMUA2; Huye1; MININFRA1).

On a regional scale, the SDF's NSAP spatially supports the NST1 and the DDS to locate investments for new industrial activities and supporting functions (i.e. transport infrastructure and services). However, because the NSAP was obtained from the MoF, it merely describes how industrial and manufacturing functions manifest themselves in Rwanda (See Section 2.4.3.1). Notably, it does not consider environmental constraints or factors. Nevertheless, several possibilities to integrate environmental considerations in these plans or the SDF methodology exist. These possibilities are presented below:

1. **SDF-methodology** (Figure 10):
   a. **Next to the MoF for industrial functions**
   A possible addition to the SDF is to include environmental functions next to the MoF. These functions can take the form of ecosystem services. A table can be drafted indicating the presence of a well-performing ecosystem service in an administrative unit. This can identify strengths, potentialities or the absence of environmental functions.
   b. **Consultations**
   It is possible that the environment was or will be mentioned during the consultative workshops of the SDF.
   c. **Performance indicator in SMCE**
   Indicators in the SMCE can measure the performance of the environment. Currently, environment is partly considered in the SDF since the SMCE addresses the NUP's four policy pillars (ITC & UN-Habitat, 2019), and the NUP includes some environmental considerations. In general, the NUP recognises the links between economic opportunities and environment and calls to initiate green growth criteria and mitigate negative environmental and social costs resulting from urban development. The policy pillars elaborate on this by targets related to green economic growth, efficient land-use based on green development principles and environmentally sensitive areas (Ministry of Infrastructure, 2015). However, these targets do not address the environment in detail (Participant: MININFRA1), do not relate to wetlands and are not always measurable.

[2] The SEZ policy (MINICOM, 2010) together with its revision (MINICOM, 2018) is the acting policy in 2020 guiding industrial park development. MINICOM (2018) updated the 2010 policy in regard to EIA, but did not make amendments to implement SEA.

Moreover, the inclusion of potential environmental impacts in the SMCE was not all-encompassing because the NUP was not yet supported by a SEA study. Nonetheless, an ex-post SEA is planned to be conducted on the NUP, which will include challenges such as increased flooding, among others (Earth Systems, 2020). Although performing this SEA might lead to different NUP targets, no intention to include these adapted targets was mentioned.

2. **NST1**
   An objective mentioned in NST1 is: "Sustainably exploit natural resources and protect the environment" (The Republic of Rwanda, 2017). Adopting this objective from NST1 through the NSAP or industrialisation policies can steer sustainable industrial development.
3. **DDS**
   A DDS points out the environmental issues present in a district. For example, the Huye DDS stated environmental weaknesses such as limited awareness on disaster risk reduction and mitigation, limited initiatives in sustainable use of natural resources and environmental management, among others (Huye district, 2018). Likewise, the Kigali city development strategy foresees wetland planning, stormwater management systems and the problems related to people living in high-risk zones (City of Kigali, 2017). Such planning related to wetlands or high-risk zones could influence locating industrial parks.

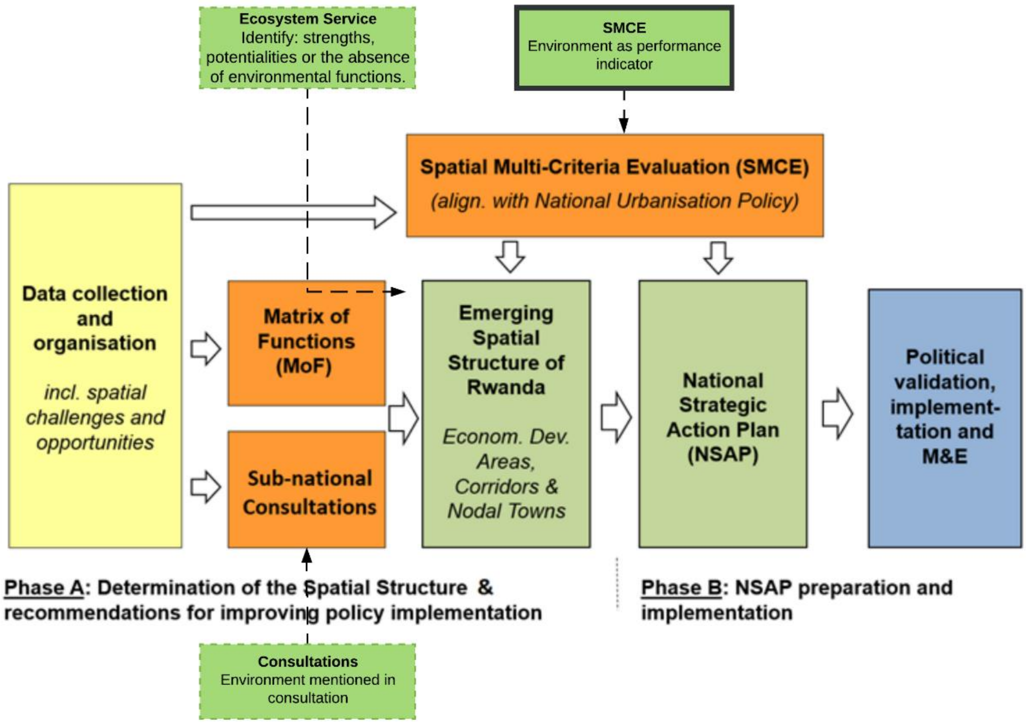


Figure 10: Possibilities to integrate environmental considerations in the SDF methodology of Rwanda. Green: possible considerations of environment (adapted from ITC & UN-Habitat (2019).

4.1.2. Environmental policy and plans

Besides the policies and plans that locate industrial development described above, other policies and plans such as environmental policy, land-use plans and catchment plans have a role in incorporating environmental considerations in spatial planning. In general, environment is considered as a cross-cutting area in the Rwandese planning framework (Ministry of Environment, 2019b; The Republic of Rwanda, 2017) (Participant: CoK1); therefore, the effectiveness of these environmental policies and plans depends on their integration into policies and plans that guide locating industrial development.

This was also recognised by NST1 that states that the focus of environment and climate change is to improve cross-sectoral coordination that ensures a smooth implementation of environmental policies and regulations (The Republic of Rwanda, 2017). Specifically, it identified agriculture, urbanization, infrastructure and land use management as critical environmental sectors that should be strengthened.

Moreover, a rationale to establish a new environmental policy was the lack of effective and appropriate mainstreaming with environment policy in some sectoral activities (e.g. unsustainable use of wetlands, water resources, environmental budgeting, etc.) (Ministry of Environment, 2019b). Accordingly, a prerequisite for fully implementing policy actions was to have clear roles and responsibilities in coordination among all institutions since limited coordination in environmental and climate change governance exist (Ministry of Environment, 2019b).

Last, according to Nabahungu (2012), wetland management is complicated due to the absence of spatial planning policies, the distinction of wetland types and well-defined wetland conservation measures. In addition, Nabahungu (2012) described the communication between ministries (e.g. environment, infrastructure, economic planning and finance, and tourism) as inefficient or non-existent and noted some contradicting policy papers. In those circumstances, the catchment plans stated that a key requirement for their effective implementation is their integration into relevant laws, policies, programmes and plans; markedly, this integration should be reflected in DDS (Ministry of Environment, 2018b, 2018c). Moreover, the catchment plans argued for cross-sectoral cooperation at catchment scale (Ministry of Environment, 2018b, 2018c). They state that for their effective implementation, central government agencies such as MINIRENA, MINAGRI and REMA should improve coordination with local governments to integrate and align catchment-wide activities across the DDS's (Ministry of Environment, 2018b, 2018c).

A cross-cutting process to improve integrating environmental considerations in planning practices is SEA. However, considering its recent implementation in Rwanda, SEA regulation, as well as the interconnected EIA processes and legislation, are still under development (Marara et al., 2010; Nieuwenhuis, 2019). Correspondingly, there has been a gap in implementing SEA practically due to the limited experiences with the process (Participants: MoE1; MoE2; REMA1; REMA2; MININFRA2), the shortcoming of trained officials that understand and act on SEA reports (Participants: CoK1; MoE1; RWB1) and the lacking enforcement of SEA related regulations and laws (Ministry of Environment, 2017) (Participant: MoE2). Under those circumstances, the possibility exists that SEA merely becomes a process to fulfil an institutional need embedded in legislation, while it should be a way to promote sustainability needs in policies, plans and programmes, also for the developments of places.

Besides these difficulties in implementation, SEA in Rwanda faced other challenges. For one, the interviewees indicated that stakeholder consultations in the SEA process have not always been extensive enough for full participation (Participant: MoE2), and correspondingly, some challenges expressed by governmental institutions were not included in SEA and plan-making (Participant: RLMUA2). Moreover, the absence of practical planning methods (Participant: MoE1) and data (Participants: MININFRA1; MoE1; RWB1) troubled extensive and quantitative environmental analysis. Most importantly, although SEA ought to be conducted prior to decision-making about industrial development locations, in reality, SEA was implemented reactive, after selecting the site, and performed with urgency (Participant: MoE2). Consequently, SEA does not contribute to the development of alternatives for these sites, nor informs other decisions taken early in the planning process (See Figure 1).

4.2. Environmental issues

Environmental issues directly linked to industrialisation were: the increase and inadequate treatment of pollution such as chemicals, dust, smoke, smell, noise, industrial waste and liquid waste water (REMA, 2017; Twagiramungu, 2006) (Participant: MoE2); soil erosion and increased siltation caused by clay production, mining and solid waste (e.g. sand, cement, plastics among others) (Ministry of Environment, 2018b, 2018c) (Participant: NGO1); and water abstraction by industrial activities that contributes to the overexploitation of lakes and water reserves (Ministry of Natural Resources, 2011; Twagiramungu, 2006) (Participant: REMA1). Moreover, some problems related explicitly to the location of an industry, including: the construction near residential areas (Twagiramungu, 2006); the degradation of land due to industrial expansion and related pressures from mining, deforestation and other forms of land-use change (Ministry of Lands and Forestry, 2017, 2018; Ministry of Natural Resources, 2011); and the development of industry in and near fragile ecosystems such as wetlands (MIDIMAR, 2015; Ministry of Environment, 2019b). Many of these issues were driven by land scarcity (MIDIMAR, 2015) (Participant: MoE2) and a high population density or population growth, along with other interrelated drivers of improved standards of living and economic development (Ministry of Environment, 2018b, 2019b).

This study found that a recurrent issue was the degradation of wetlands as a consequence of land-use change (Matto & Jainer, 2019; NISR, 2019), droughts (Nabahungu, 2012; REMA, 2019a), water pollution (Ministry of Natural Resources, 2011; REMA, 2017), sedimentation, siltation, erosion (Ministry of Natural Resources, 2011; Twagiramungu, 2006) and frequent floods (Twagiramungu, 2006) (Participants: Huye1; NGO1). Although, the Nyabugogo catchment plan issued that the development of industrialization in Economic Zones and industrial parks is a driving force of these issues (Ministry of Environment, 2018b), they generally had multiple causes of which industrial development can be one of many. In fact, in many instances, industries were nor the main contributor nor had an exact causal relationship with environmental issues. However, it was argued that cumulatively with other causes of flood issues they contribute, especially when considering larger projects such as Rwanda's industrial parks that can cover 37.9ha. up to 489.6 ha. Statements about issues related to drought, pollution, sedimentation, siltation and erosion obtained from literature and interviews were listed with their sources and grouped in Appendix II: Drought, Pollution, Sedimentation, Siltation and Erosion.. Likewise, Appendix I: Flood issues., shows an inventory of the flood issues.

The assessment of environmental issues showed that flood issues in particular were viewed as a critical. Over the years flooding became a prevalent topic on the political agenda (Ministry of Environment, 2019b) (Participants: RWB1; MoE1). Moreover, an abundance of literature identified floods as a threat to the state of wetlands, including Ministry of Environment, (2018c, 2018b, 2019), REMA, (2017) and Twagiramungu, (2006). For this reason, and the availability of spatial data, which was more difficult to collect for pollution and droughts, flood issues were further examined in the case study.

4.3. Case study: Suitability mapping for industrial development considering flood issues

The case study served to determine the suitability of industrial development locations based on flood issues and stakeholder perspectives (Sub-objective 2), thus demonstrating the method development. The first Section (4.3.1Flood issues) of the case study presents the flood issues that were key to consider when appointing a suitable location for industrial development. It describes the state of flooding to indicate the severeness of floods and the consequences of flooding in the study area. Then it lists the key flood issues that relate to industrial development (Table 3). Furthermore, it shows the SEA-objectives that were established to address these issues (Table 4). The second, third and fourth sections describe respectively the criteria tree (Section 4.3.2), the suitability in the study area per theme each reflecting a SEA-objective (Section 4.3.3) and the visions developed to map suitability for industrial development (Section 4.3.4).

4.3.1. Flood issues

Floods in Rwanda were described as a result of a combination of steep topography, high intensity rainfall and the inability of the hydrologic system to retain and store water (Habonimana, Bizimana, Uwayezu, Tuyishimire, & Mugisha, 2015 as cited in REMA, 2017; Ministry of Environment, 2018b; NISR, 2019). Since 1990, the incidence and magnitude (e.g. high water level, velocity and rising time) of these floods has increased (NISR, 2019). In particular, changes in geographical conditions have contributed to this increase by altering water regulation (e.g. infiltration, retention and storage) in the system (Ministry of Environment, 2018b; NISR, 2019; SHER Ingénieurs-Conseils s.a., 2014). Accordingly, changes in these conditions worsen local water hindrance or upstream enhanced floods, thereby affecting the industry present in areas that tend to be prone to flooding. Vice versa, new industrial development can change upstream conditions increasing the impact of floods downstream.

4.3.1.1. State of flooding

Examining the state of flooding in the study area showed that, although the mean rainfall per year has been constant from 1961-2016 (REMA, 2019b), the intensity of showers in Rwanda was perceived as increasing (REMA, 2017, 2019b; SHER Ingénieurs-Conseils s.a., 2014). Especially, the events during December 2019 and January 2020 were described as unusual (Participants: MoE1; REMA1). Furthermore, river flows were observed as being unstable (NISR, 2019; SHER Ingénieurs-Conseils s.a., 2014). In Rwanda, over the last 25 years, quickflow (i.e. a measure for disruptive water that runs off quickly during or after a storm characterised by flooding, biodiversity loss, soil erosion, soil loss and poor water quality) in billion m^3/year, has increased by 35%. Within Huye's jurisdiction, this was: 62% in the Upper Nyaburongo and 10% in the Akanyaru catchments. In Kigali, the Lower Nyaburongo and the Nyabugogo catchment together had a 51% increase and the Upper Akagera catchment 31% (NISR, 2019).

This increasing trend of floods has been evident in Huye and Kigali. In Kigali, rainfall events cause rapid surges in the rivers and drainage systems, leading to floods downstream (Matto & Jainer, 2019). Consequently, the low-lying area around Nyabugogo bus station and markets have been prone to frequent flooding (Ministry of Environment, 2018b) (Figure 11). Furthermore, flooding is common in several Kigali neighbourhoods (Matto & Jainer, 2019), where floods have significantly increased in the wetlands and valleys along the Nyabugogo, Gikondo and Lower Nyaburongo rivers in the North-West of Kigali (REMA, 2017). In West Huye, floods are recurrent in the Upper Nyabarongo catchment, specifically in the Mwogo river that flows through the Huye district (Ministry of Environment, 2018c). In some instances, heavy rains in Huye have affected over 60 per cent of households and led to food insecurity (REMA, 2011, as cited in REMA, 2017).

Figure 11: Flood near Nyabugogo bus station, Kigali (INZOZI TV, 2020).

The floods generally occurred downstream in the catchment, induced by upstream conditions. Past events showed that floods cause: business stand still, property damage (Ngabonziza, 2020), infrastructure damage, fatalities and injuries, landslides, loss and damage to agricultural crops, soil erosion and environmental degradation (MIDIMAR, 2015). Furthermore, the deterioration of hydropower generation infrastructure (NISR, 2019), shortages in drinking water (Mugisha, 2020b) and the spread of pollutants, particularly to the surrounding wetlands (Earth Systems, 2020), were mentioned. It is expected that these issues will intensify as extreme weather events are increasing in frequency (REMA, 2011, as cited in REMA, 2017).

4.3.1.2. Key flood issues of industrial development

As is shown in Figure 12, the development of industries has contributed to these flood issues; either by enhancing the degradation of wetlands leading to floods downstream (Ministry of Environment, 2018b; Twagiramungu, 2006), by decreasing infiltration due to inappropriate land-use practices and the increase of impervious areas (Matto & Jainer, 2019; NISR, 2019) or by reclaiming wetlands to build industrial sites at locations which tend to be prone to flooding (MIDIMAR, 2015; Ministry of Environment, 2019b). As a result of floods and pollution, plans to rehabilitate and conserve critical wetlands were initiated in Kigali (Participants: RWB1; MoE2) (City of Kigali, 2017; Ministry of Environment, 2019b)). However, vacating the industries from wetlands was described as cumbersome due to the high costs and the logistic difficulties of relocation (Participants: MoE1; NGO1).

Figure 12: Flood issues from industry. Left top & bottom; Flood marks found in a natural marsh downstream of Masoro industrial park in Upper Akagera catchment after industrial development (Obtained from participant: RWB1). Top-right; Demolition constructions in Ankayaru wetlands, Huye. Bottom-Right; Industries in Gikondo wetlands in Nyabugogo catchment, Kigali.

Table 3 categorizes the key flood issues that relate to industrial development into: pressures that enhance flood issues and the consequences from floods. These issues were selected from the inventory of statements about flood issues described in Appendix I: Flood issues. It was found that many of the issues do not have a direct relationship with industrial development. Instead, they manifest themselves indirectly through pressure on land-use (Earth Systems, 2020), including deforestation (RWFA, n.d.-c), construction on steep slopes (Ministry of Environment, 2018c), erosion (Twagiramungu, 2006), soil management practices with soil compaction (NISR, 2019), infiltration reduction (NISR, 2019), pollution (Twagiramungu, 2006) and encroachment on flood sensitive areas in and near wetlands (Ministry of Environment, 2018b). Also, in many cases, a combination of causes contributes to the enhancement of a flood problem cumulatively (Participant: MoE2). Industrial development is one of them (Ministry of Environment, 2019b), as well as urbanisation (REMA, 2017), agricultural practices (Nabahungu, 2012), climate change (REMA, 2017), and the loss of water regulating capacity in catchments (Nabahungu, 2012). Moreover, this cumulative effect applies even more when developing multiple industries, especially considering the argument that the effect of the development of one industrial park goes beyond the physical expansion of the park itself. It can stimulate nearby land-use changes for water, electricity and road infrastructure and possibly lead to nearby development of informal settlements, conceivably in flood-prone areas.

Table 3: Key flood issues that relate to industrial development.

Flood issues	
Pressures enhancing flood issues	Consequences from floods
Increased frequency rainfall	Landslides due to heavy rainfall.
Steep topography leading to accelerated runoff from hills.	High sediment loads.
High sediment loads.	Floods in downstream catchments.
Unstable regulation of waterflows	Degradation of wetlands (e.g. due to drought, pollution, sedimentation and erosion).
Degradation of wetlands (e.g. due to drought, pollution, sedimentation and erosion).	(Vulnerable) construction in flood prone areas.
Construction near and in natural wetlands.	Vulnerable road infrastructure.
Agricultural, industrial and urban expansion and activities leading to wetlands degradation.	Vulnerability of hydropower stations.
Expansion of impervious surfaces (land-use change).	Agricultural losses
Lack of infiltration.	Insufficient (drinking) water supply.
Floods from deforestation.	Vulnerability of natural areas.
Construction on steep slopes.	Vulnerability for diseases.
Lack of buffer zones near wetlands.	
Lack of vegetation in and nearby wetlands to mitigate floods.	
Lack of water retention in wetlands and floodplains.	
Lack of water retention and storage due to the clearing of natural marshes.	
Lack of storage capacity in reservoirs.	
Lack of flood control systems	
Inadequate drainage channels.	
Construction in flood prone areas.	
Insufficient awareness about the causes and impacts of floods and the degradation of wetlands.	

The analysis showed the complexity of the hydrologic system, where flood issues do not operate as separate entities, but have strong cause-effect interrelations. Thereupon, increased pressure on one issue can lead to poor performance of other issues. For example, sediment deposition and erosion (e.g. from deforestation, wetland degradation and industrial practices) alter riverbeds; therefore, reducing discharge locally and causing local floods (Ministry of Environment, 2018b); among those floods at industrial locations. In turn, floods at industrial sites lead to secondary effects, such as pollution from chemicals and debris, affecting wetlands (Ministry of Environment, 2018b; REMA, 2019b; Twagiramungu, 2006). Also, land-use changes stimulate the expansion of impervious surfaces and inappropriate soil management practices, which reduces infiltration in the soil. This reduction increases run-off, which leads to soil erosion and the depletion of water bodies (Matto & Jainer, 2019; NISR, 2019).

Other key phenomena were wetland degradation and insufficient awareness. Wetland degradation causes floods, because wetlands have an important role in regulating water flows to downstream areas by retaining water (Ministry of Environment, 2018b; Twagiramungu, 2006) (Participant: NGO1). Thereupon, all pressures from industries that cause wetland degradation are flood issues (e.g. practices leading to erosion, pollution, water extraction and floods). Insufficient awareness about flood issues and the role of wetlands is evident among residents, policy-makers and local community leaders (Nabahungu, 2012), and leads to poor planning practices of industries.

4.3.1.3. SEA-objectives

Combining similar key issues in overarching themes resulted in five measurable SEA-objectives that deal with the impact of new industrial development locations on floods, and thus enhance more sustainable planning of industrial locations. These SEA-objectives and their grounding issues are shown in Table 4.

Table 4: Themes & SEA-objectives derived from key flood issues.

Key flood issues	Themes & SEA-Objective	Description
- Expansion of impervious surfaces (land-use change). - Lack of infiltration. - Agricultural, industrial and urban expansion and activities leading to wetlands degradation. - Floods from deforestation. - Construction on steep slopes. - Floods in downstream catchments.	**Theme 1: Changing infiltration** Obj 1: To discourage industrial development on sites that lead to reduced infiltration and consequently to increased run-off to downstream areas.	Development is less suitable when it leads to less infiltration in the soil. This will increase the run-off from this area. The reduction in infiltration is bigger on slopes and at certain land-uses.
- Construction in flood prone areas. - Lack of infiltration. - Unstable regulation of waterflows. - Lack of storage capacity in wetlands, floodplains or reservoirs. - Lack of storage due to clearing of natural marshes. - Floods in downstream catchments.	**Theme 2: Capacity to store and retain water** Obj 2: To develop industry in catchments that have sufficient capacity to store and retain water.	Upstream areas where water does not accumulate or areas that regulate water well due to good infiltration, retention and storage, are less likely prone to severe floods. Therefore, industries should be build in these areas.
- Degradation of wetlands. - Construction near and in natural wetlands. - Lack of bufferzones near wetlands. - Lack of infiltration.	**Theme 3: Wetland degradation** Obj 3: To protect wetlands against degradation caused by nearby industrial development.	The regulating capacity of wetlands that prevent floods is harmed by degradation due to sedimentation, pollution, droughts and floods. Development near waterbodies increases the amount of pollutants, causes erosion and reduces infiltration causing overland flash floods that can carry more pollutants and sediments.
- Vulnerable construction in flood prone areas. - Vulnerable infrastructure. - Vulnerability of hydropower stations. - Agricultural losses. - Insufficient (drinking) water supply. - Vulnerability of natural areas.	**Theme 4: Vulnerable assets** Obj 4: To protect vulnerable assets in wetlands against floods that are induced by upstream industrial development.	Development in a district upstream can induce more floods downstream. The effect is more significant in downstream areas where many activities are exposed in wetlands, i.e. agriculture, roads, built-up, water treatment facilities and hydropower plants.
- Increased frequency rainfall. - Steep topography that intensifies run-off from hills. - Construction on steep slopes. - Construction in flood prone areas.	**Theme 5: Hazardous areas** Obj 5: To discourage industrial development in hazardous areas.	Areas prone to hazards, cope more often with larger amounts of run-off from showers leading to increased flood risk. Also these areas are more likely to experience water hindrance. Therefore, industries should not be build in these areas.

4.3.2. Criteria tree

A criteria tree (Figure 13) was established to structure the SEA-objectives and their related criteria and indicators. Each criterion was based on the description of key flood issues by interviewees and in reports, policy, plans and newspapers. Moreover, they were formulated in consonance with the SEA-objective that it measures.

Four constraints were found that apply to industrial development; three forbid development near wetlands and one restricts cutting trees in forests. Since different distances of the restrictive buffer zones near waterbodies were described by interviewees and in policies, restrictions set in the Law on Environment (Ministry of Environment, 2018a) were leading. Considering forestry, the Law on Environment did not define forest; therefore, its definition (i.e. size >0.25ha., height >7m, canopy cover >10 %) was obtained from the Ministry of lands and forestry (2017). Furthermore, factors indicated more and less favourable locations for industrial development by describing their relative suitability. Appendix III: Criteria tree elaborates on the structuring of these criteria and their indicators under the SEA-objectives, in the criteria tree.

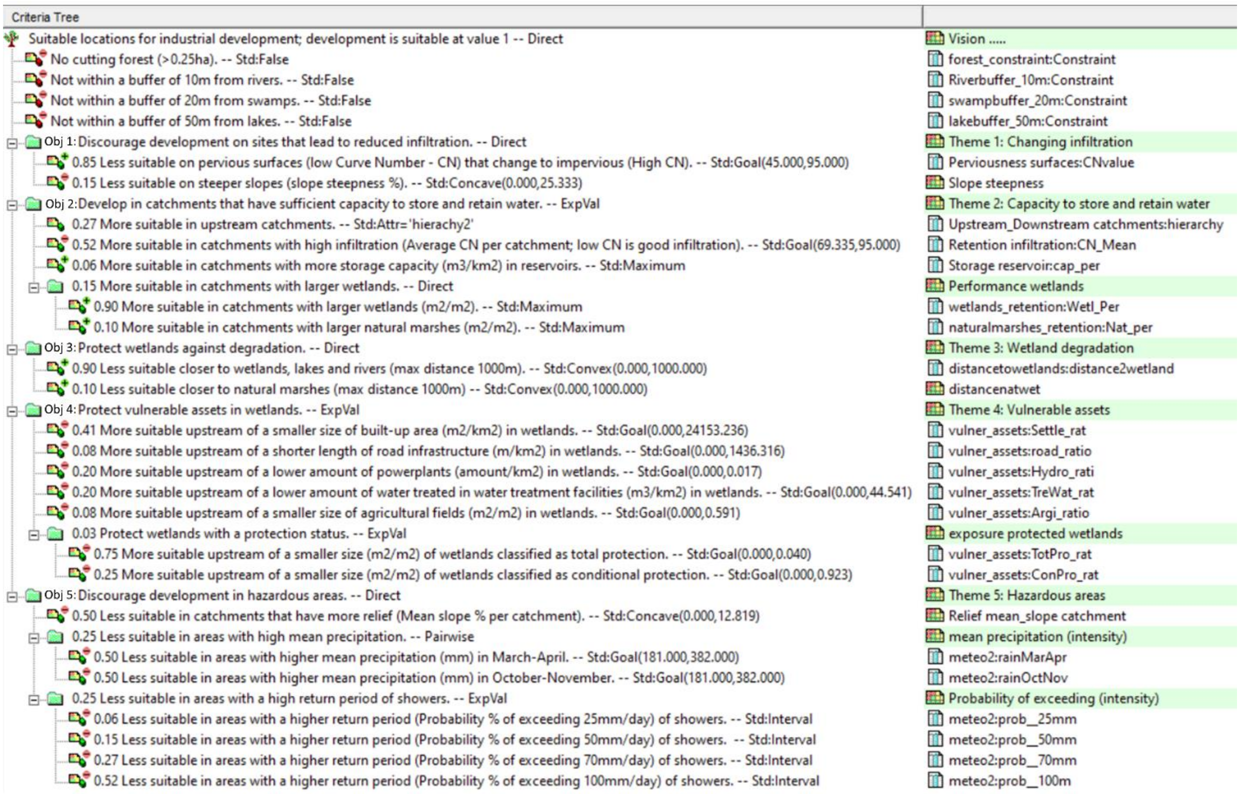


Figure 13: Criteria tree used to describe the suitable locations of industries as implemented in the SMCE module in ILWIS 3.8.6. Left: Constraints (top-four); unweighted SEA-objectives; and weighted factors & indicators with standardisation grouped under the SEA-objectives. Right: Indicator maps after processing data and output; suitability maps.

4.3.2.1. Data collection and processing

Spatial data were collected (Table 5) from governmental institutes, ministries, and open-source geoportals to represent the criteria. Appendix V: Data processing & Standardisation of indicator maps elaborates on the processing of these datasets to indicator maps. For some criteria discussed with interviewees, no data was found or acquired; these criteria and datasets are shown in Appendix IV: Missing data.

In consultation with the Rwanda Land Management and Use Authority (Participant: RLMUA1), the land-use data was updated using the forest layer to obtain a more accurate representation of land-uses. Furthermore, the swamp layer was used to indicate: the ecological condition (i.e. natural marshes), the agricultural activities and the protection status of wetlands since the more recent wetland layer did not contain this information.

Table 5: Collected spatial data.

Source data

Data layer	Format	Source	Year
Economic Specialisation Areas	.png	NSAP (ITC & UN-Habitat, 2019)	2020
Industrial parks (zoned)	.shp	RLMUA	2016
District boundaries	.shp	MININFRA	Acquired 2020
Country boundary	.shp	MININFRA	Acquired 2020
Level1-catchments	.shp	RWB	2012
Level2-catchments	.shp	RWB	2012
Level3-catchments	.shp	RWB	2012
Level4-catchments	.shp	RWB	2012
Land-use	.img Grid: 30x30	RLMUA	2015
Forest	.shp	RLMUA	2019
Digital Elevation Model (DEM)	.tif Grid 30x30	ARCGIS online (SERVIR)	2018
Rivers	.shp	RWB	Acquired 2020
Swamps	.shp	RLMUA	2016
Wetlands	.shp	MININFRA	Acquired 2020
Lakes	.shp	MININFRA	Acquired 2020
Reservoirs	.shp	MININFRA	Acquired 2020
Built-up	.shp	MININFRA	Acquired 2020
Road networks	.shp	MINIFRA	Acquired 2020
Powerplants	.shp	MINIFRA	Acquired 2020
Water processing plants	.shp	MINIFRA	Acquired 2020
Daily precipitation (mm); Measurements at 11 weather stations	.csv	METEO	1981-2017

4.3.2.2. Standardisation

The spatial influence of a criterion was expressed by an indicator map and the weighting of factors (Section 4.3.2.3). The indicator maps were standardised with value functions (Table 6); thus making indicators comparable. Appendix V: Data processing & Standardisation of indicator maps shows the argumentation to support these standardisations.

Table 6: Standardisation of indicators. The closer the value towards 100, the higher the suitability for industrial development.

Standardisation			
Constraint	**Indicator**	**Data layers**	**Value function**
Forest	Forest bigger than 0.25ha.	Land-use (forest), forest	Forest areas are 0; other areas are 100.
10m from rivers.	Distance to rivers.	Rivers	Distance ≤ 10m are 0; all other values are 100.
20m from swamps.	Distance to swamps.	Swamps	Distance ≤ 20m are 0; all other values are 00.
50m from lakes.	Distance to lakes.	Lakes	Distance ≤ 30m are 0; all other values are 100.
Factor	**Indicator**	**Data layers**	**Value function**
Theme 1: Industry changes infiltration *SEA-Obj 1: To discourage industrial development on sites that lead to reduced infiltration and consequently to increased run-off to downstream areas.*			
Perviousness surfaces.	Run-off curve number (CN-value) per land-use class.	Land-use, forest	Positive linear; [45, 95]; A lower CN has a lower score.
Slope steepness.	Slope steepness (%).	DEM	Negative concave; [0, Max. = 25%]; A steeper slope has a lower score.
Theme 2: Capacity to store and retain water *SEA-Obj 2: To develop industry in catchments that have sufficient capacity to store and retain water.*			
Upstream and downstream catchments.	Hierarchy of rivers in Level3-catchment.	Rivers (Hierarchy), Level3-catchments	Attribute table; hierarchies 0 and 5 (upstream) have a higher score than hierarchies 1 to 4 (downstream).
Retention in catchments by infiltration.	Average run-off curve number (CN-value) in Level3-catchments.	Land-use, forest, Level3-catchments	Negative linear; [69, 95]; A lower average CN per catchment has a higher score.
Storage capacity in reservoirs.	Capacity of reservoirs (m3/km2) per Level3-catchment.	Reservoirs, Level3-catchments	Positive linear; [0, Max. = 1268m3/km2]; A higher storage capacity in reservoirs has a higher score.
Retention and storage in wetlands.	Capacity (size) of wetlands (m2/m2) per Level3-catchment.	Wetlands, lakes, Level3-catchments	Positive linear; [0, Max. = 23m2/m2]; Larger wetlands have a higher score.
Retention and storage in natural marshes.	Capacity (size) of natural marshes (m2/m2) per Level3-catchment.	Swamps (végétation naturelle), Level3-catchments	Positive linear; [0, Max. = 98.4m2/m2]; Larger natural marshes have a higher score.
Theme 3: Wetland degradation *SEA-Obj 3: To protect wetlands against degradation caused by nearby industrial development.*			
Distance to wetlands, lakes and rivers.	Distance to wetlands, lakes and rivers (m).	Wetlands, lakes, rivers	Positive convex; [0, 1000m]; A shorter distance has a lower score. >1000 has a value 100.

Distance to natural marshes.	Distance to natural swamp (m).	Swamps (végétation naturelle)	Positive convex; [0, 1000m]; A shorter distance has a lower score. >1000 has a value 100.
Theme 4: Vulnerable assets *SEA-Obj 4: To protect vulnerable assets in wetlands against floods that are induced by upstream industrial development.*			
Size of built-up area.	Relative size of built-up area (m2/km2) in downstream wetlands.	Built-up, wetlands, Level2-catchments	Negative linear; [0, Max. = 24153m2/km2]; A smaller amount of built-up in wetlands has a higher score.
Length of road infrastructure.	Relative length of road infrastructure (m/km2) in downstream wetlands.	Road networks, wetlands, Level2-catchments	Negative linear; [0, Max. = 1436m/km2]; A shorter length of road network in wetlands has a higher score.
Amount of powerplants.	Relative amount of hydropower plants (amount/km2) in downstream wetlands.	Powerplants, wetlands, Level2-catchments	Negative linear; [0, Max. = 0.017 per km2]; A lower amount of powerplants dependent on wetlands has a higher score.
Amount of processed water in water treatment facilities.	Relative amount of processed water in water treatment facilities (m3/km2) in downstream wetlands.	Water processing plants, wetlands, Level2-catchments	Negative linear; [0, Max. = 44.54m3/m2]; A lower amount of water treatment facilities dependent on wetlands has a higher score.
Size of agricultural fields.	Relative size of agricultural fields (m2/m2) in downstream wetlands.	Swamps (Cultivé), wetlands, Level2-catchments	Negative linear; [0, Max. = 0.59m2/m2]; A smaller size of agricultural fields in wetlands has a higher score.
Size of wetlands with status: total protection.	Relative size of wetlands (m2/m2) with status: total protection ('protection totale') in downstream wetlands.	Swamps (total protection), wetlands, Level2-catchments	Negative linear; [0, Max. = 0.039m2/m2]; A smaller size of wetlands classified as total protection has a higher score.
Size of wetlands with status: under condition.	Relative size of wetlands (m2/m2) with status: under condition ('sous condition') in downstream wetlands.	Swamps (under condition), wetlands, Level2-catchments	Negative linear; [0, Max. = 0..92m2/m2]; A smaller size of wetlands classified as conditional protection has a higher score.
Theme 5: Hazardous areas *SEA-Obj 5: To discourage industrial development in hazardous areas.*			
Relief	Mean slope (%) per Level4-catchment.	DEM, Level4-catchments	Negative Concave; [0, Max. = 12.8%]; A catchment with more relief (mean slope) has a lower score.
Precipitation March-April	Mean precipitation (mm) rain season Mar-Apr.	Daily precipitation	Negative linear; [181.7, 344.7mm]; A higher precipitation has a lower score.
Precipitation October-November	Mean precipitation (mm) rain season Oct-Nov.	Daily precipitation	Negative linear; [181.7, 344.7mm]; A higher precipitation has a lower score.
Probability of exceeding 25mm/day.	Probability of exceeding 25mm/day (%) (return period = 0.2 year).	Daily precipitation	Negative linear; [1.96, 4.14%]; A higher probability of rainfall events has a lower score.
Probability of exceeding 50mm/day.	Probability of exceeding 50mm/day (%) (return period = 1.1 years).	Daily precipitation	Negative linear; [0.22, 0.74%]; A higher probability of rainfall events has a lower score.
Probability of exceeding 70mm/day.	Probability of exceeding 70mm/day (%) (return period = 2.1 years).	Daily precipitation	Negative linear; [0.05, 0.25%]; A higher probability of rainfall events has a lower score.
Probability of exceeding 100mm/day.	Probability of exceeding 100mm/day (%) (return period = 18 years).	Daily precipitation	Negative linear; [0.007, 0.118%]; A higher probability of rainfall events has a lower score.

4.3.2.3. Weighting factors within SEA-objective themes

The factors within the distinctive themes that reflect the SEA-objectives (Figure 13) were weighted according to the argumentation stated below. When no supporting evidence was found to justify the weights, equal weights were assumed. The SEA-objectives themselves were weighted differently to develop visions as shown in Section 4.3.4.

Theme 1: Industry changes infiltration
The interviewees (Participants: REMA2; RWB1) indicated with direct weights that land-use change is significantly more important than other factors. Therefore, the factor 'perviousness of land-use surfaces' was weighted higher than 'slope steepness'.

Theme 2: Capacity to store and retain water
Ranking the factors, the following order was obtained for criteria that indicate if a catchment has sufficient capacity to store and retain water: (1) 'retention in catchments by infiltration', (2) 'upstream-downstream catchments', (3) 'retention and storage in wetlands' and (4) 'storage in reservoirs'. According to the consulted experts, infiltration determined by land-use was found the most effective to retain water and delay run-off (Participants: REMA2; RWB1), followed by the note that floods mainly occur in downstream catchments where run-off concentrates (Participants: Huye1; NGO1; REMA2) (Matto & Jainer, 2019; Ministry of Environment, 2018b). Based on their storage capacity, 'retention and storage in wetlands' was found more important than 'storage in reservoirs' (Participant: REMA2) (Ministry of Environment, 2018b).

Finally, below the criterion 'retention and storage in wetlands', the subset 'natural marshes' describes a higher capacity to retain water than the subset 'wetlands' due to the higher valued ecological state of natural marshes. Since the factor 'retention in natural marshes' was counted double through spatial overlap between the natural marshes and wetlands datasets, a small weight to increase the marshes' contribution to the suitability score was assigned to simulate its higher retention (Participant: REMA2).

Theme 3: Wetland degradation
As described above, the factor 'distance to natural marshes' adds to the factor 'distance to wetlands, lakes and rivers'. Therefore, a small weight was assigned (i.e. direct weighting) to increase the contribution of natural marshes to the suitability score (Participant: REMA2).

Theme 4: Vulnerable assets
Vulnerable assets' weights were assigned using the ranking method applied to the six vulnerability factors (protect wetlands is one factor). The ranking was based on estimated economic costs. Within 'protect wetlands', wetlands with the status 'total protection' were ranked more important than the status 'conditional protection'. The wetlands without a status were not considered.

Theme 5: Hazardous areas
No indication was found that justifies ranking precipitation or slope higher; hence equal ranking was applied. Likewise, equal ranking was applied to the precipitation factors. Also, the mean precipitation indicators were weighted equally as they consider the same standardisation scheme. The indicators 'probability of exceedance', ranked more intense rainfall events as more significant (as is done in Van Westen et al., (2011)) because intense events are characterised by higher velocities, rising times and flood depths, which leads to higher costs exponentially (Loucks, van Beek, Stedinger, Dijkman, & Villars, 2005).

4.3.3. Spatial performance of SEA-objective themes

Below the performance of each theme (i.e. SEA-objective) is presented (Figure 14), indicating the likely effect of building a new industrial development location on flood issues. All maps show significant differences in performance across the districts. The influence of factors within theme 1, 'Industry changes infiltration', is more local, while the themes 2, 4 and 5 show more regional differences on catchment scale. Additionally, due to the dense amount of wetlands in Huye, Kigali has larger suitable areas than Huye for theme 3, 'Wetland degradation'.

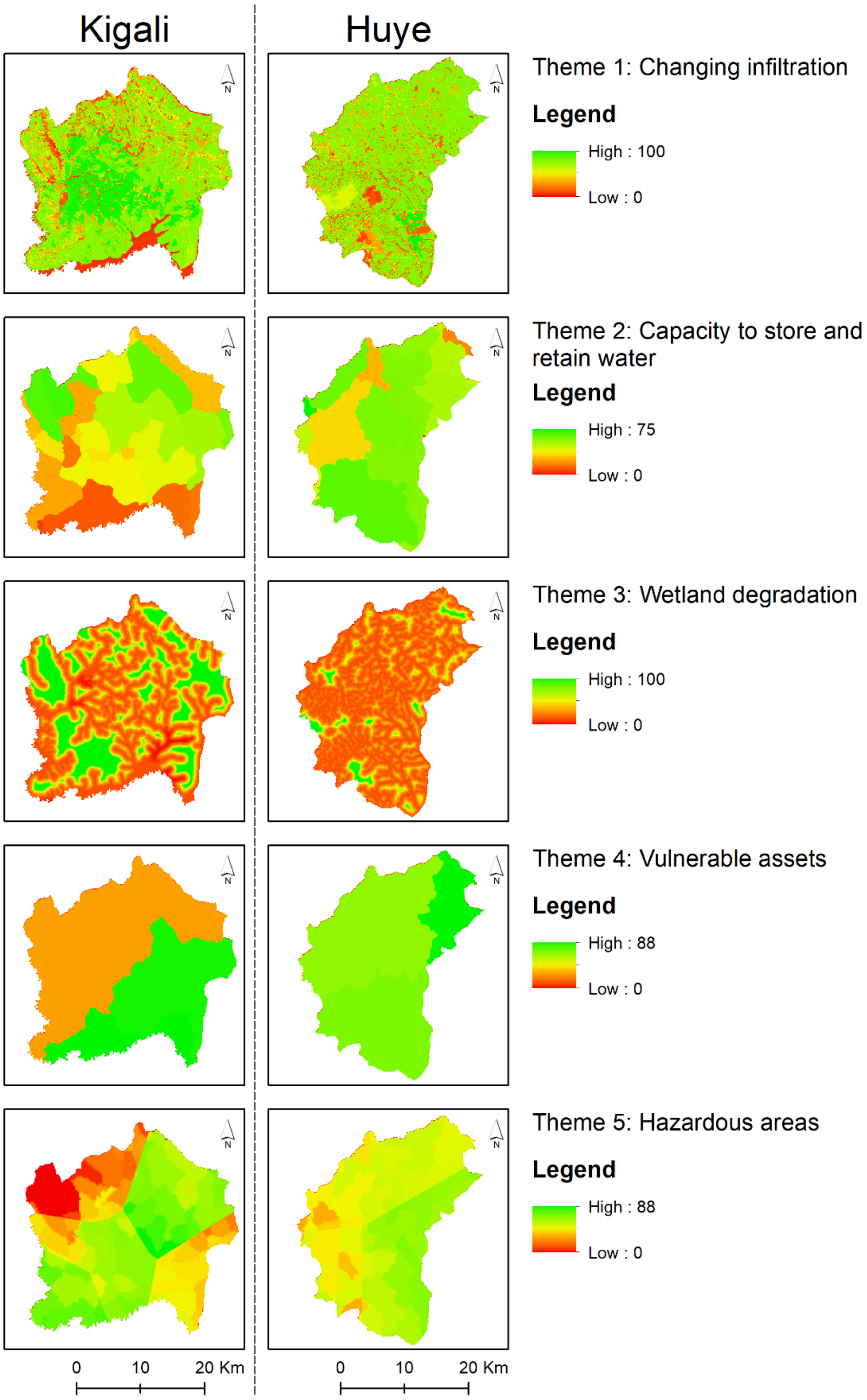


Figure 14: Suitability map per SEA-objective theme (a value closer to 100, indicates a higher suitability for new industrial development).

4.3.4. Visions

Four visions and a consensus situation were formulated to describe alternative perspectives about a location's suitability for industrial development considering flood issues. These alternatives were distinguished by prioritizing the SEA-objective themes most in concord with the vision. This resulted in the following visions: Strict compliance to legislation, Flood(nature)-oriented, Industry-oriented and Community-oriented, each aimed to represent a different range of stakeholders. Vision 1, 'Strict compliance to legislation', restrained to constraints only, while the other visions considered both constraints and factors. The SMCE method adopted each of these visions, which resulted in the suitability maps presented below.

4.3.4.1. Vision 1, Strict compliance to legislation

The Strict compliance to legislation vision reflected Rwanda's prevailing practise to protect. It restrained to considering the four constraints mentioned in policy and legislation (Figure 15). This vision was illustrated by the interviews; in example: "There are instructions by the environmental laws. Those are guides when we are making our land use plans" (Participant: RLMUA2), and by the industrial (SEZ) policies that restrain to: "upholding the environmental conservation laws and regulations" (MINICOM, 2010; UNIDO, 2016). The result of vision 1 (See Figure 15) shows that across Kigali restricted areas were relatively concentrated compared to the dispersed distribution of restricted areas across Huye.

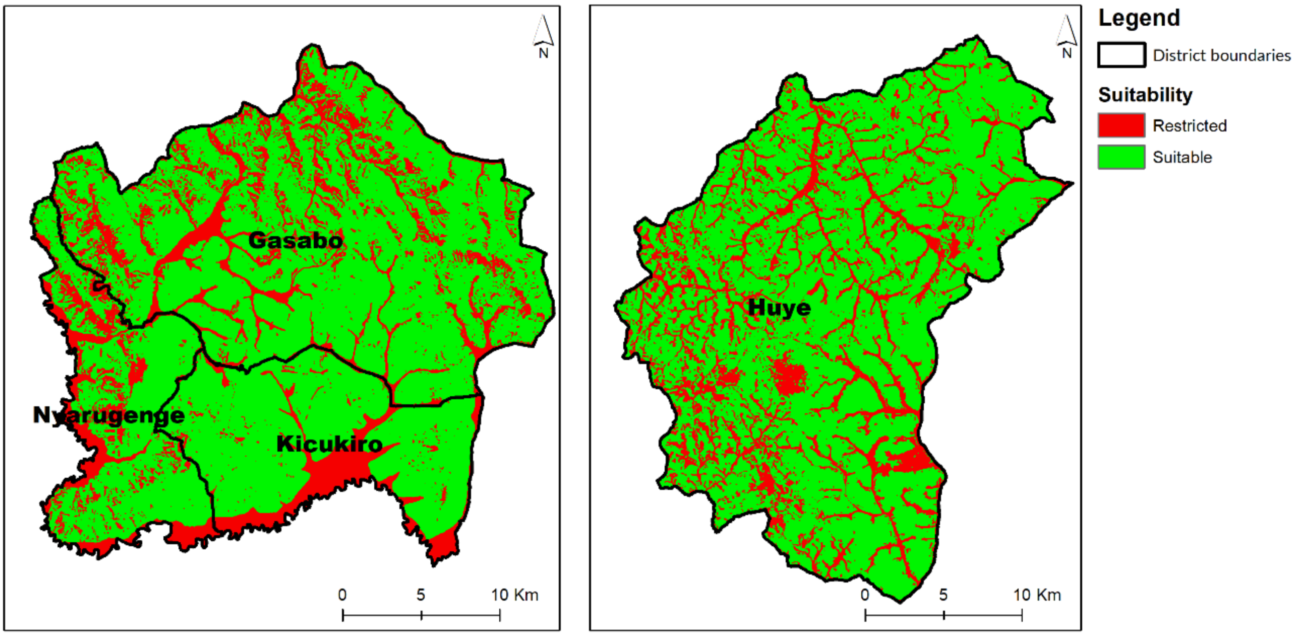


Figure 15: Vision 1, Strict compliance to legislation: Suitability map for industrial development considering flood issues. Left: Kigali. Right: Huye.

4.3.4.2. Vision 2, Flood-oriented; Industry ensures a constant waterflow through catchments

This vision prioritises nature; that is, aiming to keep an overall steady hydrological regime to minimise floodwater related disasters. Thereupon, industrial development should ensure a constant waterflow through catchments and not contribute to an increased run-off anywhere in downstream wetlands. It has a broad spatial dimension because it addressed the impact of industry on the increased occurrence and magnitude of floods throughout the catchments. Consequently, it considers the impact of floods on the assets in these wetlands, addressing group risk. Furthermore, it is environmentally focussed as it emphasised good environmental management of water flow and argued that water steers spatial planning. This vision was expressed through weighting the SEA-objective themes (Table 7).

This vision was based on the following:

- The Nyabugogo catchment plan set the objective: "Effectively managed land, water and related natural resources that takes into consideration resiliency to climate change, and that minimises water-related disasters" (Ministry of Environment, 2018b).
- The opportunity described in NISR, (2019): "A reversal of the current trend of accelerated water run-off, that is, slowing the surface water flows and providing more opportunity for water infiltration into the landscape soils, could re-instate previous natural water storage levels, thereby reduce the cost burden of flooding."

Table 7: Weighting themes in criteria tree vision 2; Flood-oriented.

Weight	Theme	Argumentation weighting
0.46	**1. Industry changes infiltration** *Obj. To discourage industrial development on sites that lead to reduced infiltration and consequently to increased run-off to downstream areas.*	High weight: It has a broad spatial dimension and it ensures a constant waterflow throughout the catchments. Its focus is on relieving flood effects in downstream catchments by having practices that do not lead to increased run-off.
0.07	**2. Capacity to store and retain water** *Obj. To develop industry in catchments that have sufficient capacity to store and retain water.*	Low weight: This objective has a local implication; it is not aimed at a regional catchment level that addresses the hydrological regime in the area. Still, areas that regulate water well to begin with are less susceptible to the enhancement of floods by new development.
0.26	**3. Wetland degradation** *Obj. To protect wetlands against degradation caused by nearby industrial development.*	Medium-high weight: This objective is highly environmentally focussed. Indirectly, the degradation of wetlands is expected to disturb having a constant water flow in catchments.
0.16	**4. Vulnerable assets** *Obj. To protect vulnerable assets in wetlands against floods that are induced by upstream industrial development.*	Medium weight: Has a broad spatial dimension due to its focus on downstream flood effects. Furthermore, it addresses group risk by a variety of assets. However, it concerns largely socio-economic assets.
0.07	**5. Hazardous areas** *Obj. To discourage industrial development in hazardous areas.*	Low weight: Areas that are more likely to experience hazards are more susceptible to further enhancement of floods and water hindrance due to new development. However, considering a regional implication to the overall hydrologic regime, this effect is limited.

Figure 16 presents the suitability for industrial development according to vision 2. It shows that locations close to wetlands generally score lower, which corresponds considerably with the performance reflected by theme 3: 'wetland degradation'. Furthermore, the larger and relatively high scoring suitable locations were found in the South-East of the Kigali districts. Locations in Huye, however, tend to score low due to their proximity to wetlands caused by the dispersed spatial distribution of these wetlands.

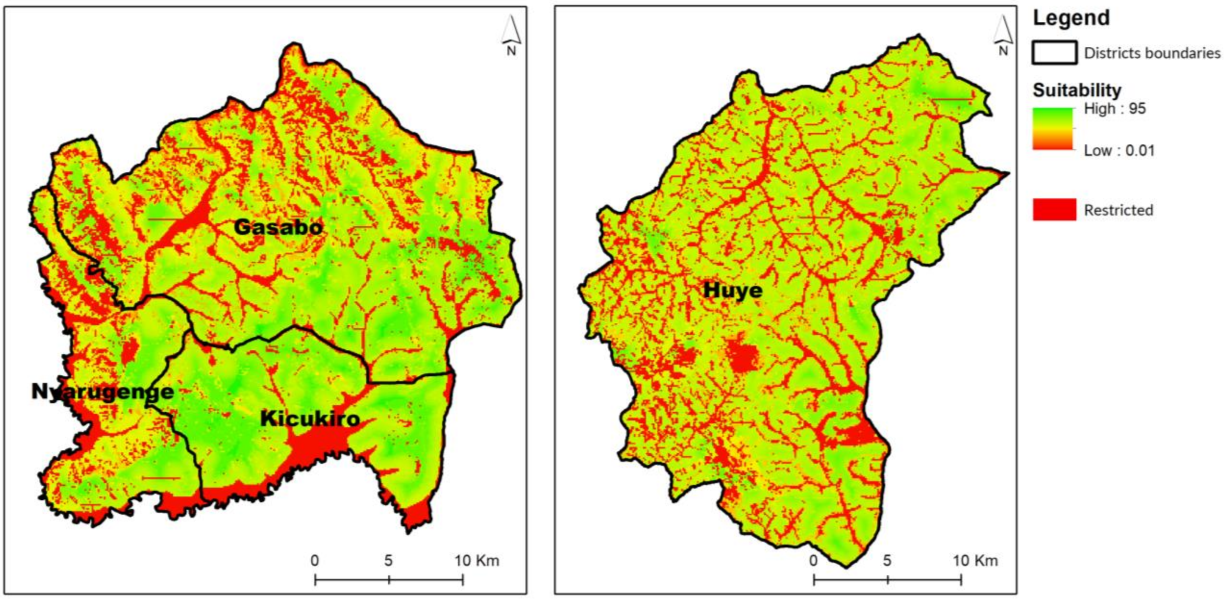


Figure 16: Vision 2, Flood-oriented: Suitability map for industrial development considering flood issues. Left: Kigali. Right: Huye.

4.3.4.3. Vision 3, Industry-oriented; No floods at new industrial sites

This vision considered the impact of floods at the industrial site itself. Thus, it aimed to avoid that new industrial development takes place at locations that are already subjected to floods or water hindrance. As such, it had a local perspective on where industry should be located, and prioritised the individual risk of the industry. This vision focussed on reducing maintenance and construction costs associated with building in flood risky areas, such as costs for insurance or mitigation technologies. Table 8 shows the weights assigned to the themes.

This vision was based on: the trend of removing industries from the Gikondo wetlands in Kigali (Participant: NGO1) (Mugisha & Byishimo, 2020; Nkurunziza, 2019) and the NUP's objective: to reduce potential damage in flood-prone areas through controlling building activities and adapted land-use zoning (Ministry of Infrastructure, 2015).

Table 8: Weighting themes in criteria tree vision 3; Industry-oriented.

Weight	Theme	Argumentation weighting
0	**1. Industry changes infiltration** *Obj. To discourage industrial development on sites that lead to reduced infiltration and consequently to increased run-off to downstream areas.*	No weight: This objective does relate to the flood effects from industries in downstream areas and not to existing floods at the location itself.
0.44	**2. Capacity to store and retain water** *Obj. To develop industry in catchments that have sufficient capacity to store and retain water.*	High weight: This objective focuses on locating industries at places where floods are less likely to occur and less severe.
0.11	**3. Wetland degradation** *Obj. To protect wetlands against degradation caused by nearby industrial development.*	Low weight: It has a small local implication because its criteria support the principle that near wetlands overland flow is more likely to occur, and causes water hindrance on the industrial site.
0	**4. Vulnerable assets** *Obj. To protect vulnerable assets in wetlands against floods that are induced by upstream industrial development.*	No weight: This objective does only relate to the flood effects on assets other than the industrial development itself.
0.44	**5. Hazardous areas** *Obj. To discourage industrial development in hazardous areas.*	High weight: This objective focuses on locating industries at places where flood hazards and water hindrance are not likely to occur.

This vision showed a more homogenous image of suitability across space for Huye than for the Kigali districts (Figure 17). Especially, North-West Kigali that is downstream and characterised by a hilly topography and forest was found less suitable for industrial development.

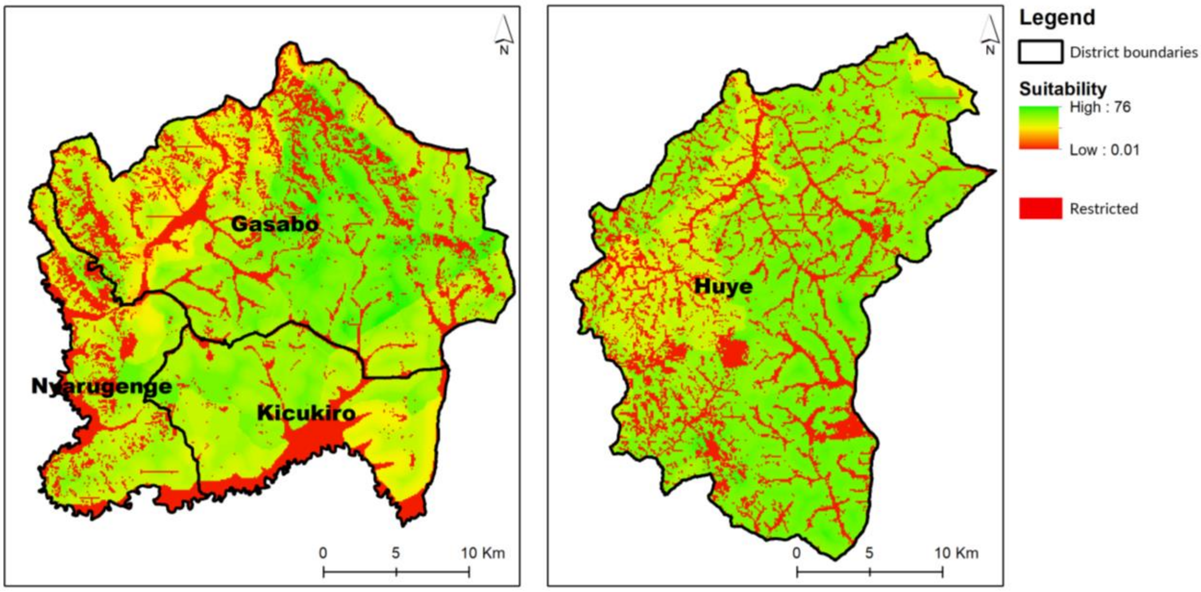


Figure 17: Vision 3, Industry-oriented: Suitability map for industrial development considering flood issues. Left: Kigali. Right: Huye.

4.3.4.4. Vision 4, Community-oriented; Industrial development safeguards the well-functioning of wetland-dependent communities

This vision promoted a well-functioning community that can live of the services a wetland provides. It looked into the social and economic consequences of industrial development induced floods, as it directly influences the prosperity of the people living in and near wetlands. Table 9 shows the weights that express this vision.

This vision was phrased by the Nyabugogo catchment plan (Ministry of Environment, 2018b): "A well-managed catchment is home to prosperous communities living in harmony with their environment and drawing social and economic benefits from sustainable ecosystem services". This was supported by the plan's objectives such as: "Effectively managed land, water and related natural resources that contribute to sustainable socio-economic development and improved livelihoods" and "protection of natural resources that the catchment offers that form a strong basis for socio-economic development and green growth" (Ministry of Environment, 2018b). The NUP elaborates: "Physical planning and development shall aim at improving quality of life and mitigation of disaster risk", and "Safety is a priority concern to ensure the quality of life. Safety and security of persons and goods is a need for urban residents in their daily life" (Ministry of Infrastructure, 2015). Furthermore, the importance of including this vision was illustrated by (Participant: RLMUA2), who described difficulties in implementing environmental policies that protect wetlands due to their conflict of interest with local governments and local communities who benefit from the wetlands.

Table 9: Weighting themes in criteria tree vision 4; Community-oriented.

Weight	Theme	Argumentation weighting
0.21	**1. Industry changes infiltration** *Obj. To discourage industrial development on sites that lead to reduced infiltration and consequently to increased run-off to downstream areas.*	Medium weight: This objective aims to relieve downstream flood effects from industries and therefore address group risk of communities living downstream. The floods are considered a threat to well-being in wetlands since higher water levels will cause more damage. However, this objective relates better to an environmentally focussed vision.
0.07	**2. Capacity to store and retain water** *Obj. To develop industry in catchments that have sufficient capacity to store and retain water.*	Low weight: Areas that have sufficient capacity are less susceptible to enhancement of floods by new development. Therefore, the local flood implication of development on surrounding areas and communities living nearby is less. However, this objective does not address the effects of industrial development on communities living in downstream areas.
0.21	**3. Wetland degradation** *Obj. To protect wetlands against degradation caused by nearby industrial development.*	Medium weight: The degradation of wetlands has an immediate impact on the communities that depend on them.
0.46	**4. Vulnerable assets** *Obj. To protect vulnerable assets in wetlands against floods that are induced by upstream industrial development.*	High weight: Prioritising communities draws more attention to the activities and assets in wetlands.
0.07	**5. Hazardous areas** *Obj. To discourage industrial development in hazardous areas.*	Low weight: Areas that are more likely to experience hazards are more susceptible to further enhancement of floods due to new development. This will affect nearby communities. However, this objective does not address communities living remotely from the new development.

The suitability map of vision 4 (Figure 18Figure 18: Vision 4, Community-oriented: Suitability map for industrial development considering flood issues. Left: Kigali. Right: Huye.) shows that the South-East of Kigali scored significantly better than the North-West. This difference in suitability scores follows the catchment boundaries and resembles the performance of theme 4: 'Vulnerable assets' to a degree. Therefore, it can be assumed that the lower suitability in the North-West is a result of catchments that counted many assets in wetlands.

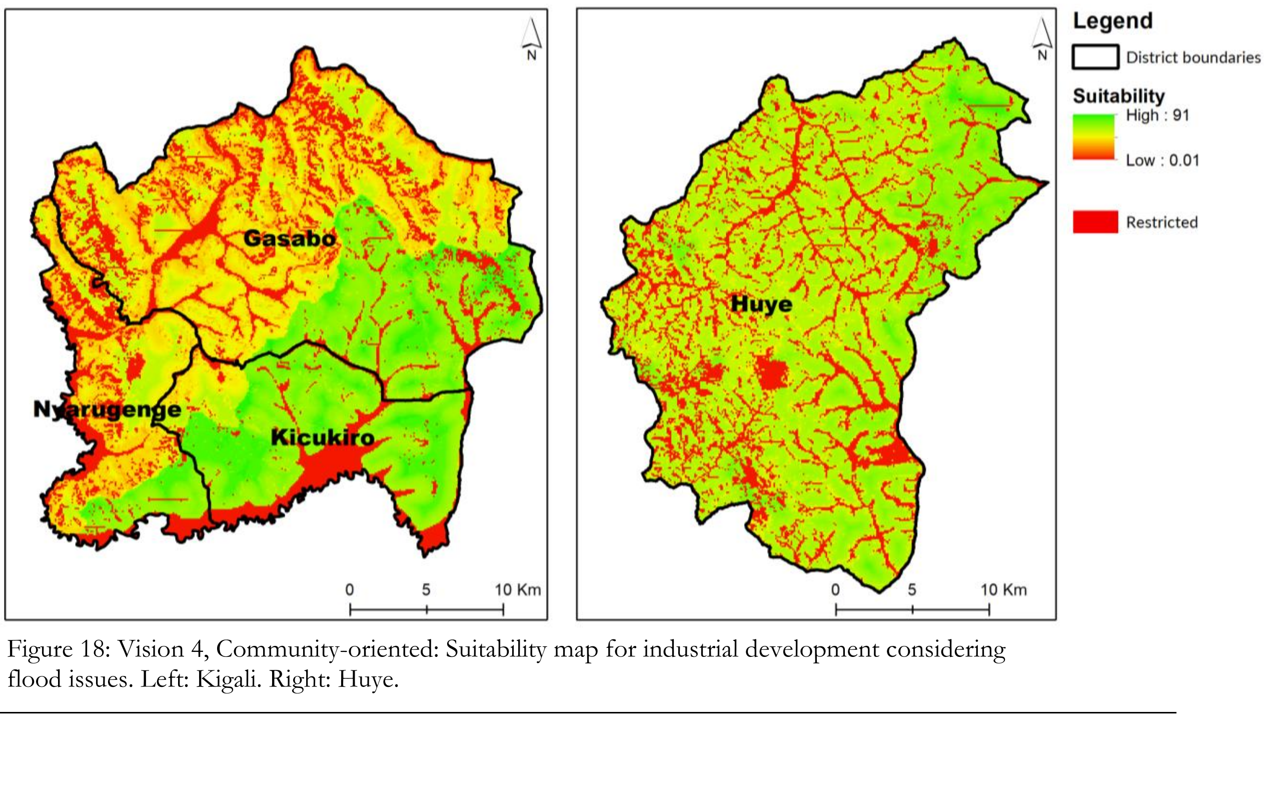


Figure 18: Vision 4, Community-oriented: Suitability map for industrial development considering flood issues. Left: Kigali. Right: Huye.

4.3.4.5. Vision 5: Consensus

The consensus displayed the effect of compromising among the visions. Four different consensus agreements were tested; suitability index standards (I) >40, >50, >60 and >70. Figure 19 shows where consensus was achieved for each suitability standard in Kigali. To clarify >60 displays the locations where all visions score at least higher than 60 in their suitability map. The results indicated that the less suitable areas for industrial development regarding flood issues are in the North-West of Kigali, especially when considering a standard of above 50 (i.e. all visions need a value above 50 at this location for industry to be found suitable). This low score in the North-West corresponded with the reported flood events in the Nyabugogo, Gikondo and Lower Nyaburongo Rivers (REMA, 2017). Furthermore, the map showed that the most suitable areas are concentrated in the Gasabo district.

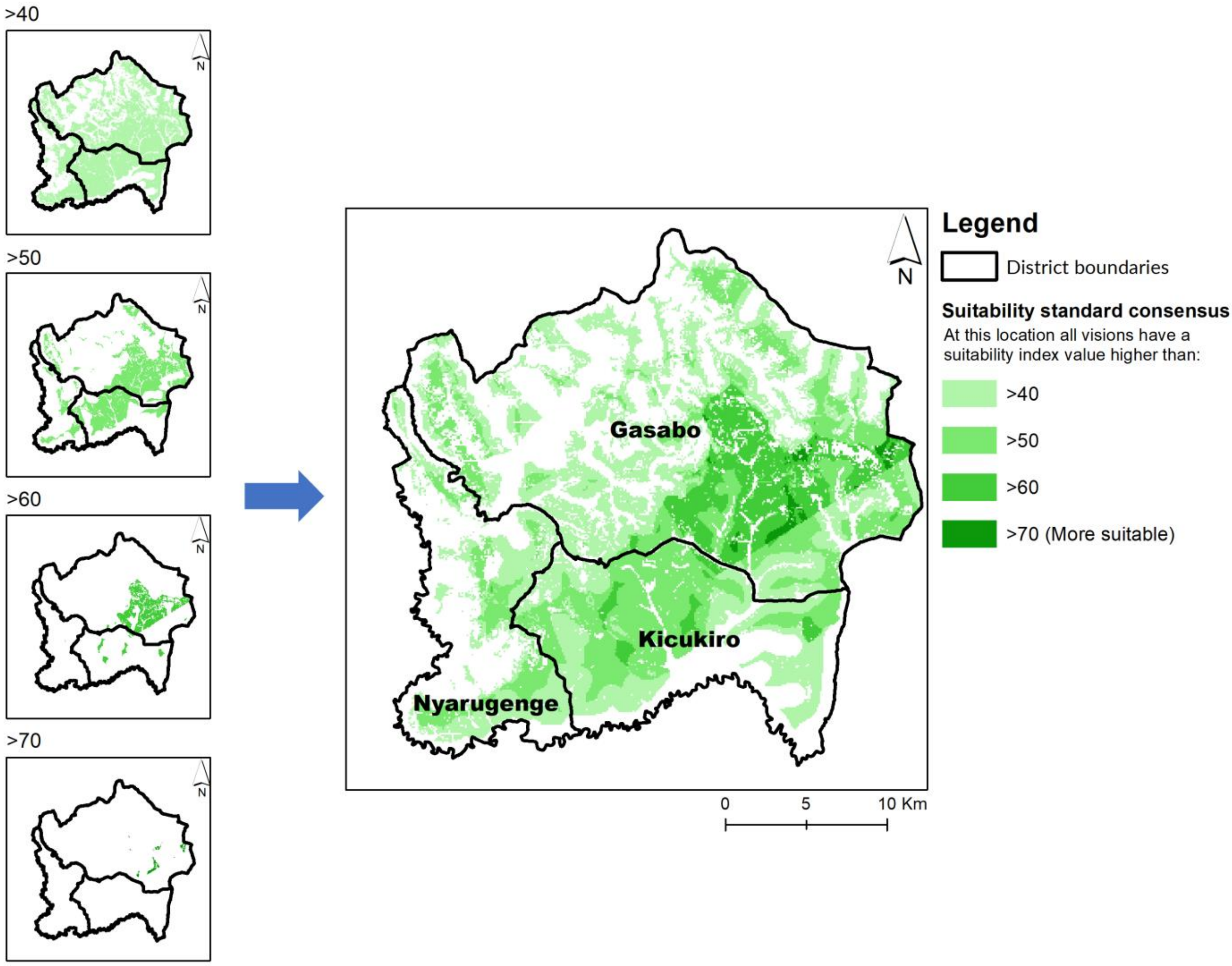


Figure 19: Consensus at Kigali: Suitability map for industrial development considering flood issues. Left: Suitability maps for each suitability standard. Right: Compiled suitability map showing all standards.

Figure 20 shows consensus in Huye. The less suitable areas with a suitability standard below 50 and 60 were located at the West of Huye, which resembled the Mwogo river catchment where floods are reported (Ministry of Environment, 2018c). The more suitable spots in Huye could be found in the South-East. Comparing Kigali with Huye, the larger tracts of land with a relatively high suitability (>70) were found in Kigali. However, in Kigali, a smaller area complies with a suitability standard of >40 and >50 in comparison to Huye.

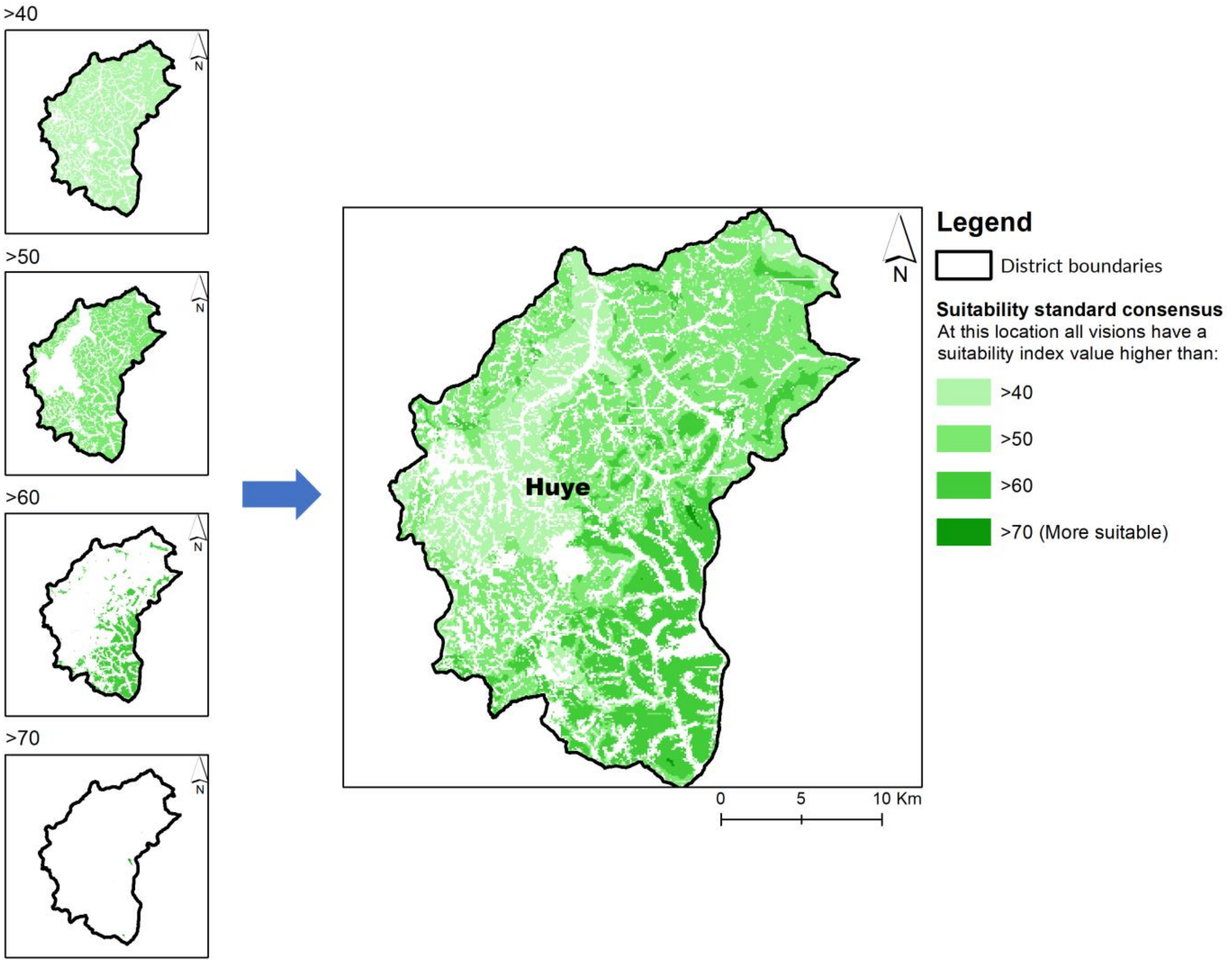


Figure 20: Consensus at Huye: Suitability map for industrial development considering flood issues. Left: Suitability maps for each suitability standard. Right: Compiled suitability map showing all standards.

4.4. Assessing the suitability of potential and existing industrial development locations considering their impact on flood issues

This chapter presents the results of possible applications of the method's suitability maps into planning practices for industrial development locations (See Sub-objective 3). First, it describes the steps and results of a proposed approach that can assist planners and decision-makers in identifying potential industrial development locations considering flood issues. Then, this chapter evaluates the industrial park locations and the zoned NSAP's Economic Specialisation Areas by comparing their locations with the suitability maps created for the visions.

4.4.1. Industrial park design

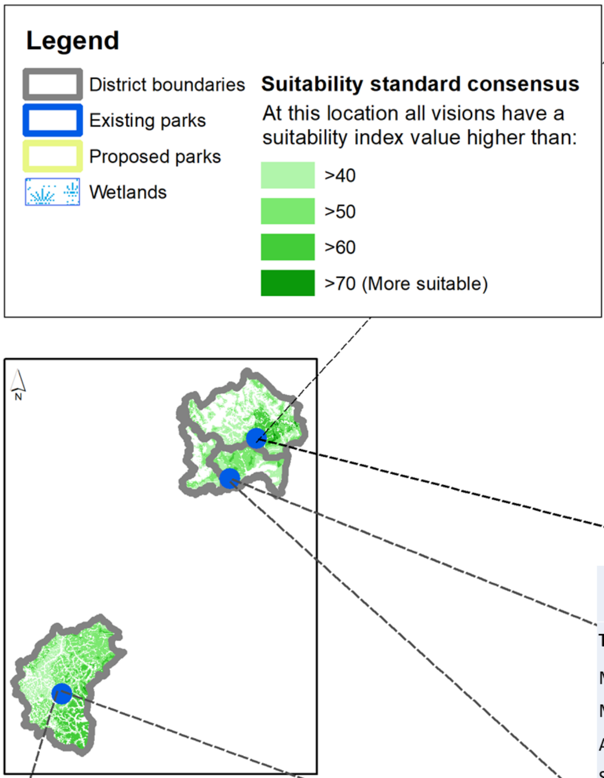
The SMCE method applied to design for new industrial park locations demonstrated a five-step planning approach:

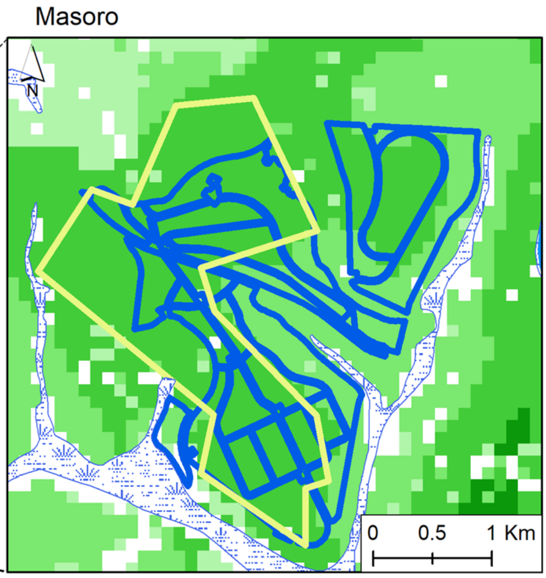
1. Identify flood issues.
2. Develop a criteria tree with experts.
3. Define suitable locations with stakeholders:
    a. Formulate visions and weigh the themes to express these visions.
    b. Determine the consensus' suitability standard and the minimum size of the park to filter the suitable areas for industrial development.
4. Draft new industrial park locations using the consensus' suitability map (after running the SMCE model) and calculate the themes' statistical performance at the park locations.
5. Review why park locations perform well or poorly to understand how to avoid or mitigate specific flood issues.

Figure 21Figure 21 shows the results of applying this approach to draft potential alternative locations for existing industrial parks. Comparing the existing and proposed locations, aims to detect potential opportunities for more sustainable industrial development that avoids flood issues based on the judgement of stakeholders. Moreover, by showing each themes' performance, it identifies the type of flood issues more likely to occur when developing new industry, creating an understanding for planners why a location has a low performance. These same issues underly the performance of a vision since the visions are a result of combined themes.

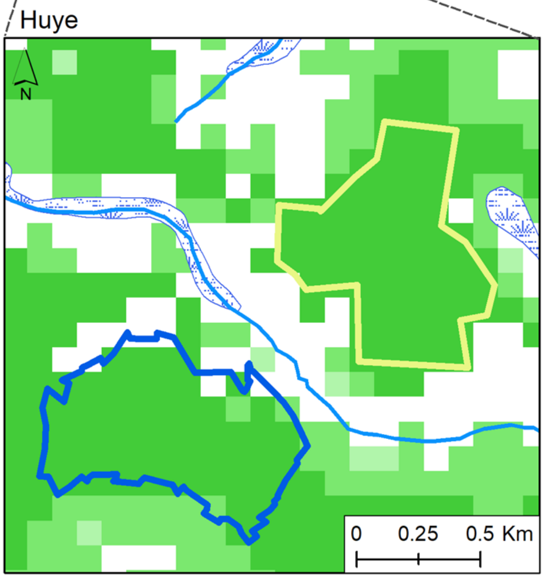
The alternatives for three designated industrial parks were proposed considering a consensus' suitability standard of more than 60 and minimum park sizes of 490ha. (Masoro), 41ha. (Gahanga) and 52ha (Huye). As indicated by the low minimum values, the more prominent issues at Masoro park were the reduction in infiltration (theme 1: 'Industry changes infiltration') and its closeness to wetlands (theme 3: 'Wetland degradation'). The alternative design for Masoro had a higher average than the existing park for theme 3, since it was further from wetlands. Gahanga park scored relatively low for theme 2: 'Capacity to store and retain water'. Consequently, the proposed movement to another catchment was necessary to meet consensus. However, as a result, scores in the other themes declined. Last, the existing park in Huye locally showed low minimum values for 'Industry changes infiltration' (theme 1) and 'Wetland degradation' (theme 3). Although the proposed alternative heightened these minima and reduced their standard deviation, it did not benefit their average suitability within the park.

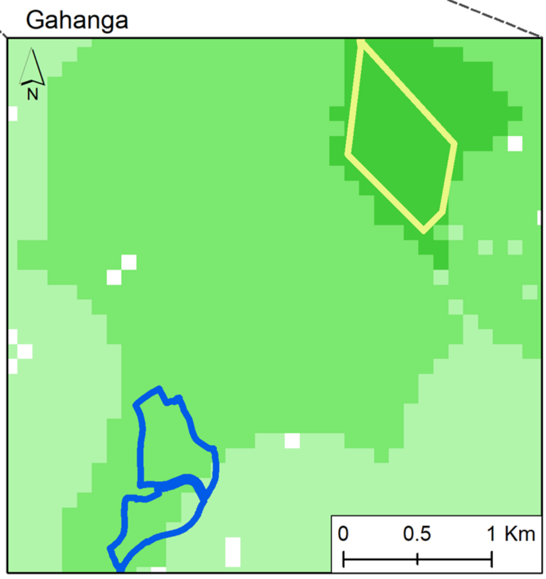
Furthermore, the themes 'Industry changes infiltration' (theme 1) and 'Wetland degradation' (theme 3) showed a high variability in suitability (i.e. standard deviation) across all parks, indicating a local influence. Consequently, the local alternatives for Huye and Masoro parks only impacted the scores of these two themes, significantly. On the contrary, other themes operate area-wide per catchment (theme 2 and 4) or per meteorological area (theme 5). This effect was illustrated by the regional alternative for Gahanga industrial park, which primarily improved theme 2: 'Capacity to store and retain water'.





	Existing park					Proposed park				
Theme	1	2	3	4	5	1	2	3	4	5
Min.	22	46	10	87	84	23	46	10	87	83
Max.	100	46	100	87	88	100	46	100	87	88
Avg.	85	46	30	87	86	86	46	39	87	87
Std.	10.5	0	18.1	0	1.7	10.7	0	33.4	0	1.8





	Existing park					Proposed park				
Theme	1	2	3	4	5	1	2	3	4	5
Min.	23	62	13	71	69	82	62	16	67	71
Max.	82	62	46	71	71	83	64	35	71	72
Avg.	78	62	27	71	71	82	62	24	71	71
Std.	14.3	0	7.5	0	0.6	0.3	0.5	4.3	0.9	0.3

	Existing park					Proposed park				
Theme	1	2	3	4	5	1	2	3	4	5
Min.	74	20	61	88	74	66	44	90	88	68
Max.	99	20	100	88	75	83	44	100	88	74
Avg.	84	20	94	88	75	81	44	100	88	69
Std.	6.6	0	10.8	0	0.2	3.7	0	1.4	0	1.8

Figure 21: Proposed and existing industrial development parks at consensus and their suitability scores for each theme (Themes: 1. Industry changes infiltration (index 0-100), 2. Capacity to store and retain water (index 0-75), 3. Wetland degradation (index 0-100), 4. Vulnerable assets (index 0-88) and 5. Hazardous areas (index 0-88)).

4.4.2. Evaluation of existing industrial parks

The comparisons with the suitability maps showed that the industrial parks; Masoro (Figure 23), Gahanga (Figure 22) and Huye (Figure 24) were not located on large tracts of relatively unsuitable land. Most locations within the parks complied with the constraints set in the 'Strict compliance to legislation' vision. Not to mention that the Masoro and Huye industrial parks had an average suitability index score of above 60 for all visions (Table 10).

Table 10: Suitability index score per vision within industrial park boundaries (Vision 1: Strict compliance to legislation, Vision 2: Flood-oriented, Vision 3: Industry-oriented, Vision 4: Community-oriented & Vision 5: Consensus).

	Masoro (490ha.)			Gahanga (41ha.)			Huye (52ha.)		
	Vision 2 (Flood-oriented)	**Vision 3** (Industry-oriented)	**Vision 4** (Community-oriented)	**Vision 2** (Flood-oriented)	**Vision 3** (Industry-oriented)	**Vision 4** (Community-oriented)	**Vision 2** (Flood-oriented)	**Vision 3** (Industry-oriented)	**Vision 4** (Community-oriented)
Min.	0	0	0	73	49	77	0	0	0
Max.	85	69	86	91	53	88	69	64	68
Avg.	68.2	61.3	71.5	82.4	52.4	83.1	61.5	60.5	61.8

Although industrial parks did not cover relatively unsuitable land, they were neither located on land with relatively high suitability scores. For example, Table 11shows that consensus among visions for suitability index values higher than 70 is never reached. Moreover, the Masoro and Huye park areas do not fully meet consensus with a suitability index >40. Within these parks, a few restricted spots (value 0), which lower the average suitability scores, were found, respectively: in the South-East of Masoro (Figure 23; Vision 1) and the North of Huye (Figure 24; Vision 1). Avoiding these spots or applying mitigation measures can potentially improve the flood issues related to these parks. Furthermore, Table 10 and Figure 22 showed that, on average, the Gahanga park scored well for vision 2 (Flood-oriented) and vision 4 (Community-oriented) but scored considerably less for the 'Industry-oriented' vision (vision 3). Consequently, consensus at Gahanga is not achieved for a suitability standard >60 (Table 11). Last, Table 11 shows that consensus among the visions is best achieved in Huye industrial park since a higher percentage of land exceeds the suitability standard of >60.

Table 11: Consensus. Percentage (%) of land within industrial park boundaries where consensus is achieved.

Suitability standard consensus	**>70**	**>60**	**>50**	**>40**
Masoro (490ha.)	0	69	98	98
Gahanga (41ha.)	0	5	88	100
Huye (52ha.)	0	88	94	94

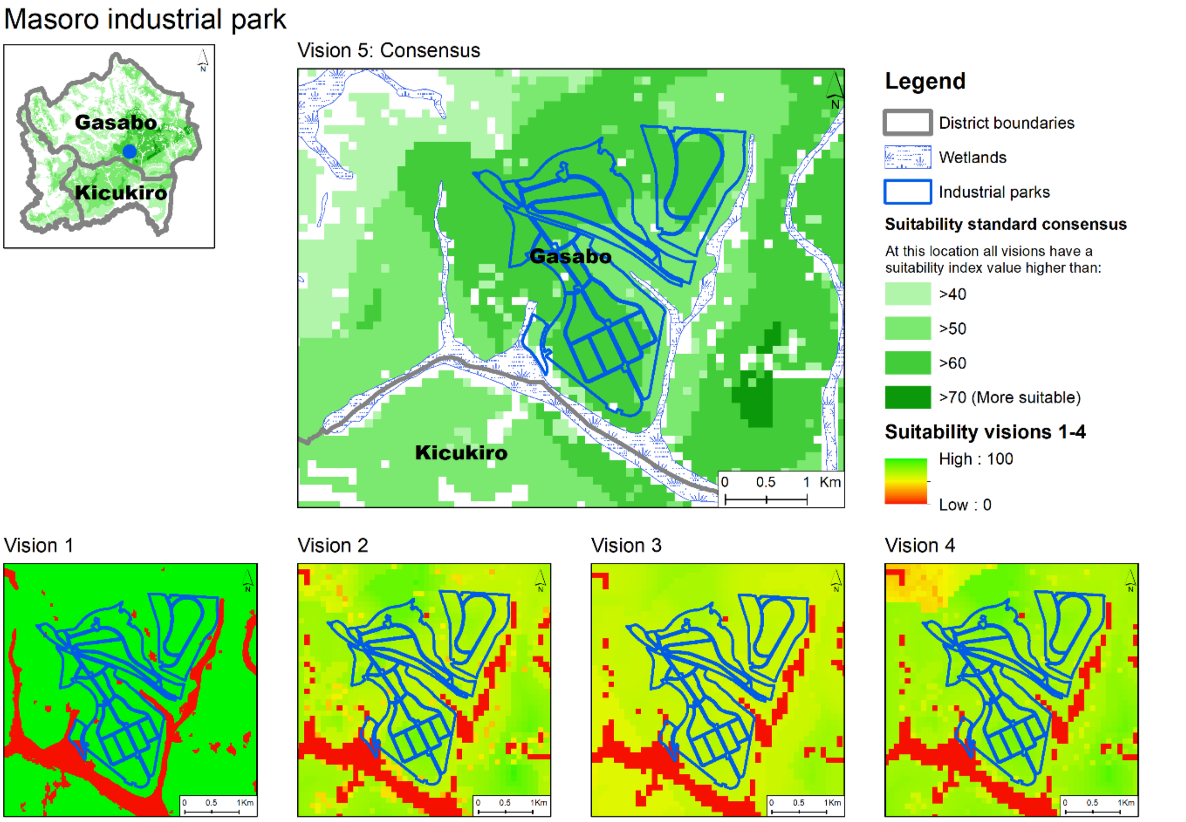


Figure 23: Suitability at Masoro industrial park in Kigali (Vision 1: Strict compliance to legislation, Vision 2: Flood-oriented, Vision 3: Industry-oriented, Vision 4: Community-oriented & Vision 5: Consensus).

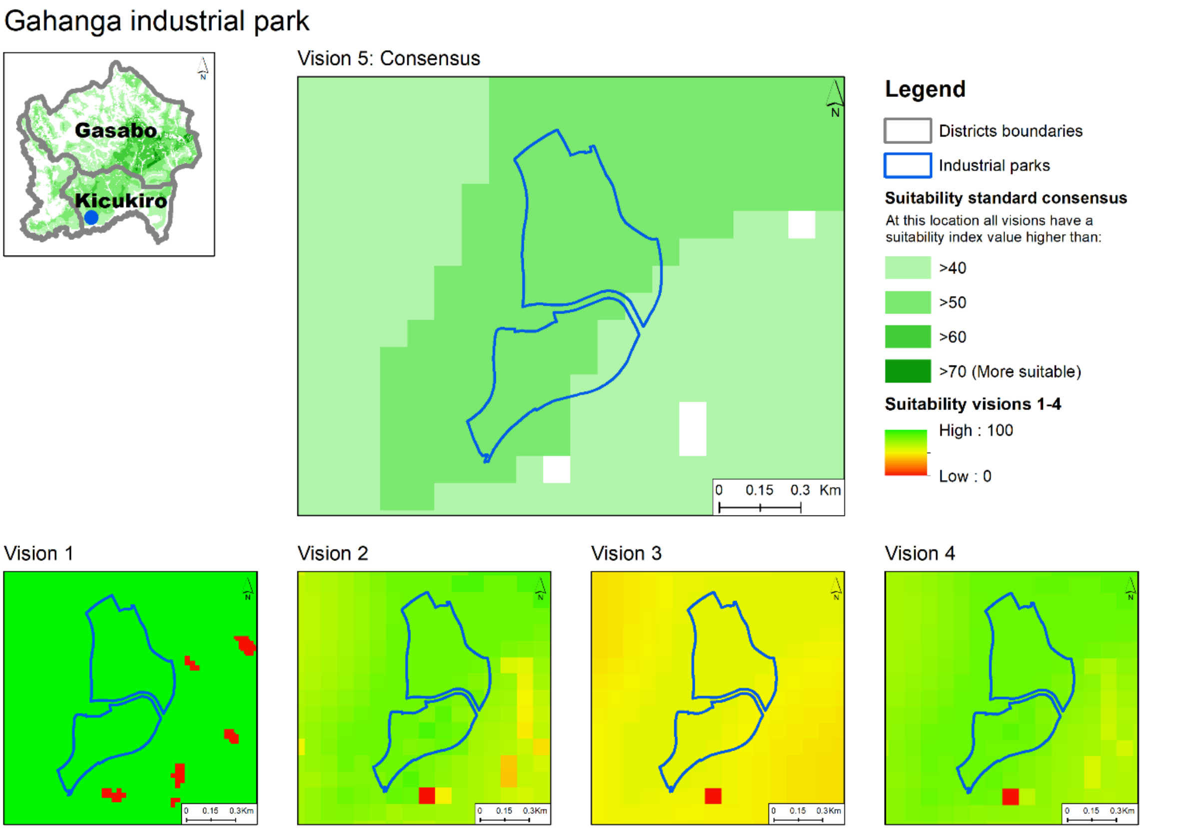


Figure 22: Suitability at Gahanga industrial park in Kigali (Vision 1: Strict compliance to legislation, Vision 2: Flood-oriented, Vision 3: Industry-oriented, Vision 4: Community-oriented & Vision 5: Consensus).

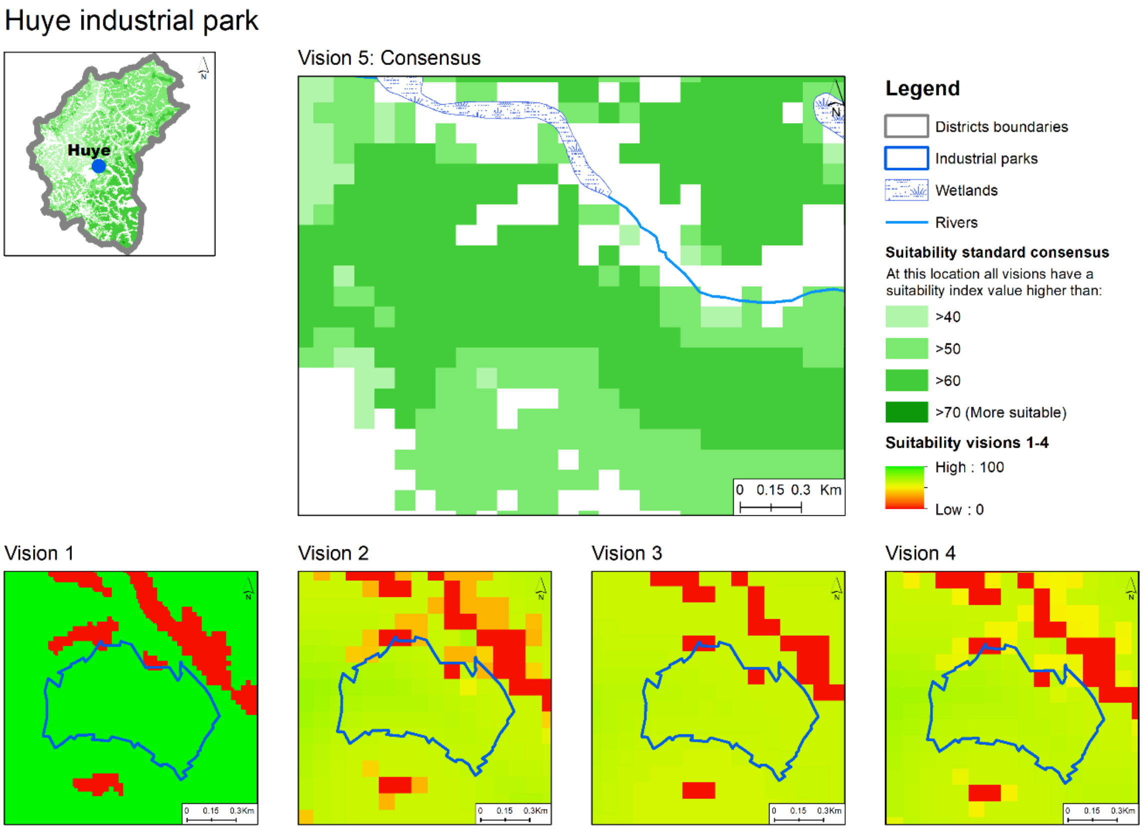


Figure 24: Suitability at Huye industrial park in Huye (Vision 1: Strict compliance to legislation, Vision 2: Flood-oriented, Vision 3: Industry-oriented, Vision 4: Community-oriented & Vision 5: Consensus).

4.4.3. Evaluation of Economic Specialisation Areas

Figure 25 and Figure 26 compare the suitability maps with the Economic Specialisation Areas, respectively at Kigali and Huye, to examine the additional value of the suitability maps to the regional planning practices guided by the NSAP. The results (Figure 25) indicated that the region in the North-West of Kigali was less suitable for all types of Economic Specialisation due to low suitability values, particularly present in vision 3 (Industry-oriented) and vision 4 (Community-oriented). However, in the east of Gasabo, relatively high suitable areas were indicated in all visions. Therefore, it is expected that, in the east of Gasabo, the negative impact on flood issues from the development of new industries and (service) functions supporting these industries will be smaller.

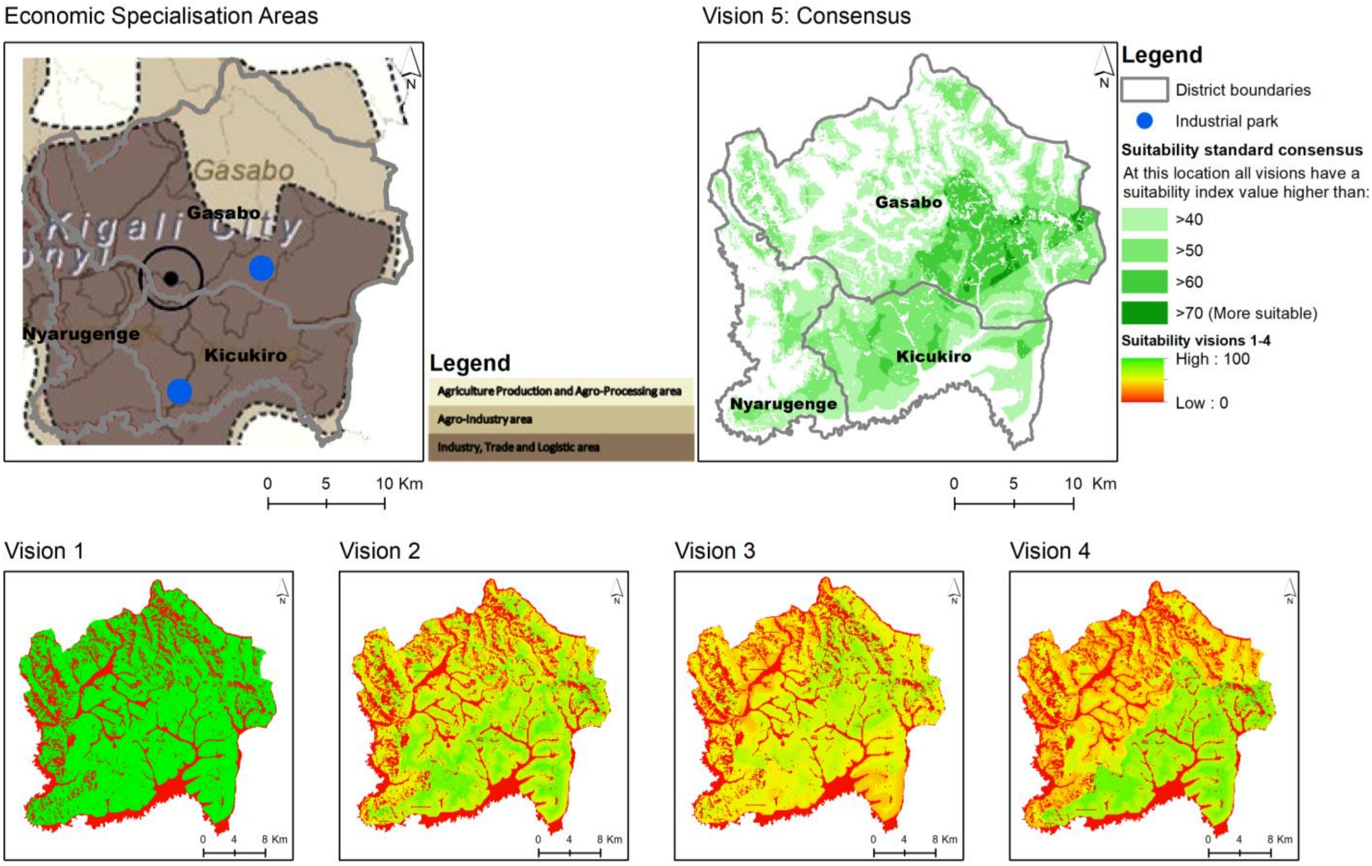


Figure 25: Comparison Economic Specialisation Areas in Kigali with suitability maps for industrial development considering flood issues (Vision 1: Strict compliance to legislation, Vision 2: Flood-oriented, Vision 3: Industry-oriented, Vision 4: Community-oriented & Vision 5: Consensus).

In Huye (Figure 26), the visions demonstrated a more constant suitability score across the map, while in Kigali (Figure 25), the variation across was higher. Consequently, based on Huye's suitability maps, no regional locations could be appointed as more appropriate for developing industries and their supporting functions.

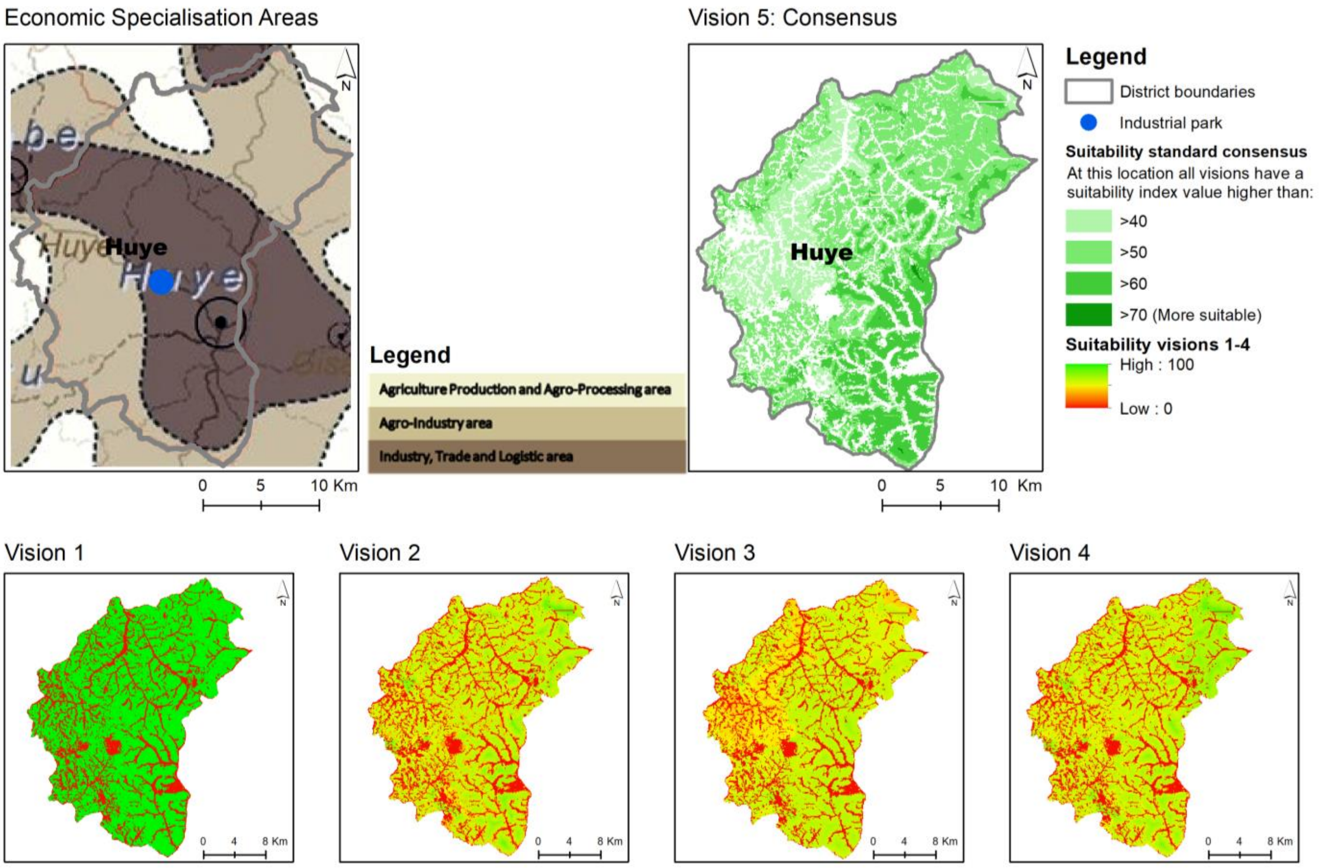


Figure 26: Comparison Economic Specialisation Areas in Huye with suitability maps for industrial development considering flood issues (Vision 1: Strict compliance to legislation, Vision 2: Flood-oriented, Vision 3: Industry-oriented, Vision 4: Community-oriented & Vision 5: Consensus).

5. DISCUSSION

This study investigated the development of a method that can integrate environmental impacts into spatial plan-making for industrial development locations in countries experiencing challenges in institutional coordination and data scarcity, while following SEA guidelines. By means of a case study, applied in the context of industrialisation policies and the NSAP of the SDF-method in Rwanda, it adopted the SMCE method and technology to assess the suitability for new industrial development locations based on flood issues. To this extent, the assessment of flood issues in this research aimed to illustrate and reflect on the SMCE method as a potential tool to avoid environmental issues that emerge from new industrial development. Hence, Section 5.1 discusses the contribution of the SMCE's suitability maps to design industrial development locations and to evaluate designated sites regarding flood issues (See Sub-objective 3). Then, Section 5.2 evaluates and verifies the SMCE model and Section 5.3 reviews the SMCE method to determine if the method can adequately assess the suitability of industrial development locations (See Sub-objective 2). Finally, Sections 5.4 and 5.5 place the method into the spatial planning context for planning industrial parks and planning industrial activities using the NSAP (See Sub-objective 1).

5.1. Application SMCE: assessing suitable industrial development locations based on flood issues

By providing an overview of suitable locations that avoid, nor enhance, flood issues, the application of the SMCE method demonstrated a couple of possibilities to inform spatial planning practices about opportunities for more sustainable industrial development locations. For one, the method could be applied to design alternatives for new industrial development that aim to avoid flood issues (Section 5.1.1). Furthermore, it could identify potentially missed opportunities at designated locations and accordingly improve flood issues through mitigation measures or local adaptations in an industrial areas' size or shape (Section 5.1.2).

The application of the SMCE analysed the suitability of locations according to five themes that encompass a wide range of flood issues (Section 5.1.3). By analysing the performance of these themes individually, the method can detect which type of flood issues are more likely to occur when industry is being developed at a location. Likewise, the suitability performance of stakeholder's visions at a location can be measured, indicating the visions unaccounted for.

5.1.1. Design alternative industrial development locations

The SMCE on flood issues can inform spatial planning practices in a couple of ways. First, as demonstrated by the five-step planning approach in Section 4.4.1, SMCE can assist the design of industrial (park) locations by proposing sustainable alternatives that indicate more suitable locations concerning flood issues, while adhering to multiple stakeholder visions. In this approach, a suitable area was characterised by each visions' ability to meet the consensus' suitability index standard (value I>60) over a large and connected area. These areas were obtained by discarding locations with an insufficient suitability index score in at least one of the visions. Using the approach to design three alternative park locations did raise average and minimum suitability scores of poorly performing themes, suggesting that the alternative park would avoid impacts from these themes' corresponding flood issues. However, although the three alternatives heightened the score at poor-performing themes to achieve consensus, it does not necessarily improve the performance of sufficient-scoring themes and their related flood issues.

Second, applied to a regional level and complementary to the NSAP, the SMCE method can guide locating industrial investments and the placement of new industrial units proposed by local governments in District Development Strategies (DDS). This planning practice would add information on flood issues to the NSAP that could be used to exclude less suitable regions or recommend more suitable regions for industrial development (See Section 4.4.3). In the case of Rwanda, this was demonstrated by the high variation in suitability across Kigali (See Figure 25), which favoured the east of Gasabo over the northwest of Kigali for new industrial development.

5.1.2. Suitability of existing industrial development locations

Besides using the SMCE method to design for alternatives at locations indicated as suitable, it can be used to evaluate suitability scores at existing or planned industrial (park) locations (See Section 4.4.20). In decision-making, evaluating a few proposed alternatives using suitability scores of multiple factors (i.e. flood and other social, economic and environmental factors) can help to rank and choose a location from a list of alternative options (Zucca et al., 2008). Moreover, the evaluation can add to planning practices by recommending potential flood mitigation measures or local adaptations to the shape or size of a designated industrial area.

The assessment on flood issues showed that despite the large unsuitable tracts of land across the Huye and Kigali districts (See Section 4.3.4), no existing industrial parks were located at these unsuitable areas (See Section 4.4.2). This suggests that the existing planning process can provide in well-performing locations for these parks: either due to legislative constraints (i.e. most locations within the parks complied to the constraints shown by vision 1: 'Strict compliance to legislation') or other suitability studies that consider floods or disregard geographical conditions that cause floods (e.g. high relief, wet soils, existing built-up). Be that as it may, past feasibility studies are characterised as superficial (UNIDO, 2016), and within Huye's and Masoro's industrial park boundaries single unsuitable spots were found by the analysis (See Figure 23Figure 24). This is where the SMCE method can contribute: when the SMCE indicates single unsuitable spots, flood issues might be avoided by improving local minima in suitability scores through mitigation measures or local adaptations in park size or shape.

5.1.3. Impact of new industrial development locations on flood issues

The suitability of industrial development locations was assessed based on the judgements of stakeholders as displayed through visions and consensus. However, to take adequate measures to improve flood issues, the underlying causes of this (un)suitability at mapped locations should be explored and understood. The SMCE attempted to explore these causes by dividing the impact of industrial development on flood issues into smaller understandable parts. Consequently, it simplified the complex and interrelated hydrological processes grounding flood issues by isolating these issues into themes, criteria and indicators.

Some of these themes were visible in the suitability maps for visions. For example, in vision 2 (Flood-oriented) (Figure 16), issues related to wetland degradation (Theme 3) had the overhand. Second, Vision 3 (Industry-oriented) (Figure 17) depicted a clear contrast in suitability in the South-East of Kigali from the Thyssen polygons used to display precipitation as part of theme 5: 'Hazardous areas'. Third, in the Community-oriented vision (Vision 4) (Figure 18), the catchment boundaries as reflected in theme 4: 'Vulnerable assets' became visible in the suitability maps.

The examples above illustrated the effect of the themes on the visions' suitability and consequently on locating industrial development. Presumably, the weighting of themes to express stakeholder preferences in visions had a significant impact. Therefore, this study would benefit from sensitivity analysis addressing the exact influence of weights. Besides, adjusting weights strengthens the SMCE because it deals with uncertainties within the model (Malczewski & Rinner, 2015). In particular, re-weighting theme 3: 'Wetland degradation' potentially can alter the visions' suitability maps since this theme was assigned a low weight in each vision and shows high variability in suitability index values across the districts. This is especially true in Huye (See Figure 14). In addition, theme 3 showed a significant difference in suitability between the existing industrial park locations and their proposed alternatives (See Figure 21).

Although isolating flood issues through themes allows for a more specified understanding of the impact of new industrial development locations, it is important for planners to realise that the scores in the suitability maps indicate the likeliness of flood impacts to occur when an industry is being developed at that spot. That is to say that, in reality, industrial development at an unsuitable location does not always lead to flood issues; vice versa, development at a suitable location does not avoid all flood issues. To illustrate, industrial development nearby wetlands (Theme 3) at the cost of forestry (i.e. reducing infiltration (Theme 1)) in an already poorly performing area regarding the capacity to store and retain water (Theme 2) does not lead to floods when precipitation does not lead to hazards (Theme 5). Thus, a potential industrial development location has to be reviewed in respect to the combination of themes in order to draw adequate conclusions on a location's suitability.

5.2. Evaluation of the SMCE model

The SMCE model attempted to give an adequate indication of the less suitable locations for industrial development as they likely have a relatively high impact on flood issues. However, the study might benefit from alternative criteria and indicators as these might better reflect the impact of industrial development on flood issues. Based on the resemblance between the low scores in the suitability maps and recorded flood events (See Section 4.3.4.5), it appears that the SMCE in its current form approximates reality. However, for proper model validation more information about real-life events is necessary.

Alternatively, the SMCE model is verified using previous studies that incorporated flood water processes in their SMCE applications. In general, this showed that the SMCE model developed in this study uses similar evaluation criteria as other studies. For instance, Wang et al. (2011) structured its criteria according to: hydrological and geographical conditions (e.g. slope, flood control and vegetation cover); the trigger of a hazard (e.g. rainfall); and social, economic and physical vulnerability criteria. Although applied to a different context and in a different form, this study showed a similar pattern to organise flood themes, namely: 'Industry changes infiltration' (condition), 'Capacity to store and retain water' (condition), 'Wetland degradation', expressed as distance to wetlands (condition), 'Vulnerable assets' (social-economic vulnerability) and 'Hazardous areas' (trigger). In the same fashion, common denominators verifying the criteria are: conditions such as storage capacity (Tims, 2009; Zarkesh, 2005), infiltration, slope (Karlsson et al., 2017; Kourgialas & Karatzas, 2011; Zarkesh, 2005) and distance to streams and lakes (Karlsson et al., 2017); vulnerability criteria related to infrastructural and agricultural damages (Zarkesh, 2005); and triggers encompassing floodwater (Zarkesh, 2005) and rainfall intensity (Kourgialas & Karatzas, 2011).

5.3. SMCE and other methods for locating industrial development considering flood issues

There are multiple methods available that can assist the identification of suitable locations for industrial development. Ruiz et al. (2012) describe the application of a predefined model that uses a multi-criteria evaluation method to assist in planning sustainable industrial development locations. This model uses a comprehensive set of sustainability criteria to minimize environmental impacts generated by an industrial area, including factors related to preserving: the presence, the quality and the quantity of water (Fernández & Ruiz, 2009). Flood risks are integrated as a separate component within this model; using a constraint the areas prone to floods are excluded for potential development (Fernández & Ruiz, 2009).

On that note, there are several qualitative, quantitative (e.g. SOBEK (Van Westen et al., 2011), HBV (Bergström, 1992)), and semi-quantitative (i.e. SMCE as adopted by Karlsson et al. (2017), Kourgialas & Karatzas (2011) and Wang et al. (2011)) flood modelling approaches that can assess flood risk to exclude potential development areas. However, this study considered another way of looking at the suitability of locations for industrial development, which is twofold: First, equal to the flood risk assessment described above, it finds; industry should not be developed in areas prone to floods. Second, it adds; industrial development should not contribute to increased flood issues elsewhere. Nevertheless, by running scenarios, most flood modelling approaches are able to define the impact of industrial development while adhering to these two objectives; thus, providing similar input as this studies' SMCE into a SEA context. However, these extensive approaches are rarely applied in Rwanda due to the absence of the necessary data (MIDIMAR, 2015; REMA, 2017) (Participant: MoE2) and/or the scarcity of human resources (Participant: RWB1). Not to mention the time it would take to run such models, especially when simulating multiple industrial development alternatives. Different from these conventional methods, the SMCE developed is relatively quick and able to deal with data scarcity.

5.3.1. Limitations of the Spatial Multi Criteria Evaluation method

Although this study created a comprehensive SMCE, improvements to address the uncertainties inherent to the SMCE method could be made. Malczewski and Rinner (2015) indicate that the uncertainty of the multicriteria decision analysis can come from an incomplete understanding of a decision problem, the specification of the model and input data. The model's specification is associated with uncertainty from the choice of criteria, criterion values, standardisation and criterion weights (Malczewski & Rinner, 2015). Particularly in this study*,* uncertainty arises from the translation of flood issues into SEA-objectives and corresponding criteria and indicators. Especially, the form of the value function (e.g linear vs non-linear)*,* criterion values (e.g. min and max thresholds), the spatial scale to which an indicator applies and assigning weights to criteria were considered as the main causes of uncertainty. The most significant uncertainties that require further investigation are described below:

- The result of vision 3 (Industry-oriented) at Gahanga industrial park illustrated uncertainty caused by the spatial scale of indicators. This vision aimed to avoid that new industrial development is located at places already subjected to floods. Although the park is situated on a hill, the location was relatively unsuitable (See Figure 22). The low suitability scores that underestimate the effect of small hilltops are a result of indicators acting on a scale of large catchments and Thyssen polygons in combination with the absence of a criterion representing the hilltop.
- Criteria related to theme 2: 'Capacity to store and retain water', might benefit from indicators with a different spatial scale or standardisation. In the SMCE model, these criteria were calculated as a ratio on a Level3-catchment scale. However, some Level3-catchments were relatively small and had outliers that increased the maximum value in the standardisation.

- To simplify the criterion: 'Distance to wetlands, lakes and rivers', Euclidean distances were used. However, hydrological processes such as overland flash floods generally act following catchment boundaries and streambeds.
- Datasets for urban land-uses and built-up areas did not distinguish between paved areas, roads, fallow areas and informal and formal settlements. Therefore, urban areas were not considered as a constraint for industrial development in the criteria tree.
- In theme 1: 'Industry changes infiltration', the argumentation to support a higher weight for the criterion 'changes in land-use' over the criterion 'building on slopes' was missing.

Moreover, the weighting process of factors in the SMCE method allows trade-offs between factors with a low suitability value against factors with a high suitability value (Malczewski & Rinner, 2015). This compensatory nature is sometimes considered to be a negative aspect, if a factor should not be traded-off (Karlsson et al., 2017). An example from this study is the potential underrepresentation of urban areas in the SMCE model at Kigali's urban fringes in the East of Gasabo, where relatively high suitability scores were displayed (See Figure 25). However, these high scores were unexpected since it was assumed that an urbanised area with many impervious land-uses is less capable of infiltrating and retaining water (Matto & Jainer, 2019; NISR, 2019); thus, causing floods.

In addition, the SMCE model development can be limited due to its dependency on the expertise and judgements of experts and decision-makers involved (Malczewski & Rinner, 2015). As part of ongoing model development, this study adapted the criteria tree using input from interviews. However, additional interviews could improve the understanding of the decision problem and the specification of the model. First of all, consultations with additional water management experts could provide a more accurate representation of industrial development impacts in the criteria tree. Particularly, the value functions, the thresholds and the weighting within the five themes would benefit from closer expert examination, as in some cases, assumptions had to be made. Second, for adequate representation of stakeholders' perspectives, the visions should have had a final stakeholder validation. Currently, the visions were implemented after the final interviews using a combination of statements from these interviews and literature. Third, a stakeholder discussion in a group setting would sharpen these visions by augmenting the different and similar views. Most importantly, this study would have benefited from including stakeholder representatives from the Ministry of Trade and Industry, citizen groups and the Rwanda Development Board (executes SEA).

Last, some limitations in the processing and collection of data were found. To begin, waterbodies projected discrepancies due to the dissimilar dataset swamps (2016) from RLMUA and wetlands (achieved 2020) from MININFRA. Another limitation is that some criteria could not be considered in the criteria tree due to missing data (See Appendix IV: Missing data). Finally, the model output had a resolution of $100x100m^2$ due to limitations in the speed of processing data. However, based on the input data, it would be possible to obtain suitability maps with a $30x30m^2$ resolution. As a result, the constraint: 'distance to rivers' was not fully captured at all locations in the suitability maps.

5.4. Integration of environmental impacts through SEA

The SMCE method on flood issues demonstrated a possibility to implement SEA and environmental impacts into planning practices for industrial development locations. As if the SMCE method was part of a complete SEA study, the method embedded SEA practices to plan for industrial development. In accordance with SEA, the SMCE: adapted to the Rwandese industrial planning context; explored a comprehensive set of flood issues and their cumulative effects to ensure that potentially significant flood impacts from new industrial development locations are identified (Sadler et al., 2011); and incorporated visions to design for and improve the consideration of alternatives in industrial plans (Thérivel, 2004).

In spite of these adaptations to the SMCE, this study needs to consider all SEA components and requirements to fully comprehend the advantages of adapting SMCE to SEA guidelines. In particular, successful implementation of SMCE in a planning process depends on the integration of SEA early and throughout the various stages of the planning process (Walker et al., 2016), which is not always the case in Rwanda (See Section 4.1.2), leading to decision-making without SEA input. Moreover, the SMCE method should include the assessment of other social, economic and environmental impacts when locating industrial development (Thérivel, 2004). Such assessment expansion to include more impacts would benefit from using a pre-described expert-based model to locate sustainable industrial areas as is described by Fernández and Ruiz (2009) to simplify the process of criteria selection.

Besides, this study would benefit from a more extensive analysis of flood issues during the scoping steps of SEA. This would lead to a better understanding of the impact of industry on floods, and therefore improved specification of the SMCE model. Especially, assessing the cumulative effects from new industrial development locations is complex due to the uncertainty inherent to most natural systems and the difficulty in predicting secondary and interacting effects (MacDonald, 2000). Run-off (MacDonald, 2000) and flood hazards (Karlsson et al., 2017) are examples of cumulative effects, because the gravity of these issues depends on a complex mixture of interrelating and added causes that together enhance floods. For this reason, the exact impact of developing one industry relative to other causes of floods might be insignificant. Moreover, the relationship between industrial development and flood issues found in policies and plans was often implicit, which suggest a minor influence. In contrast, the relation of industry with other issues, such as the drainage of wetlands, pollution and siltation, was clearly and explicitly described.

Although the above suggests that the impact of industrial development on floods is minor, the impact may become major when industries are collectively assessed on a regional plan scale or together in a large industrial park. Correspondingly and inherent to SEA (Thérivel, 2004), this research builds on the assumption that a single industry's influence becomes more significant by adding cumulatively to other impacts that enhance flood issues and to more industrial development.

5.5. Implementation SMCE method into the spatial planning context for industrial development

Integrated spatial planning implies that decision-makers need to consider economic, social and environmental impacts next to traditional factors, such as proximity to raw materials, existence of basic infrastructures and qualified workforce, to locate suitable areas for sustainable industrial development (Fernández & Ruiz, 2009). To inform industrial location design about all these aspects, these planning practices often implement a couple of methods and tools separately. However, in support of decision-making, integrating individual tools into a unified whole, is more valuable than the sum of the parts (Malczewski & Rinner, 2015). On that note, Fiave (2020) demonstrated the integration of labour accessibility, connection costs for water and power, environmental impacts and economic growth into a single planning system to select suitable industrial sites in Rwanda. The inclusion of environmental impacts in such a planning system is vital because the consideration of the environment in Rwandan plan-making largely depends on successful cross-sectoral coordination among institutions. Especially, considering that the consideration of environment in plans that guide locating industrial development has been described as lacking.

The SMCE method for flood issues complements the spatial planning system for industrial sites developed by Fiave (2020), the identification of industrial park locations and locating industrial activities and investments using the SDF's NSAP. Each of these can steer spatial planning at a different level of government by providing unique information about where, or where not, to invest in industrial development; thereupon, selecting regional areas or local spots for industrial development. Correspondingly, regional industrial activity planned with the NSAP tool can be concretized to local industrial plans by applying the SMCE for flood issues. By the same token, planning industrial locations benefits from the inclusion of other methods and tools; encompassing, for instance: the spatial distribution of agro-industries based on the value chain mapping of irish-potato production (Marete, 2020), market demand analysis, financial feasibility studies (Unido, 2016) or land-use planning (Participant: RLMUA2).

The above alignment between the SMCE for flood issues and methods intended for other disciplines and sectors illustrates the possibility of the method to cope with challenges in cross-sectoral coordination among institutions. Moreover, this study showed the method's potential to integrate environmental impacts in the spatial planning context of developing countries while following SEA guidelines. However, using the SMCE in practice is expected to be challenging. For one, its implementation is challenged by the insufficient human and financial resources and the existing difficulties of implementing SEA in practice (See Section 4.1.2), especially considering that SEA takes time and resources (Thérivel, 2004). Furthermore, expanding the SMCE to cover other environmental issues might be challenging due to data limitations and the complexity of environmental processes and their interrelated cause-effect relationships, respectively illustrated by the difficulties of collecting data to represent pollution and droughts, and the hydrological complexity experienced when investigating flood issues.

6. CONCLUSIONS AND RECOMMENDATIONS

This study developed a method that informs spatial planning practices about the suitability of locations for new industrial development to improve the integration of environmental impacts in spatial planning and decision-making. This was achieved by developing an SMCE model that assesses the suitability of locations based on the impact of new industry on flood issues, using a case study in the Huye and Kigali districts in Rwanda. This case study showed that the SMCE is able to inform spatial planning practices about sustainable alternative choices for industrial development locations and the possible environmental pitfalls and potentials of such alternatives regarding flood issues, while adhering to SEA principles and dealing with data scarcity and difficulties with cross-sectoral coordination. As such, the SMCE method can complement the planning of industrial park locations and assist in locating industrial activities and investments with the NSAP.

Examining the consideration of environmental issues in the spatial planning process for industrial parks showed that although the environmental impacts from industrial development are acknowledged, environmental considerations are not necessarily included in plan-making. The main reasons for this were the superficial feasibility studies conducted to select a location and the more prevalent inclusion of industries' non-environmental impacts. Moreover, because the environment is considered a cross-cutting topic among policies and plans, the integration of environmental regulations and impacts into industrial planning practices depends on the coordination among governmental institutions and well-performed SEA prior to plan-making. Therefore, embedding methods in these planning practices that follow SEA guidelines and improve the coordination among government institutions can promote the inclusion of environmental information in plan-making of industrial development locations.

This research has shown that a prevalent environmental issue in Rwanda is flooding. Water hindrance and upstream floods, especially in hazardous areas with a low capacity to store and retain water, can affect industrial development locations in areas prone to flooding. At the same time, new industrial development can change upstream hydrological conditions, increasing floods; affecting vulnerable areas downstream. Hence, based on these flood issues, the case study constructed a criteria tree that uses five flood issue related themes to depict the suitability of locations for industrial development. This criteria tree provided a structure that categorises criteria either under themes related to the impact of floods on industry: 'Hazardous areas' or 'Capacity to store and retain water' or under themes associated with the impact of new industrial development on flood issues downstream: 'Industry changes infiltration', 'Wetland degradation' or 'Vulnerable assets'. Although these flood issues and their related criteria are context-dependent, the themes can potentially provide structure in similar case studies elsewhere that determine the suitability of industrial development locations.

Using these themes, this study provided a participative approach that advises spatial planning practices by proposing sustainable alternative options regarding the location, shape or size of industrial development, or by advising on potential flood mitigation measures. First, based on the identified flood issues, this approach constructed an SMCE model that indicates the relative performance of potential industrial development locations in avoiding flood issues. Second, it proposed alternative locations for industrial parks considering an industrial park's size and stakeholders' consensus agreeing about the most suitable industrial development locations. Although the approach was developed based on the geological and hydrological conditions within the Huye and Kigali districts, it can be adapted to other regions by changing the criteria and indicators in the SMCE. However, whether it can be applied to assess other environmental impacts remains a question because impacts can be too complex in nature or the necessary data can be scarce.

All in all, the results showed that the approach can inform planners about the suitability of industrial development locations according to flood issues, enabling them to evaluate proposed industrial development locations or to design for new locations. This can be applied when locating industrial parks, or complementary to locating industrial activities and investments using the SDF's NSAP. The latter would specify regional allocations provided by the NSAP to more concrete industrial development locations locally. To this extent, the assessment of flood issues in this research illustrated the potential of the SMCE method to implement SEA in a context characterised by data scarcity and difficulties with cross-sectoral coordination; thereby, introducing a method that can help to avoid environmental impacts that emerge from industrial development.

6.1. Future research:

This study presented some opportunities to expand the research on the consideration of environmental impacts during the spatial planning and decision-making processes for industrial development locations. Considering the development of the method, future work could be dedicated to:

- Exploring a more accurate approximation of the model to reality by expert consultation or the potential inclusion of flood risk models, supported by validation with real-life flood events.
- Expanding on the integration of multiple environmental issues in the model. In particular, impacts contributing to the degradation of wetlands: droughts, water pollution, sedimentation, siltation and erosion.
- Address the influence of the size of industrial development. To illustrate, one big industry has a different impact than two smaller ones.
- Explore the application of the method to address flood issues for other land-use change driven development.

Moreover, the usefulness of the method in spatial planning practices for industrial development is unclear. Therefore, this study recommends future studies that:

- Aim to bridge the gap between the development of suitability models and their implementation by planners, who expressed the need more for practical, efficient and effective tools.
- Investigate the contribution of the method to a complete SEA on industrial development plans.
- Compare this method with other methods to see how to best addresses the difficulties of integrating environmental considerations in industrial spatial planning practices in developing countries.

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APPENDICES

Appendix I: Flood issues.

Table 12 shows an overview of the statements collected related to flood issues.

Table 12: Flood issues & Strategic (plan) objectives and their sources.

Environmental issue	Description problem	Strategic (plan) objective	Source
Increased frequency rainfall.	Maintaining and repairing damage caused by floods is financially challenging, and the problem is likely to worsen as floods potentially occur more frequently with climate change.		(REMA, 2017)
	Intense floods and landslides, existing climate variability, land-use pressure, hilly land and erosion are putting pressure on Rwanda's environment.		(Earth Systems, 2020)
	With higher rainfall intensities due to climate change and larger investments due to economic development, a 5-fold increase in costs related to disaster is expected by 2030		(REMA, 2019b)
	Flood probability and potential flood damage are increasing due to climate change and continued investment in areas at risk of flooding.		(Ministry of Infrastructure, 2015)
	Extreme weather events such as droughts and floods are increasing in frequency with disastrous effects.		(REMA, 2011, as cited in REMA, 2017)
Steep topography leading to accelerated runoff from hills.	The combination of steep topography, inappropriate soil management practices with soil compaction and high intensity rainfall leads to reduced water infiltration into the soil and accelerated rainwater run-off.		(NISR, 2019)
	In Kigali, the hilly topography and the higher proportion of urbanized areas, high precipitation and instances of high intensity rainfall that lead to flash floods are some of the causes of flooding. Flood risks are common in the valleys and wetlands, such as along the Nyabugogo, Gikondo and Nyabarongo Rivers.		(Habonimana et al., 2015, as cited in REMA, 2017)
	In Rwanda, many settlements are often located on the top of the hills. When runoff from hills concentrates, it creates gullies that grow and descend to the valley where the stones and sediments are deposited. Even small runoff flows can create deep gullies and damage large tracts of agricultural land.		(Ministry of Environment, 2018b)
Landslides due to heavy rainfall.	Landslides prone areas should be avoided because places with heavy rain are likely to experience landslides such as sloppy and wet highlands.		(Mugisha, 2020b)
	We cannot control floods and this has an impact on landslides.		Participant: NGO1

High sediment loads.	High amounts of sediments (e.g. from deforestation, agricultural practices, wetland degradation) in rivers cause floods because the erosion and siltation alter the riverbeds reducing the discharge, and causing local flooding.		(Ministry of Environment, 2018b)
	High sediment loads increase flood risk as they deposit in the riverbeds and reduce the flow capacity in floodplains.		(Ministry of Environment, 2018c)
Unstable regulation of waterflows		Districts with stable baseflows could be maintained and not be further transformed. It is economically strategic to maintain high-value areas before they are degraded. Policy could be developed and implemented to promote higher land-use regulation levels in these highly functional areas.	(NISR, 2019)
Floods in downstream catchments.	The altered hydrology causes environmental impacts, including downstream flooding.		(Matto & Jainer, 2019)
	Heavy rainfall events cause rapid surges in the flow of rivers and drainage systems leading to floods downstream.		(Matto & Jainer, 2019)
	People settling on hills affect flooding in the area downstream.		Participant: Huye1
Degradation of wetlands.	Wetland reclamation and consequent cultivation have serious impacts upon the regulatory capacity of the wetlands, causing a reduction in water storage and creates a more variable stream flow. These changes in regulation capacity can have serious implications for local communities and downstream farmers who are dependent upon the stream flow out of the wetlands.		(Schuyt, 2005, as cited in Nabahungu, 2012)
	"Wetlands have a role to filter and retain water from the hills. Rwanda is made up of many hills, and because of that, there are many wetlands. This means that if encroached on, the risk of flooding becomes higher."		(Minister of Environment Vincent Biruta, as cited in Nkurunziza, 2019)
	Degradation of water resources (e.g. surface waters such as wetlands and underground waters) by frequent flooding, pollution, erosion, silting and overexploitation of lakes and water reserves.		(Twagiramungu, 2006)
	Wetland does increase storage capacity, but we have to protect them as well and not store too much. Floods can damage the areas.		Participant: REMA2
	Wetlands are degrading due to draining wetlands for agricultural, urban and industrial expansion and the poor use of wetlands.	Promote sustainable management of wetlands, promote and intensify wetland protection, and restoration and rehabilitation of degraded wetlands.	(Ministry of Environment, 2019b)
	Agricultural, industrial and urban expansion in wetlands decreasing flood and pollution abatement capacity of wetlands. During storms, urban wetlands absorb excess rainfall, which reduces flooding. The abundant vegetation in urban wetlands acts as a filter for domestic and industrial waste, and this contributes to improving water quality.		(GGGI, n.d.)
		Ensure the protection of wetlands, riverbanks, hilltops and slopes from unsustainable practices to prevent soil erosion and	(Ministry of Environment, 2019b)

		environmental degradation.	
		To redevelop marshlands *(From Context: to a more natural state).*	(Ministry of Environment, 2018b)
Construction near and in natural wetlands.	The main drivers of this (flood risk) are the rapid growth in population and land scarcity that has pushed the establishment of industry and human settlements into fragile ecosystems such as wetlands, which tend to be prone to flooding		(MIDIMAR, 2015)
	Construction in wetlands.		(Ministry of Environment, 2018b)
	(illegal) Urban and industrial activity in wetlands. Rwanda Environment Management Authority (REMA) revealed that approximately 55 per cent of the activities in wetlands don't have any legal documents.	Clearing Gikondo Industrial Zone: The Director-General of Industry and Entrepreneurship at the Ministry of Trade and Industry, Telesphore Mugwiza, says that 22 of 82 activities in former Gikondo Industrial Zone have been relocated.	(Nkurunziza, 2019)
	Some of the illegal activities in wetlands were set up with government authorisation in the past. The relocation costs money.	To relocate industries from wetlands.	(Mugisha & Byishimo, 2020; Nkurunziza, 2020)
	Encroachment on wetlands by illegal construction, damping of waste and illegal agricultural activities.		(City of Kigali, 2017)
	There is many encroachment on wetlands in Kigali. From industries, garage (sheds), commercial activities.		Participant: NGO1
	The capacity of wetlands to act as buffer zones for floods has been restricted by encroachment. Consequently, frequent flooding occurs in the Nyabugogo floodplain and routinely disrupts business and damages infrastructure around Nyabugogo bus park.		(Ministry of Environment, 2018b)
	There is little or no enforcement aimed at providing room to the rivers to flood.		(Ministry of Environment, 2018b)
	Intensive agricultural expansion in wetlands.		(Nabahungu, 2012)
	Whilst altering wetlands through cultivation can adversely affect wetlands and downstream areas, it is very likely that further development of wetlands for agriculture will be difficult to prevent when alternative livelihood opportunities are lacking in Africa in general and more specifically in Rwanda.		(Nabahungu & Visser, 2013; Rebelo, McCartney, & Finlayson, 2009, as cited in Nabahungu, 2012)
	Many conversions to agriculture have occurred in wetlands in the past.		Participant: RLMUA1
	Large tracts of marshland have been converted to agricultural fields (marshlands are often better capable of holding water and mitigating flood peaks).	To redevelop marshlands (to a more natural state).	(Ministry of Environment, 2018b)
Agricultural, industrial and urban expansion and activities leading to	Rapid and unmanaged urbanization has also caused increased flooding in Kigali which has resulted in the spread of pollutants, particularly in the surrounding wetlands.		(Earth Systems, 2020)

wetlands degradation.	Given the widespread intensive cultivation with inadequate soil management, catchment benefits or services, such as erosion control, slope stability and flood reduction are declining.		(NISR, 2019)
	Increased water abstraction from wetlands by agricultural intensification leads to degradation of wetlands and a reduced ability of wetlands to buffer peak flows, leading to increased floods.		(Nabahungu, 2012)
	Kigali is highly populated. So many activities in wetlands were happened here in Kigali. In Huye there is not much activities in wetlands apart from agriculture. … (In Kigali) There's a few activities of constructions, but there is no industries in wetland in Huye. So Kigali, were more affected by human activities than Huye. In the current situation Huye wetlands may be more affected by agriculture activities.		Participant: NGO1
Expansion of impervious surfaces (land-use change).	A key driver of increased quickflow has been the transformation of natural vegetation, such as forests, to cropland and the growth of urban settlement with impervious or sealed surfaces.		(NISR, 2019)
		Reduce potential damage in flood-prone areas by introducing upstream land-use adaptations.	(Ministry of Infrastructure, 2015)
	High percentages of impervious surfaces in urban areas alter runoff and drainage patterns. The storm flows of high volume and velocity cause additional adverse environmental consequences, such as flooding and riparian habitat loss.		(Matto & Jainer, 2019)
	The concentration of rainwater in built-up areas leads to soil erosion and gully forming.		(Ministry of Environment, 2018b)
	Flash floods due to rapid urbanisation.		(Twagiramungu, 2006)
	People settling on hills affect flooding in the area downstream (e.g. by water running from rooftops).		Participant: Huye1
	Impervious surfaces prevent rainwater from seeping into the ground. This results in degradation and depletion of water bodies in urban areas.		(Matto & Jainer, 2019)
		Limit the expansion of impervious surfaces (roads, parking lots and buildings) that cover coarse soils that enable good infiltration (such as riverbanks and floodplains).	(NISR, 2019)
		Flood management programs, including water and soil conservation measures.	(NISR, 2019)
Lack of infiltration.	Water infiltration will reduce as a result of urbanization, and so runoff and soil erosion will increase. For all types of wetlands an reduced infiltration lead to the more or less gradual drainage of the wetland, which affects its capacity for sedimentation and flood control.		(Nabahungu, 2012)

	The type of soil is important to handle floods.		Participant: REMA1
		Slowing the surface water flows and providing more opportunity for water infiltration into the landscape soils.	(NISR, 2019)
		Stimulate green urbanisation, including urban food gardens and green open space to promote infiltration and to dissipate local flooding.	(NISR, 2019)
		To stimulate more green in the city to mitigate floods. Indicators could be % of greenspace or green along rivers.	Participant: MoE2
		Ideally, upstream wetlands are natural and downstream wetlands can be used for agriculture. *(From context: This ideal is based on having a good hydrologic regime that simulates upstream infiltration to combat floods and droughts).*	Participant: NGO1
Floods from deforestation.	Pressure on land coupled with deforestation and inadequate farming techniques leads to land degradation (increases run-off time and decreases infiltration to the soil).		(Ministry of Natural Resources, 2011)
		To increase land coverage by forestry, since forestry reduces erosion and regulates water flows, mitigating floods and droughts.	(RWFA, n.d.-c)
		To increase land coverage of forestry. I.e., increase the intensity of planting agroforestry trees.	(Ministry of Environment, 2018c)
Construction on steep slopes.	Flash floods are observed mainly in areas where rapid urbanization on hill slopes has dramatically increased the runoff water.		(Matto & Jainer, 2019)
	Built-up on steep slopes increases negative effects of floods locally, especially near informal settlements; new constructions on hills divert the courses of streams and drainage sometimes into the homes of people.		Participant: Huye1
	Often vulnerable people life on steep hills.		Participant: RHA1.
Lack of buffer zones near wetlands.	The vegetation near waterbodies reduces the velocity of overland flow which helps to prevent erosion and creates a better opportunity for the water to percolate into the soils. This helps to reduce the "flashy" nature of runoff from upland and urbanized areas.		(RWFA, n.d.-g)
		Greenbelts mitigate pollution, flash floods and erosion.	(RWFA, n.d.-g)
Lack of vegetation in and nearby wetlands to mitigate floods.	Lack of buffer zones that are delimitated by hedges and trees (This limits encroachment near waterbodies).		(Ministry of Environment, 2018b)
		To construct greenbelts to mitigate pollution, flash floods and erosion.	(RWFA, n.d.-g)
		Interventions in areas where propagate destructive water flows occur, such as agricultural engineering of terraces, riverbank vegetation buffers or perennial crops composed of high-value trees such as fruit trees.	(NISR, 2019)

		Flood management programs include riverside landscape improvement, water-way rehabilitation (e.g. sedimentation cleaning and enlarging channels) and interventions in areas where propagate destructive water flows occur such as agricultural engineering of riverbank vegetation buffers.	(NISR, 2019)
Lack of water retention in wetlands and floodplains.	There is a lack of retention ponds to store and retain water. The presence of industrial development limits spaces for reservoirs and wetlands to release floods downstream. Installing ponds, will reduce the speed of the water before reaching the downstream region of Nyabugogo	Part of the Gikondo wetland restoration is the re-instalment of retention ponds to reduce floods downstream at Nyabugogo.	Participant: REMA2
		Wetlands increase the capacity of coping with floods.	Participant: MoE2
		Reduce potential damage in flood-prone areas through adapted land use planning and zoning, controlling building activities and introducing water retention areas.	(Ministry of Infrastructure, 2015)
		Create flood retention ponds upstream.	(Ministry of Environment, 2018b)
		A national policy on water harvesting and soil water storage could help to promote water storage on farmland in the upper catchments of the Nile basin.	(NISR, 2019)
Lack of water retention and storage due to the clearing of natural marshes.	Pressure on wetlands by flooding due to the clearing of natural marshes and hydro-agricultural development, resulting in a reduced capacity of flood accumulation.		(Twagiramungu, 2006)
	Wetlands under traditional use for livestock, fodder, water, craftwork and small-scale agriculture, have the capacity to regulate the water flow. When drained and used for intensive agriculture, the water is conveyed rapidly downstream reducing the wetlands ability to buffer peak flows, retain sediment and hold water.		(Nabahungu, 2012)
Lack of storage capacity in reservoirs.	There is a limited capacity to capture and store volumes of water in large dams.		(NISR, 2019)
	Dam construction to regulate flows.		(SHER Ingénieurs-Conseils s.a., 2014)
		To increase water storage, i.e. Lake Muhazi (Artificial lakes planned in Kigali Master Plan).	(City of Kigali, 2017; Ministry of Environment, 2018b)
		Runoff from roads or hillsides and small streams can be stored in runoff ponds and valley dams.	(Ministry of Environment, 2018b)
	Unplanned settlements need upgrading to store more water.	Rainwater harvesting must be included in unplanned settlement upgrading.	(Ministry of Environment, 2019a)
	Insufficient mitigation of floods by water harvesting through rooftop collection, runoff ponds and valley dams.	Mandatory to have an above or underground surface tank.	(Ministry of Environment, 2019a)
		It is a must to have a system to keep your rainwater the negative effect people are having downhill.	Participant: NGO1

		Harvesting installation is implemented by law. To overcome water, we aim to provide rainwater collection on public buildings	Participant: REMA2
		Green urbanisation, including water harvesting.	(NISR, 2019)
		To harvest rainwater from buildings and hard surfaces like roads or school yards, from hillside runoff and by increasing infiltration in the soil via terracing, soil improvement, cut off drains and vegetation strips. Rain Water Harvesting (RWH) is a simple effective technology to reduce runoff and waterlogging in urban and settlement areas. Applications are rooftop rainwater harvesting, runoff ponds and valley dams.	(Ministry of Environment, 2018b)
		RWH keeps the rainfall close to where it falls and stores it for use afterwards, reducing runoff locally. Though the stored volume is low (especially from domestic household rooftops), harvesting is important as a collective approach to gathering rainwater in settlements or in cases where institutions and commercial buildings possess large roof surfaces.	(Ministry of Environment, 2018b)
Lack of flood control systems		We should build at places with adequate flood control systems.	Participant: REMA2
Inadequate drainage channels.	Flooding due to inadequate drainage systems.		(Matto & Jainer, 2019)
	One of the problems is the sedimentation in the channels. It reduces the capacity of the channels. Another is the size of the channels, we would like to make more discharge channels; however, it is costly as space is scarce.		Participant: MININFRA3
	One concern is the lack of drainages in informal settlements to protect the properties of people living there.		Participants: MININFRA2 and RHA1.
	Inadequate drainage channels		Participant: MoE2
		Wetland rehabilitation by the removal of drain ditches (because they increase the discharge from wetlands).	(Ministry of Environment, 2018b)
(Vulnerable) construction in flood-prone areas.	Business stand still and damaged properties by floods.		(Ngabonziza, 2020)
	We are wasting too much money (referring to the relocation of industries from wetlands).		Participant: MoE1
	A current trend of moving industries out of wetlands is already occurring due to legislation. The issue is; this costs a lot, and not everyone wants to move out.		Participant: NGO1
	One of the major problems is related to the location of industrial units as some of them are installed in valleys (wetlands).		(Twagiramungu, 2006)
	Low protection of public assets, habitation, and crop lands in floodplains.		(Ministry of Environment, 2018b)
	Stormy water: triggering landslides, destroying houses, killing people, disrupting transportation and flooding roads.		(de la Croix Tabaro, 2020; Floodlist News, 2020)

	According to disaster officials, the torrential rain destroyed 113 houses and wide areas of crops across the country. Roads were damaged and water and power supply were interrupted.		(Floodlist news, 2019)
	Inadequate drainage systems and constructions in flood-prone zones have made many neighbourhoods in the city of Kigali highly susceptible to flooding and erosion.		(Matto & Jainer, 2019)
	Spreading of illegal settlements including into high risk (flood) zones.		(Ministry of Environment, 2018b)
	People are living in high-risk zones like wetlands.		(City of Kigali, 2017)
	"We (CoK, Rwanda housing authorithy, MoE) are eliminating unplanned settlements and every year, we allocate a certain budget for relocation of households from high risk zones and wetlands or improving some settlements without relocation."		(Mayor of the City of Kigali; Marie Chantal Rwakazina, as cited in Nkurunziza, 2019)
	Houses were damaged or completely destroyed by floods.		(MIDIMAR, 2015)
	Vulnerability houses made of mudbricks.		(IFRC, 2018)
Vulnerable road infrastructure.	Damaged roads and traffic jams by floods.		(Ngabonziza, 2020)
	In the areas susceptible to flooding events, runoff water with very high velocity and peak discharges have been associated with damage to roads, culverts and bridges.		(Habonimana et al., 2015, as cited in REMA, 2017)
	The increasing trend in quickflow indicates increasing run-off and soil erosion, increasing incidence and magnitude of flooding, which can contribute to road transport infrastructure damage, health and safety risks in the rural and urban areas, and deterioration of hydropower generation infrastructure.		(NISR, 2019)
	Increasing risk and incidence of infrastructure flooding, road wash-aways and landslides.		(NISR, 2019)
	Utility bodies were warned about the likely negative impact on the different infrastructure (of floods).		(Mugisha, 2020b)
	Flooding can cover the roads.		Participant: REMA2
	Road maintenance from floods.		Participant: MoE2
	There is a bus station in the wetland of Nyabugogo		Participant: REMA1
Vulnerability of hydropower stations.	River water often unsuitable for hydropower generation intake; High river discharge often has high turbidity, forcing water intakes to shut off. Hydropower equipment and water treatment plants can not operate under these conditions.		(Ministry of Environment, 2018b)
	Sediments that are washed out in rivers due to elevated run-off create negative impacts such as; high turbidity in rivers with elevated water purification costs and turbine erosion with elevated electricity generation costs.		(NISR, 2019)
Agricultural losses	The agriculture sector is the most affected by flood hazards.		(MIDIMAR, 2015)
	We cannot use the part which is directly to the hill for activities because when we have rains those areas can be flooded. We can lose		Participant: NGO1

	even the crops a little bit down, far from the hills. … the crops are damaged by floods and washed away.		
	The ever increasing floods across the country lead to a loss of crops and livestock, injuries and damage to housing.		(REMA, 2019b)
	High rainfall caused the loss of life, infrastructure and crop yield.		(Ngabonziza, 2020)
	69% Of the farmers have experienced damages from floods and in some incidents people as well as animals were killed by floods.		(Nabahungu, 2012)
	More than 60 percent of the wetlands are used for agriculture		Participant: RLMUA2
	Wetland degradation not only has a significant impact on the environment, but also on economic growth, livelihoods and food security.		(Earth Systems, 2020)
	Fertilizers are stored near the rivers and washed away by floods.		Participant: NGO1
		To protect farmland.	(Ministry of Environment, 2018b)
Insufficient (drinking) water supply.	All water processing plants can shut down during floods causing a shortage of drinking water.		(Mugisha, 2020b)
	Interruption of water supply systems by floods.		(IFRC, 2018)
	During floods, water processing plants are affected by high sedimentation loads and rapid and high flood waves. All water taps, except for wells, are dependent on the water from these processing plants		Participant: MININFRA3
	Degradation of water resources by frequent flooding, pollution, erosion, silting and overexploitation of lakes and water reserves.		(Twagiramungu, 2006)
Vulnerability of natural areas.	Flood events resulted in infrastructure damage, fatalities and injuries, landslides, loss and damage to agricultural crops, soil erosion and environmental degradation.		(MIDIMAR, 2015)
		Wetlands, especially when classified as RAMSAR sites, should be under conservation by the implementation of an ecosystem approach.	(Nabahungu, 2012)
Vulnerability for diseases.	Rapid spread of diseases in flooded areas.		(IFRC, 2018)
Insufficient awareness about the causes and impacts of floods and the degradation of wetlands.	Ignorance and negligence of people and business on environmental vulnerabilities.		(Ministry of Environment, 2018b)
	There is a limited long-term and holistic development view of politicians is a driving force behind environmental issues in catchments.		(Ministry of Environment, 2018b)
		To create awareness (about environment) among policy-makers and local community leaders; wetlands play a vital role in controlling flood waters, reducing erosion, improving water quality and serving as habitats for diverse species of plants.	(Nabahungu, 2012)

Appendix II: Drought, Pollution, Sedimentation, Siltation and Erosion.

Besides flood issues, in the early stages of this research, issues and strategic plan objectives regarding drought, pollution, sedimentation, siltation and erosion were identified using literature and during interviews. These issues were not related to the suitability of industrial locations nor elaborated in the later stages of the research. However, initially, it was intended to incorporate these issues in the SMCE as well.

Many of these issues and strategic plan objectives interrelate. For instance, the abstraction of water for irrigation purposes can enhance drought in wetlands. This leads to the degradation of wetlands. Consequently, the wetlands will be less capable of capturing sediments, storing water for dry periods or mitigating floods (Ministry of Environment, 2019b). These relationships stress the system's complexity and indicate that increased pressure on one issue can lead to poor performance of other criteria in the water system.

a) Drought

Table 13 shows an overview of the statements collected related to droughts. Droughts were understood as a shortage of water that arises from an insufficient supply by water bodies. The main causes mentioned were: overexploitation of water sources through water abstraction that is more than a rational management regime would allow (Ministry of Natural Resources, 2011); insufficient water harvesting; and unstable baseflows through rivers during the year. It is expected that these issues will intensify as extreme weather events such as droughts and floods are increasing in frequency (REMA, 2017).

Due to their ability to store and retain water, wetlands play a major role to overcome periods of droughts. However, this ability is reduced due to the degradation of wetlands (Nabahungu, 2012) driven by factors such as the draining of wetlands for agriculture, urban and industrial expansion and poor use of wetlands (Ministry of Environment, 2019b). To avoid degradation and to maintain the wetlands in a sustainable manner, the water supply should be sufficient (Ministry of Natural Resources, 2011). Besides, other threats (e.g. frequent flooding, pollution, erosion and silting (Twagiramungu, 2006)) should be minimised.

Table 13: Drought issues & Strategic (plan) objectives and their sources.

Environmental issue	Description problem	Strategic (plan) objective	Source
Too much abstraction of water due to inefficient water use in agriculture.	Droughts occur due to farm practices that exhaust the soil and mono-agriculture. To combat this awareness on sustainable farming techniques and improved irrigation systems are needed. In Huye the use of water is too much, therefore, cultivation improvements are aimed here.		Participant: NGO1
	Inefficient water abstraction by agriculture & limited irrigation development to combat droughts in agriculture efficiently.	Irrigation development should be optimised to maintain an equilibrium in the water balance.	(SHER Ingénieurs-Conseils s.a., 2014)

		To use water efficient methods and technologies, like drip irrigation, sprinkler irrigation and hill side irrigation.	(RWFA, n.d.-d)
		To create awareness among local community leaders to help implement good case practices. (This was discussed in the context of farming techniques and droughts and pollutants).	Participant: NGO1
Overexploitation of water reserves.	Overexploitation lakes and water reserves.		(Twagiramungu, 2006)
	Rwanda faces a critical situation of water stress …, which includes increasing need for substantial amounts of water for irrigation, industry, growing cities among other requirements.		(REMA, 2019a)
	Degradation of water resources (surface waters like wetlands and underground waters) by frequent flooding, pollution, erosion, silting and overexploitation of lakes and water reserves.		(Twagiramungu, 2006)
	Unhealthy catchment due to too little water to meet demands.		(RWFA, n.d.-a)
	Water abstraction for agriculture (irrigation).		(Ministry of Natural Resources, 2011)
	Water abstraction for agriculture and inappropriate use of water resources.		(FAO, 2019)
	Increased water abstraction from wetlands by agricultural intensification leading to degradation of wetlands and a reduction of the ability of wetlands to hold water. The storage of water in wetlands reduces.		(Nabahungu, 2012)
	Water abstraction for recreation.		(Ministry of Natural Resources, 2011)
	Water abstraction for water-intensive industries (i.e. coffee washing).		(Ministry of Natural Resources, 2011)
	Water abstraction to exploit hydropower generation.		(Ministry of Natural Resources, 2011)
		For sustainable management water needs for forest and wetlands need to be assured. Pressure is increased due to more water abstraction from water bodies.	(Ministry of Natural Resources, 2011)
Unstable regulation of water flows	Due to the degradation of wetlands, the ability of wetlands to store water is reduced.		(Nabahungu, 2012)
.		Districts with high water yields and stable baseflows could be maintained and not be further transformed. It is economically strategic to maintain high-value areas before they are degraded. Policy could be developed and implemented to promote higher levels of land use regulation in these highly functional areas, to avoid deforestation and bush fires.	(NISR, 2019)

Lack of groundwater recharge.	Impervious surfaces prevent rainwater from seeping into the ground, thereby preventing groundwater recharge (This is necessary for combatting droughts in the long term).		(Matto & Jainer, 2019)
		To harvest rainwater by increasing infiltration in the soil via terracing, soil improvement, cut off drainage systems and creating vegetation strips. Rain Water Harvesting (RWH) is a simple effective technology to increase resilience to droughts and reduce runoff and water logging in urban and settlement areas.	(Ministry of Environment, 2018b)
		Green urbanisation, including green open space, to promote infiltration and to dissipate local flooding.	(NISR, 2019)
		Slowing the surface water flows to increase water infiltration into soils.	(NISR, 2019)
		Removal of drain ditches in wetland. To slow down run-off (and therefore increase infiltration).	(Ministry of Environment, 2018b)
Lack of storage capacity.	Limited capacity to capture and store this volume of water in large dams.		(NISR, 2019)
	Dam construction to regulate flows.		(SHER Ingénieurs-Conseils s.a., 2014)
		Dam construction for the supply of water for irrigation downstream.	Participant: NGO1
		To increase water storage i.e. Lake Muhazi (water storage);`Artificial lakes planned in Kigali Master Plan.	(City of Kigali, 2017; Ministry of Environment, 2018b)
		Create flood retention ponds upstream.	(Ministry of Environment, 2018b)
		A national policy on water harvesting and soil water storage could help to promote water storage on farmland in the upper catchments of the Nile basin.	(NISR, 2019)
		Green urbanisation including water harvesting.	(NISR, 2019)
		To harvest rainwater from buildings and hard surfaces like roads or school yards. Rain Water Harvesting (RWH) is a simple effective technology to increase resilience to droughts and reduce runoff and water logging in urban and settlement areas.	(Ministry of Environment, 2018b)
		To harvest rainwater from hillside runoff. Rain Water Harvesting (RWH) is a simple effective technology to increase resilience to droughts and reduce runoff and water logging in urban and settlement areas.	(Ministry of Environment, 2018b)

The expansion of agricultural, industrial and urban areas leading to the degradation of wetlands.	Wetland degradation due to draining wetlands for agricultural, urban and industrial expansion and the poor use of wetlands.	Promote sustainable management of wetlands, promote and intensify wetland protection, and restoration and rehabilitation of degraded wetlands.	(Ministry of Environment, 2019b)
	Wetlands in Rwanda have been traditionally used for agriculture. Intensive forms of use can involve drainage of entire wetlands.		(Roggeri, 1998, as cited in Nabahungu, 2012)
		Limit the expansion of impervious surfaces (roads, parking lots and buildings) that cover coarse soils that enable good infiltration (such as riverbanks and floodplains).	(NISR, 2019)
	Exploitation of water bodies by complete drainage for agricultural expansion, commercial cropping and dairying.		(Nabahungu, 2012)
	Large tracts of marshland have been converted to agricultural fields (marshlands are often better capable of holding water and mitigating flood peaks)	To redevelop marshlands (to a more natural state).	(Ministry of Environment, 2018b)
		Ideally, upstream wetlands are natural and downstream wetlands can be used for agriculture. (this ideal is based on having a good hydrologic regime that causes no floods or droughts).	Participant: NGO1
	Wetland reclamation and consequent cultivation has serious impacts upon the regulatory capacity of the wetlands, causing a reduction in water storage and creates a more variable stream flow (Schuyt, 2005). These changes in regulation capacity can have serious implications for local communities and downstream farmers who are dependent upon the stream flow out of the wetlands (Nabahungu, 2012).		(Schuyt, 2005, as cited in Nabahungu, 2012)
Deforestation.	Deforestation leading to land degradation (increases run-off time and decreases storage capacity of soils).		(Ministry of Natural Resources, 2011)
	Deforestation leading to land degradation (increases run-off time and decreases storage capacity of soils).		(Twagiramungu, 2006)
		To increase land coverage by forestry as it functions to reduce erosion, and to regulate water flows mitigating floods and droughts.	(RWFA, n.d.-c)
Vulnerability of hydropower stations.	Drought means hydropower stations stops generating electricity.		(RWFA, n.d.-b)
	Vulnerable hydro-electric centres due to water supply changes by agriculture, drainage of marshes, deforestation and overexploitation		(Twagiramungu, 2006)
Agricultural losses.	Loss of crops.		(Ngabonziza, 2020)
Insufficient (drinking) water supply.	Shortage of water (access to municipal water)		(Matto & Jainer, 2019)
Insufficient awareness about drought mitigation.	There is a limited long-term and holistic development view of politicians is a driving force behind environmental issues in		(Ministry of Environment, 2018b)

	catchments.		
		To create awareness among local community leaders to help implement good case practices. (This was discussed in the context of farming techniques, droughts and pollution).	Participant: NGO1

b) Pollution

Table 14 shows an overview of the statements collected related to pollution. The definition of pollution was considered broadly by including heavy metals, human waste, nutrients and sedimentation, among others. All relate to the objective mentioned in the NUP; to enhance the ecological quality of rivers and floodplains (Ministry of Infrastructure, 2015).

Pollution deteriorates wetlands (Twagiramungu, 2006). Due to extreme pollution, the biodiversity in wetlands has been declining drastically (Mugisha, 2020a). To combat this wetland degradation from pollution, legislative restrictions of construction near wetlands were initiated (Participants: NGO1; REMA2). Conversely, wetlands also contribute to the betterment of the water quality. The vegetation in urban wetlands acts as a filter for industrial and domestic waste (GGGI, n.d.). The minister of environment affirmed this role of wetlands: "Wetlands have a role to filter and retain water from the hills." (Nkurunziza, 2019).

The main contributors to the poor water quality were the degradation of wetlands through deforestation, over-exploitation of agricultural land, urban and industrial expansion and unsustainable mining activities, causing high sediment loading, nutrients loads and siltation (Ministry of Environment, 2018c, 2019b). Another issue was pollution from industries and urban areas because they were not treated by wastewater treatment plants (Ministry of Environment, 2018c, 2019b).

Table 14: Pollution issues & Strategic (plan) objectives and their sources.

Environmental issue	Description problem	Strategic (plan) objective	Source
Discharge of wastewater in surface waters.	Pollution of industrial units that are installed in valleys (waste, wastewater, gasses).		(Twagiramungu, 2006)
	Water pollution of the surrounding urban areas, industrial waste, and use of agrochemicals, all adversely affect water quality.		(Ministry of Environment, 2018c)
	Organic load discharged by coffee washing stations.		(Ministry of Environment, 2018c)
	Wastes and industrial effluents from Kigali city, due to poor sewage and waste-treatments, are adding to pollution.		(REMA, 2017)

	Wastewater is not well canalised and not always treated.		Participant: NGO1
	Pollution from heavy metal substances from surrounding factories had injected poison in vegetables and fish.		(Nkurunziza, 2019)
Pollution from urban run-off (wash of pollution).	Wash of pollutants in water bodies next to impervious surfaces.		(Matto & Jainer, 2019)
	Heavy metals load in catchments due to mining and urban runoff.		(Ministry of Environment, 2018b)
	Erosion and water pollution due to poor stormwater management systems. (The pollution is considered here as a secondary effect of floods).		(City of Kigali, 2017)
	Impervious surfaces in urban areas alter runoff and drainage patterns, making natural events of rain an enabling pathway for oil, grease, toxins, pathogens, nutrients, and other pollutants to reach nearby waterways.		(Matto & Jainer, 2019)
Degradation of wetlands.	Pollution by watershed degradation due to deforestation and over-exploitation of agricultural land.		(Ministry of Environment, 2018c)
	Degradation of water resources (surface waters like wetlands and underground waters) by frequent flooding, pollution, erosion, silting and overexploitation of lakes and water reserves.		(Twagiramungu, 2006)
Encroachment of agricultural, urban and industrial activities on wetlands leading to degradation.	Construction of informal settlements leads to generation of liquid and solid wastewater without treatment.		(Ministry of Environment, 2018c)
	Encroachment on wetlands by illegal construction, damping of waste and illegal agricultural activities.		(City of Kigali, 2017)
	There are signs of wetland degradation due to factors including the draining of wetlands for agriculture, urban and industrial expansion and poor use of wetland catchments leading to siltation and pollution of wetlands and rivers.	Promote sustainable management of wetlands, Promote and intensify wetland protection, and restoration and rehabilitation of degraded wetlands.	(Ministry of Environment, 2019b)
	Agricultural expansion in wetlands decreasing flood and pollution abatement capacity of wetlands. The abundant vegetation in urban wetlands acts as a filter for domestic and industrial waste, and this contributes to improving water quality.		(GGGI, n.d.)
Loads of organic matter, sediments and nutrients from agriculture.	Pollution due to sediment transport is named as the most important issue.		Participant: RWB2
	Pollution due to high sedimentation caused by traditional farming methods and organic loads in rivers. This is characterised by poor farming practices.	The Nyabarongo is a source for the water supply of Kigali, and a source for irrigation development. It is, therefore, most important to monitor, protect and reduce loads of organic matter and nutrients.	(Ministry of Environment, 2018c)
	Polluters are pesticides.		Participant: MoE2
	Demanding techniques in agriculture; use of pesticides and other		Participant: RLMUA2

	fertilizers that affect the quality of those wetlands near the water.		
	Fertilisers that are stored near the rivers are washed away during floods.		Participant: NGO1
Release of chemical substances	Release of chemical substances: Apart from some industrial residuals which are yet to be monitored; PCBs … , widely use as coolant fluids, for example in electric transformers, capacitors or electric motors … were monitored. 283 (out of 2344) electricity transformers were suspected to be contaminated with PCBs as well as sites, which will require further soil and water analysis.		(REMA, 2019b)
No wastewater treatment systems.	Pollution due to untreated sewage.		(Ministry of Environment, 2018b)
	Pollution due to lack of wastewater management.	The Nyabarongo is a source for the water supply of Kigali, and a source for irrigation development. It is, therefore, most important to monitor, protect and reduce loads of organic matter and nutrients.	(Ministry of Environment, 2018c)
	Pollution in the form of ecoli due to untreated sewage and lack of proper sanitation.		(Ministry of Environment, 2018c)
		To make sure that the factories have waste treatment systems to avoid polluting Nyandungu and other wetlands around it.	(Nkurunziza, 2019)
		Mitigation by water harvesting (pollution in the form of bathwater, cleaning water). Mandatory to have a septic tank or a water collection pit-hole below every house.	Participant: NGO1
		Wastewater treatment development since no wastewater treatment installations exist in Rwanda and wastewater collects in the valleys. The question is where to strategically put wastewater treatment.	Participant: MoE2
	An issue is wastewater treatment. … Original (indigenous) species in water are well for wastewater treatment.		Participant: MoE1
Lack of vegetation in and nearby wetlands to filter pollutants.	The vegetation in the greenbelt uptakes excess nutrients and pollutants in overland flow and thereby protects the wetland.		(RWFA, n.d.-g)
		Minister of environment: "Wetlands have a role to filter and retain water from the hills."	(Nkurunziza, 2019)
		To create buffer zones vegetated with suitable species of bamboo and tree and erosion control structures. Vegetative buffers also help to reduce the concentration of nitrates, phosphorous, and pesticides.	(Ministry of Environment, 2018c)
		Vegetation buffers near streams to reduce pollutants.	(Ministry of Environment, 2018c)

Pollution from mining.	Pollution and deterioration due to mining activities.		(RWFA, n.d.-e)
	Pollution and deterioration due to mining activities.		(Ministry of Natural Resources, 2011)
	Wetlands are affected by the pollution of brick factories.		(Government of Rwanda & GGGI, 2015)
	Pollution due to high sedimentation and organic loads caused by mining methods.		(Ministry of Environment, 2018c)
	Heavy metals load in catchments due to mining and urban runoff.		(Ministry of Environment, 2018b)
	Pollution from quarries and mines with wolfram, gravel, bricks, cassiterite and coltan deposits.		(Ministry of Environment, 2018b)
Solid waste pollution	Solid waste collection from sand, bricks, cement, plastics from construction, commercial activities, houses.		Participant: NGO1
Vulnerability of (drinking) water sources.		The Nyabarongo is a source for the water supply of Kigali, and a source for irrigation development. It is, therefore, most important to monitor, protect and reduce loads of organic matter and nutrients.	(Ministry of Environment, 2018c)
Vulnerability fishing industry and agriculture.	Pollution from heavy metal substances from surrounding factories had injected poison in vegetables and fish.		(Nkurunziza, 2019)
Vulnerability biodiversity.	Due to extreme pollution, the biodiversity in wetlands has been declining drastically.		(Mugisha, 2020a)
	Plants are growing in polluted water. This could have a negative impact on the biodiversity.		Participant: NGO1
Insufficient awareness about pollution in wetlands.		To create awareness among local community leaders to help implement good case practices. (This was discussed in the context of farming techniques, droughts and pollution).	Participant: NGO1
	There is a limited long-term and holistic development view of politicians is a driving force behind environmental issues in catchments.		(Ministry of Environment, 2018b)
		To create awareness (about environment) among policy-makers and local community leaders to recognise the full range of stakeholders in decision-making. Wetlands play a vital role in controlling floodwaters, reducing erosion, improving water quality and serving as habitats for diverse species of plants.	(Nabahungu, 2012)

c) Sedimentation, Siltation & Erosion

Table 15 shows an overview of the statements collected related to sedimentation, siltation and erosion. These issues consider a disturbance of a balanced sedimentation flow. The deposition of sediments is seen as a form of pollution because it makes the water unusable for hydropower or drinking water. During the interviews, pollution from sediment transport was named as the most important issue (Participant: RWB2). Some other issues mentioned were the degradation of wetlands by the siltation and erosion from deforestation, cultivation of lands, especially on slopes, urban and industrial expansion in wetlands and poor use of wetlands (Ministry of Environment, 2019b; RWFA, n.d.-g; Twagiramungu, 2006). Another significant cause of sedimentation is mining (Ministry of Environment, 2018c).

High amounts of sedimentation in rivers are also a cause of floods because erosion and siltation alter riverbeds and reduces discharge; this causes local flooding (Ministry of Environment, 2018b). Besides, flood waves with many suspended sediments are more disastrous.

Table 15: Sedimentation issues & Strategic (plan) objectives and their sources.

Environmental issue	Description problem	Strategic (plan) objective	Source
Erosion due to flood events.	The increasing trend in quickflow indicates increasing run-off and soil erosion.		(NISR, 2019)
	Sediment deposition reduces discharge, causing local floods.		(Ministry of Environment, 2018b)
	The video shows rapid floods near Nyabugogo bus station. The brown waters indicate a high concentration of sediments.		(INZOZI TV, 2020)
	Concentration of rain water in built-up areas, leading to soil erosion and gully forming.		(Ministry of Environment, 2018b)
Inadequate drainage channels.	Erosion and water pollution due to poor storm water management systems (The erosion is considered here as a secondary effects of floods).		(City of Kigali, 2017)
	One of the problems is the sedimentation in the channels. It reduces the capacity of the channels. Another is the size of the channels; we would like to make more discharge channels, however, this is costly as space is scarce.		Participant: MININFRA3
		Flood management programs, including water-way rehabilitation (i.e. sedimentation cleaning and enlarging channels).	(NISR, 2019)
Dam construction.	Dam construction leads to an unnatural flow of sediment transport (because the sediment flow is blocked).		(SHER Ingénieurs-Conseils s.a., 2014)
Degradation of wetlands.	Erosion due to drained swamps.		(RWFA, n.d.-g)

	Degradation of water resources (surface waters like wetlands and underground waters) by frequent flooding, pollution, erosion, silting and overexploitation of lakes and water reserves.		(Twagiramungu, 2006)
	A significant threat of depletion of water resources due to various factors including increased siltation among others.		(Ministry of Natural Resources, 2011)
	Sedimentation of lakes due to clearing of natural marshes and hydro-agricultural development.		(Twagiramungu, 2006)
	Water infiltration will reduce as a result of urbanisation and so runoff and soil erosion will increase. For all types of wetlands the competition for water and reduced infiltration lead to the more or less gradual drainage of the wetland, which affects its capacity for sedimentation and flood control.		(Nabahungu, 2012)
	There are signs of wetland degradation due to factors including industrial expansion leading to siltation and pollution of wetlands and rivers.	Promote sustainable management of wetlands, Promote and intensify wetland protection, and restoration and rehabilitation of degraded wetlands.	(Ministry of Environment, 2019b)
		Ensure the protection of wetlands, riverbanks, hilltops and slopes from unsustainable practices to prevent soil erosion and environmental degradation.	(Ministry of Environment, 2019b)
Deforestation.	The highland soils are particularly prone to erosion and landslides especially, valleys and lowlands (peat lands) as well as highland meadows due to deforestation and inappropriate agricultural practices.		(Twagiramungu, 2006)
	Erosion and siltation due to deforestation.		(Ministry of Environment, 2018c)
	Soil erosion, resulting from either improper management or protection of the catchment and deforestation.		(Ministry of Environment, 2018b)
	Siltation and erosion due to deforestation and cultivation on slopes.		Participant: NGO1
		To increase land coverage by forestry as it functions to reduce erosion, and to regulate water flows mitigating floods and droughts.	(RWFA, n.d.-c)
		Target reforestation on sensitive slopes and soils, especially those prone to erosion.	(NISR, 2019)
Erosion from agriculture practices.	Pollution due to high sedimentation caused by traditional farming methods.	The Nyabarongo is a source for the water supply of Kigali, and a source for irrigation development. It is, therefore, most important to monitor, protect and reduce loads of organic matter and nutrients.	(Ministry of Environment, 2018c)
	High sediment load due to farming.		(Ministry of Environment, 2018b)
	Erosion due to over-cultivation.		(FAO, 2019)

	Given the widespread intensive cultivation with inadequate soil management, catchment benefits or services, such as erosion control, slope stability, and flood reduction are at risk and/or declining.		(NISR, 2019)
	Erosion control is required to preserve the fertile humus layer for agriculture.		(Huye district, 2018)
	Increased water abstraction from wetlands by agricultural intensification leading to degradation of wetlands and a reduction of the ability of wetlands to retain sediments.		(Nabahungu, 2012)
	Soil erosion by cultivation on steep slopes without adequate soil conservation measures such as terraces and mulching.		(Ministry of Environment, 2018b)
		To create more soil conservation measures like terraces and filtration trenches.	(RWFA, n.d.-f)
	The highland soils are particularly prone to erosion and landslides especially, valleys and lowlands (peat lands) as well as highland meadows due to deforestation and inappropriate agricultural practices.		(Twagiramungu, 2006)
	Siltation due to inadequate farming techniques.		(Ministry of Natural Resources, 2011)
	Land fragility due to high slopes, agriculture and cattle.		(Ministry of Environment, 2018c)
Erosion from unstable slopes.	Erosion due to unstable slopes (this is also related to landslides).		(Ministry of Environment, 2019b)
	Siltation due to erosion of unstable slopes.		(FAO, 2019)
	Contribution of landslides to soil erosion.		(MIDIMAR, 2015)
Lack of vegetation in and nearby wetlands to capture sediment transport.	Greenbelts mitigate pollution, flash floods and erosion. The vegetation also serves to slow the velocity of overland flow which helps to prevent erosion and creates a better opportunity for the water to percolate into the soils. This helps to reduce the "flashy" nature of runoff from upland and urbanised areas.		(RWFA, n.d.-g)
		To create buffer zones vegetated with suitable species of bamboo and tree and erosion control structures. Vegetative buffers also help to reduce concentration of nitrates, phosphorous, and pesticides.	(Ministry of Environment, 2018c)
Soil dumping.	Soil dumping.		(Mugisha, 2020a)
Sedimentation from mining.	High sediment load and soil erosion due to mining, leading to sediment ingress to watercourses.		(Ministry of Environment, 2018b)
	Pollution due to high sedimentation caused by mining methods.	The Nyabarongo is a source for the water supply of Kigali, and a source for irrigation development. It is, therefore, most important to monitor, protect and reduce loads of organic matter and nutrients.	(Ministry of Environment, 2018c)

	Siltation due to mining exploitation.		(Ministry of Environment, 2018c)
	The use of wetland as a mine for sand, gravel, clay and peat forms the most direct threat for the wetlands.		(Nabahungu, 2012)
	Sediment loads in rivers are further aggravated by mining activities throughout the catchment. Both formal licensed and informal, unlicensed, usually artisanal, mines use poor, environmentally damaging practices that lead to ingress of large quantities of sediment into watercourses.		(Ministry of Environment, 2018c)
Siltation from brick production.	Siltation due to brick production and the exploitation of river sand		(RWFA, n.d.-e)
	Siltation due to brick production in rivers		Participant: NGO1
	The discharge of clay into rivers reduces water quality, biodiversity, dam storage capacity and hydropower capacity.		(NISR, 2019)
Vulnerability of hydropower stations.	River water is often unsuitable for hydropower generation intake (by sedimentation which occurs mostly during floods).		(Ministry of Environment, 2018b)
	The discharge of clay and nutrients into rivers reduces water quality, biodiversity, dam storage capacity and hydropower capacity.		(NISR, 2019)
Vulnerability of drinking water treatment stations.	The costs of drinking water treatment from rivers are high, and during periods of high river discharge, intakes often have to be shut off completely because treatment is severely hampered by sediments in the intake water.		(Ministry of Environment, 2018b)
	During floods, water processing plants are affected by high sedimentation loads and rapid and high flood waves. All water taps, except for wells, are dependent on the water from these processing plants		Participant: MININFRA3
Insufficient awareness about the causes of erosion in wetlands.	There is a limited long-term and holistic development view of politicians is a driving force behind environmental issues in catchments.		(Ministry of Environment, 2018b)
		To create awareness (about environment) among policy-makers and local community leaders to recognise the full range of stakeholders in decision-making. Wetlands play a vital role in controlling floodwaters, reducing erosion, improving water quality and serving as habitats for diverse species of plants.	(Nabahungu, 2012)

Appendix III: Criteria tree

This appendix provides an elaborate description of the constraints and factors that apply to the study area. The constraints are shown in Table 16 and the themes, their corresponding SEA-objectives and their relating factors and indicators in Table 17.

Table 16: Constraints that apply to locating industries in Huye and Kigali.

Constraint	Indicator	Source
Not allowed to cut forest for construction.	Forest bigger than 0.25ha., trees >7m, canopy cover >10 % *	Law on environment, 2019, article 44 (Ministry of Environment, 2018a).
Not allowed to build within a buffer of 10m from rivers.	Distance to rivers (max 10m)	Law on environment, 2019, article 42 (Ministry of Environment, 2018a).
Not allowed to build within a buffer of 20m from swamps.	Distance to swamps (max 20m)	Law on environment, 2019, article 42 (Ministry of Environment, 2018a).
Not allowed to build within a buffer of 50m from lakes.	Distance to lakes (max 50m)	Law on environment, 2019, article 42 (Ministry of Environment, 2018a).

*The law on environment did not define forest; therefore, the definition and forest size was obtained from Ministry of Lands and Forestry (2017).

Table 17: Criteria tree (factors) constructed for assessing the suitable locations for industrial development regarding flood issues. W: weight

Themes: SEA-objective	W	Criterion	W		Indicator
1) Industry changes infiltration Obj 1: To discourage industrial development on sites that lead to reduced infiltration and consequently to increased run-off to downstream areas.	0.85	Industrial development is **less suitable on pervious surfaces that change to impervious** when being developed.			Run-off curve number (CN). (Represents direct run-off from land-uses such as; agri, urban, grass, and forestry).
	0.15	Development is **less suitable on steeper slopes.**			Slope steepness (%).
2) Capacity to store and retain water Obj 2: To develop industry in catchments that have sufficient capacity to store and retain water.	0.27	Development is **more suitable in upstream catchments** that serve as source areas characterized by small streams.			Hierarchy of rivers.
	0.52	Development is **more suitable in catchments with** higher water retention due to **high infiltration** into the soil.			Average CN value in catchments.
	0.06	Development is **more suitable in catchments with more storage capacity in reservoirs.**			Capacity of reservoirs (m3/km3) per catchment.
	0.15	Development is **more suitable in catchments with larger wetlands** to store and retain water.	0.90	Development is **more suitable in catchments with larger wetlands** to store and retain water.	Capacity (size) of wetlands (m2/m2) per catchment.
			0.10	Development is **more suitable in catchments with larger natural marshes** to store and retain water.	Capacity (size) of natural marshes (m2/m2) per catchment.
3) Wetland degradation Obj 3: To protect wetlands against degradation caused by nearby industrial development.	0.90	Development is **less suitable closer to wetlands, lakes and rivers**.			Distance to wetlands, lakes and rivers (Max: 1000m).
	0.10	Development is **less suitable closer to natural marshes.**			Distance to natural swamp (Max 1000m).

4) Vulnerable assets Obj 4: To protect vulnerable assets in wetlands against floods that are induced by upstream industrial development.	0.41	Development is **more suitable upstream of** areas with **a smaller size of built-up area** in downstream wetlands.			Relative size of built-up area (m2/km2) in downstream wetlands.
	0.08	Development is **more suitable upstream of** areas with **a shorter length of road infrastructure** in downstream wetlands.			Relative length of road infrastructure (m/km2) in downstream wetlands.
	0.20	Development is **more suitable upstream of** areas with a **lower amount of powerplants** in downstream wetlands.			Relative amount of hydropower plants (amount/km2) in downstream wetlands.
	0.20	Development is **more suitable upstream of** areas with **a lower amount of water treated in water treatment facilities** in downstream wetlands.			Relative amount of processed water in water treatment facilities (m3/km2) in downstream wetlands.
	0.08	Development is **more suitable upstream of** areas with **a smaller size of agricultural fields** in downstream wetlands.			Relative size of agricultural fields (m2/m2) in downstream wetlands.
	0.03	To **protect wetlands with a protection status** against floods that are induced by upstream development.	0.75	Development is **more suitable upstream of** areas with **a smaller size of** downstream **wetlands classified as total protection.**	Relative size of wetlands (m2/m2) with status: total protection ('protection totale') in downstream wetlands.
			0.25	Development is **more suitable upstream of** areas with a **smaller size of** downstream **wetlands classified as conditional protection.**	Relative size of wetlands (m2/m2) with status: under condition ('sous condition') in downstream wetlands.
5) Hazardous areas Obj 5: To discourage industrial development in hazardous areas.	0.50	Development is **less suitable in catchments** that have **more relief.**			Mean slope (%) per catchment.
	0.25	Development is **less suitable in areas** with **high mean precipitation.**	0.50	Development is **less suitable in areas** with **higher mean precipitation in March-April.**	Mean precipitation (mm) rain season Mar-Apr.
			0.50	Development is **less suitable in areas** with **higher mean precipitation in October-November.**	Mean precipitation (mm) rain season Oct-Nov.
	0.25	Development is **less suitable in areas** with a **high return period of showers.**	0.06	Development is **less suitable in areas** with a **higher return period of showers.**	Probability of exceeding 25mm/day (%).

	0.15	Development is **less suitable in areas** with a **higher return period of showers.**	Probability of exceeding 50mm/day (%).
	0.27	Development is **less suitable in areas** with a **higher return period of showers.**	Probability of exceeding 70mm/day (%).
	0.52	Development is **less suitable in areas** with a **higher return period of showers.**	Probability of exceeding 100mm/day (%).

Appendix IV: Missing data

For some criteria, no data was found or acquired; these indicators are shown in Table 18.

Table 18: Missing data and criteria in the criteria tree.

Additional criterion	Dataset	Status	Ownership	Year	Description
Theme 2: Capacity to store and retain water Development is more suitable in catchments with more storage incapacity harvesting tanks.	Harvesting tanks on buildings	Not acquired	RHA		RHA records installed harvesting tanks.
Theme 2: Capacity to store and retain water Development is more suitable in catchments with sufficient capacity in drainage channels.	Discharge in drainage channels.	No data found			
Theme 1: Industry changes infiltration & Theme 2: Capacity to store and retain water In SEA-Obj. 1 & SEA-Obj. 2: To calculate CN.	Land treatment	No data found			Factor to determine the infiltration into the soil with the CN formula.
Theme 5: Hazardous areas Development is less suitable in areas with more recorded floods.	Recorded floods	Not acquired	MIDIMAR		Rwanda lacks most of the hydrological and hydraulic data needed for flood hazard analysis. Although flood modelling is done for only a few catchments, MIDIMAR registers flood notifications.
Theme 4: Vulnerable assets Development is more suitable upstream of areas with a smaller size of informal settlements in wetlands.	Location informal settlements	Not acquired	RHA	2014	Classified into poor, medium and good conditions of settlements. These conditions would resemble the capacity of settlements to cope with floods. Neighbourhoods with good conditions are less vulnerable (Participant: RHA1)
Theme 5: Hazardous areas Development is less suitable in areas with a higher slope susceptibility.	Slope susceptibility	Not acquired	MIDIMAR	2014	Indicates the effect of floods on landslide vulnerability.
Not categorised in a theme.	Catchment awareness	No data found			

Appendix V: Data processing & Standardisation of indicator maps

Datasets were processed, and indicator maps were standardised to represent the criteria accurately. In Table 19 and Table 20 the processing and standardisation activities for respectively constraints and factors are described, and the argumentation for this standardisation is given. For each standardisation map, it applies; the closer the value towards 100, the higher the suitability for industrial development. Furthermore, this appendix elaborates on the frequency analysis and the SCS-method.

Table 19: Processing of data layers for the constraints and the value function for standardisation of indicators.

Constraint	Indicator	Data layers	Processing	Value function
Forest	Forest bigger than 0.25ha.	Land-use (forest), forest	-Filter forest attributes >0.25ha. trees >7m, canopy cover >10 %. -Update land-use with forest map.	Forest areas are 0; other areas are 100.
10m from rivers.	Distance to rivers.	Rivers	Buffer	Distance ≤ 10m are 0; all other values are 100.
20m from swamps.	Distance to swamps.	Swamps	Buffer	Distance ≤ 20m are 0; all other values are 100.
50m from lakes.	Distance to lakes.	Lakes	Buffer	Distance ≤ 30m are 0; all other values are 100.

Table 20: Processing of data layers for the factors and the standardisation of indicators.

Factor	Indicator	Data layers	Processing	Standardisation	
				Value function	Argumentation
Theme 1: Industry changes infiltration					
SEA-Obj 1: To discourage industrial development on sites that lead to reduced infiltration and consequently to increased run-off to downstream areas.					
Perviousness surfaces.	Run-off curve number (CN-value) per land-use class.	Land-use, forest	-Update land-use with forest map. -Assign CN-values to agri, urban, grass, wetlands, other and forestry.	Positive linear; [45, 95]; A lower CN has a lower score.	-**Development** that leads to a change in land-use from a low CN to a high CN results in higher immediate run-off, because a location with a low value infiltrates better and thereby retains more water. In other words, new development that replaces urban areas (high CN-value) is more suitable than new development that replaces forest or grasslands (low CN-value). -**Function:** Although the relation between discharge and the CN-value is not linear, the function is simplified to linearity as it approximates a linear function (United States Department of Agriculture, 1986). -**Other:** The land-use data below the existing industrial parks consisted largely of cropland.
Slope steepness.	Slope steepness (%).	DEM	-	Negative concave; [0, Max. = 25%]; A steeper slope has a lower score.	-**Development** should not occur on steep slopes, because steep paved slopes cause rapid run-off and often increase risk by landslides and erosion. Flat surfaces infiltrate, retain and store water easier. -**Function:** Slope steepness behaves exponentially compared to run-off because a steeper and longer slope leads to a faster run-off (Fang, Sun, & Tang, 2015). Furthermore, significant adverse effects will occur at 15% (Participant: RHA1); hence, slopes <15% are close to 100 and slopes >15% are close to 0.
Theme 2: Capacity to store and retain water					
SEA-Obj 2: To develop industry in catchments that have sufficient capacity to store and retain water					
Upstream and downstream catchments.	Hierarchy of rivers in Level3-catchment.	Rivers (Hierarchy), Level3-catchments	-Categorise river hierarchy in upstream (class 0 and 5) and downstream catchments (class 1-4). -Level3-catchments: Defines hydraulic boundaries to which retention and storage applies.	Attribute table; hierarchies 0 and 5 (upstream) have a higher score than hierarchies 1 to 4 (downstream).	-**Development** is better located in source areas because they are less likely prone to floods. Source areas are upstream catchments often on higher grounds and characterised by small rivers. These catchments are more effective in retaining water, while in downstream catchments water accumulates. -**Function:** Catchments that have a big river were labelled hierarchy 1-4, catchments that have a small river were labelled hierarchy 5 and catchments with no river hierarchy 0.

Retention in catchments by infiltration.	Average run-off curve number (CN-value) in Level3-catchments.	Land-use, forest, Level3-catchments	-Update land-use with forest map. Assign CN-values to agri, urban, grass, wetlands, other and forestry. -Average CN-value ($\sum_{i=1}^{n} CN_n\, Area_n \;/\; \sum_{i=1}^{n} Area_n$, with Area the catchment size) per Level3-catchment. -Level3-catchments: Defines hydraulic boundaries to which retention and storage applies.	Negative linear; [69, 95]; A lower average CN has a higher score.	-**Development** is better located in areas with surrounding land-uses that infiltrate water well as these areas are less likely to be flooded. This infiltration capacity is described by the average CN-value of the catchment area. A high CN results in immediate run-off (e.g. urban) causing floods, whereas a location with a lower value (e.g. forest and grassland) stores the water in the soil. -**Function:** Although the relation between discharge and the CN-value is not linear, the function is simplified to linearity as it approximates a linear function (United States Department of Agriculture, 1986). -**Projection:** Based on past flood events, the CN-values apply to a Level3-catchment scale. Floods descent from a Level3-catchment of 10.7km2 at Nyabugogo (INZOZI TV, 2020). -**Other:** The land-use data below the industrial park consisted largely of cropland.
Storage capacity in reservoirs.	Capacity of reservoirs (m3/km2) per Level3-catchment.	Reservoirs, Level3-catchments	-Sum capacity reservoirs per Level3-catchment; divided by size Level3-catchment (ratio). -Level3-catchments: Defines hydraulic boundaries to which retention and storage applies.	Positive linear; [0, Max. = 1268m3/km2]; A higher storage capacity in reservoirs has a higher score.	-**Development** is more suitable in areas with sufficient storage capacity in reservoirs or ponds. These areas are less likely to be flooded since water retention reduces the peak run-off, reducing flash floods. -The **function** is linear because each m3 of new storage capacity equally contributes to improving the suitability for development.

Retention and storage in wetlands.	Capacity (size) of wetlands (m2/m2) per Level3-catchment.	Wetlands, lakes, Level3-catchments	-Union between wetlands and lakes. -Sum size wetlands per Level3-catchment; divided by size Level3-catchment (ratio). -Level3-catchments: Defines hydraulic boundaries to which retention and storage applies.	Positive linear; [0, Max. = 23m2/m2]; Larger wetlands have a higher score.	-**Development** is more suitable in areas with sufficient storage capacity in wetlands and natural marshes. These areas are less likely to be flooded since water retention reduces the peak run-off, reducing flash floods. -The **function** is linear because increasing the size of a wetlands or natural marsh to retain water, equally contributes to improving the suitability for development. -**Weighting:** Natural marshes have a good ecological state; therefore, they retain water better than degraded wetlands or cultivated wetlands with drainage (i.e. Wetlands should be as natural as possible (Participant: REMA1; REMA2). -**Other:** Rivers are not considered in the wetland dataset, because their primary function is to discharge water and not to store.
Retention and storage in natural marshes.	Capacity (size) of natural marshes (m2/m2) per Level3-catchment.	Swamps (végétation naturelle), Level3-catchments	-Sum size natural marshes per Level3-catchment; divided by size Level3-catchment (ratio). -Level3-catchments: Defines hydraulic boundaries to which retention and storage applies.	Positive linear; [0, Max. = 98.4m2/m2]; Larger natural marshes have a higher score.	

Theme 3: Wetland degradation

SEA-Obj 3: To protect wetlands against degradation caused by nearby industrial development.

Distance to wetlands, lakes and rivers.	Distance to wetlands, lakes and rivers (m).	Wetlands, lakes, rivers	-Union wetlands, lakes and rivers. -Euclidean distance (5m steps).	Positive convex; [0, 1000m]; A shorter distance has a lower score. >1000 has a value 100.	-Industrial **development** should not be located near natural marshes and waterbodies such as rivers, lakes and wetlands as development increases flooding, pollution, sedimentation and water extraction harming nearby marshes and wetlands. The degradation of wetlands diminishes the regulating capacity of natural marshes and wetlands -A convex **function** was used because development close to a waterbody has an immediate impact (value 0) while development further away is less impactful due to mitigating factors that play a more and more prominent role in addressing pollutants, sediments and overland flow. E.g. closer to wetlands overland flash floods are more occurrent due to the soil's reduced ability to infiltrate water (Hayashi, 2014). -**Function:** The maximum distance was based on a theoretical spatial scale of saturation excess overland flow (~15 to 10000m) and infiltration excess overland flow (~5 to 1000m) (Bloschl & Sivapalan, 1995), and the advised distance of buffer zones of 20 to 150m (Fischer & Fischenich, 2000). -**Weighting:** The regulating capacity of marshes, is higher than the regulating capacity of wetlands. Wetlands should be as natural as possible (Participant: REMA1; REMA2).
Distance to natural marshes.	Distance to natural swamp (m).	Swamps (végétation naturelle)	-Euclidean distance (5m steps).	Positive convex; [0, 1000m]; A shorter distance has a lower score. >1000 has a value 100.	

Theme 4: Vulnerable assets

SEA-Obj 4: To protect vulnerable assets in wetlands against floods that are induced by upstream industrial development.

Size of built-up area.	Relative size of built-up area (m2/km2) in downstream wetlands.	Built-up, wetlands, Level3-catchments, Level2-catchments	-Sum size built-up in wetlands; divided by wetland size (measured per Level2-catchment) to indicate ratio. -Wetland boundaries define which assets are within the wetlands. -Downstream wetlands were defined by: 1. Selecting Level3-catchments till 80km river length downstream of districts. 2. Clip wetlands on downstream Level3-catchments.	Negative linear; [0, Max. = 24153m2/km2]; A smaller amount of built-up in wetlands has a higher score.	-**Development** is less suitable upstream of wetlands with many activities. Activities become increasingly more vulnerable for floods induced by upstream development as more assets that can be damaged exist. Especially, mud houses, businesses and industries have high costs when exposed during floods or when floods hinder activities. -A linear **function** was used because each construction equally contributes to increasing vulnerability; a goal function was used based on the ideal state of having no assets; A ratio considers the mitigation capacity of the wetland size. -**Projection:** The districts were divided into five areas (Huye 1, 2 & 3 and Kigali 1 & 2) distinguished by the catchment to which water flows (Figure 27). The downstream areas were limited by wetland boundaries and by Level2-catchments within reach of 80km river length measured from the point where the river leaves the district. -**Other:** Legally, construction in wetlands is not allowed, but it still is happening.
Length of road infrastructure.	Relative length of road infrastructure (m/km2) in downstream wetlands.	Road networks, wetlands, Level3-catchments, Level2-catchments	-Sum length road network in wetlands; divided by wetland size (measured on Level2-catchment) to indicate ratio. -Wetland boundaries define which assets are within the wetlands. -Downstream wetlands were defined by: 1. Selecting Level3-catchments till 80km river length downstream of districts. 2. Clip wetlands on downstream Level3-catchments.	Negative linear; [0, Max. = 1436m/km2]; A shorter length of road network in wetlands has a higher score.	-**Development** is less suitable upstream of wetlands with many activities. Activities become increasingly more vulnerable for floods induced by upstream development as more assets that can be damaged exist. The flooding of infrastructure can disturb emergency response or harm the transport sector. Also, it can lead to extra costs for road maintenance. -A linear **function** was used because each meter of road segment equally contributes to increasing vulnerability; a goal function was used based on the ideal state of having no assets; A ratio considers the mitigation capacity of the wetland size. -**Projection:** The districts were divided into five areas (Huye 1, 2 & 3 and Kigali 1 & 2) distinguished by the catchment to which water flows (Figure 27). The downstream areas were limited by wetland boundaries and by Level2-catchments within reach of 80km river length measured from the point where the river leaves the district.

Amount of powerplants.	Relative amount of hydropower plants (amount/km2) in downstream wetlands.	Powerplants, wetlands, Level3-catchments, Level2-catchments	-Sum number of powerstations in wetlands; divided by wetland size (measured on Level2-catchment) to indicate ratio. -Wetland boundaries define which assets are within the wetlands. -Downstream wetlands were defined by: 1. Selecting Level3-catchments till 80km river length downstream of districts. 2. Clip wetlands on downstream Level3-catchments.	Negative linear; [0, Max. = 0.017 per km2]; A lower amount of powerplants dependent on wetlands has a higher score.	-**Development** is less suitable upstream of wetlands with many activities. Activities become increasingly more vulnerable for floods induced by upstream development as more assets that can be damaged exist. At hydropower stations it has occurred that during floods sedimentation and water pressure was too high to generate electricity, reducing power supply. -A linear **function** was used because each powerplant equally contributes to increasing vulnerability; a goal function was used based on the ideal state of having no assets; A ratio considers the mitigation capacity of the wetland size. -**Projection:** The districts were divided into five areas (Huye 1, 2 & 3 and Kigali 1 & 2) distinguished by the catchment to which water flows (Figure 27). The downstream areas were limited by wetland boundaries and by Level2-catchments within reach of 80km river length measured from the point where the river leaves the district.
Amount of processed water in water treatment facilities.	Relative amount of processed water in water treatment facilities (m3/km2) in downstream wetlands.	Water processing plants, wetlands, Level3-catchments, Level2-catchments	-Sum amount of processed water by water treatment facilities in wetlands; divided by wetland size (measured on Level2-catchment) to indicate ratio. -Wetland boundaries define which assets are within the wetlands. -Downstream wetlands were defined by: 1. Selecting Level3-catchments till 80km river length downstream of districts. 2. Clip wetlands on downstream Level3-catchments.	Negative linear; [0, Max. = 44.54m3/m2]; A lower amount of water treatment facilities dependent on wetlands has a higher score.	-**Development** is less suitable upstream of wetlands with many activities. Activities become increasingly more vulnerable for floods induced by upstream development as more assets that can be damaged exist. Water processing plants have shut off during floods causing shortages of drinking water. -A linear **function** was used because each cube of treated water equally contributes to increasing vulnerability; a goal function was used based on the ideal state of having no assets; A ratio considers the mitigation capacity of the wetland size. -**Projection:** The districts were divided into five areas (Huye 1, 2 & 3 and Kigali 1 & 2) distinguished by the catchment to which water flows (Figure 27). The downstream areas were limited by wetland boundaries and by Level2-catchments within reach of 80km river length measured from the point where the river leaves the district.

Size of agricultural fields.	Relative size of agricultural fields (m2/m2) in downstream wetlands.	Swamps (Cultivé), wetlands, Level3-catchments, Level2-catchments	-Sum size of agricultural fields 'Cultivé' in wetlands; divided by wetland size (measured on Level2-catchment) to indicate ratio. -Wetland boundaries define which assets are within the wetlands. -Downstream wetlands were defined by: 1. Selecting Level3-catchments till 80km river length downstream of districts. 2. Clip wetlands on downstream Level3-catchments.	Negative linear; [0, Max. = 0.59m2/m2]; A smaller size of agricultural fields in wetlands has a higher score.	--**Development** is less suitable upstream of wetlands with many activities. Activities become increasingly more vulnerable for floods induced by upstream development as more assets that can be damaged exist. When fields get flooded, crops get damaged, threatening the food security and income of communities. However, some crops such as rice and sugarcanes grow naturally in wetlands. These crops are therefore less vulnerable. In the dataset, no distinction was made between the crop types. -A linear **function** was used because each square meter of agricultural fields equally contributes to increasing vulnerability; a goal function was used based on the ideal state of having no assets; A ratio considers the mitigation capacity of the wetland size. -**Projection:** The districts were divided into five areas (Huye 1, 2 & 3 and Kigali 1 & 2) distinguished by the catchment to which water flows (Figure 27). The downstream areas were limited by wetland boundaries and by Level2-catchments within reach of 80km river length measured from the point where the river leaves the district.
Size of wetlands with status: total protection.	Relative size of wetlands (m2/m2) with status: total protection ('protection totale') in downstream wetlands.	Swamps (total protection), wetlands, Level3-catchments, Level2-catchments	-Sum size of wetlands with status: "total protection"; divided by wetland size (measured on Level2-catchment) to indicate ratio. -Wetland boundaries define which assets are within the wetlands. -Downstream wetlands were defined by: 1. Selecting Level3-catchments till 80km river length downstream of districts. 2. Clip wetlands on downstream Level3-catchments.	Negative linear; [0, Max. = 0.039m2/m2]; A smaller size of wetlands classified as total protection has a higher score.	-**Development** is less suitable upstream of wetlands under local, national or international protection (RAMSAR). Larger areas are increasingly more vulnerable for floods induced by upstream development as more damage to these areas can possibly occur. To conserve these areas, water velocity and water levels should not rise too high and too fast, because floods and sedimentation can destruct habitats and plant species. Floods are only allowed once in a while. The effects of these floods are more severe when more protected wetlands exist downstream. -A linear **function** was used because each square meter of protected area equally contributes to increasing vulnerability; a goal function was used based on the ideal state of having no assets; A ratio considers the mitigation capacity of the wetland size. **-Weighting:** Wetland categories are no protection, exploitation under condition (this requires EIA) and total protection (Participant: REMA1). Where total protection is the most valuable. -**Projection:** The districts were divided into five areas (Huye 1, 2 & 3 and Kigali 1 & 2) distinguished by the catchment to which water flows (Figure 27). The downstream areas were limited by wetland boundaries and by Level2-catchments within reach of 80km river length measured from the point where the river leaves the district.
Size of wetlands with status: under condition.	Relative size of wetlands (m2/m2) with status: under condition ('sous	Swamps (under condition), wetlands, Level3-	-Sum size of wetlands with status: "under condition"; divided by wetlands (measured on Level2-catchment) to indicate	Negative linear; [0, Max. = 0.92m2/m2]; A smaller size of wetlands classified as	

	condition') in downstream wetlands.	catchments, Level2-catchments	ratio. -Wetland boundaries define which assets are within the wetlands. -Downstream wetlands were defined by: 1. Selecting Level3-catchments till 80km river length downstream of districts. 2. Clip wetlands on downstream Level3-catchments.	conditional protection has a higher score.	

Theme 5: Hazardous areas

SEA-Obj 5: To discourage industrial development in hazardous areas.

Relief	Mean slope (%) per Level4-catchment.	DEM, Level4-catchments	-Average slope over Level4-catchment (Zonal statistics). -Level4-catchment: Defines hydraulic boundaries to which water from hills propagates.	Negative Concave; [0, Max. = 12.8%]; A catchment with more relief (mean slope) has a lower score.	-**Development** is less suitable in hilly catchments because the steep topography intensifies the run-off from hills causing floods. -A concave **function** was used because flat surfaces do not cause rapid run-offs, while it becomes more likely to happen when an area is more hilly. -**Projection:** Due to the local impact, the indicator was applied on a Level4-catchment scale (average area of 7km2) instead of a Level3-catchment scale (average area of 47km2).
Precipitation March-April	Mean precipitation (mm) rain season Mar-Apr.	Daily precipitation	-Average rainfall in Mar-Apr. -Thyssen polygons	Negative linear; [181.7, 344.7mm]; A higher precipitation has a lower score.	-**Development** is less suitable in areas with a large amount of run-off from showers, since rainy areas are more subjected to floods. -**Other:** Different indicators were used to represent a wide range of shower events. -A linear **function** was used as no indication was found to do otherwise. -**Projection:** Thiessen polygons were used to indicate climatic areas over Kigali and Huye based on the location of the rainfall stations. -**Other:** The maximum and minimum value were based on the mean precipitation measured in Mar-Apr and Oct-Nov.
Precipitation October-November	Mean precipitation (mm) rain season Oct-Nov.	Daily precipitation	-Average rainfall in Oct-Nov. -Thyssen polygons	Negative linear; [181.7, 344.7mm]; A higher precipitation has a lower score.	

Probability of exceeding 25mm/day.	Probability of exceeding 25mm/day (%) (return period = 0.2 year).	Daily precipitation	-Frequency analysis -Thyssen polygons	Negative linear; [1.96, 4.14%]; A higher probability of rainfall events has a lower score.	-**Development** is less suitable in areas with a large amount of run-off from showers, since rainy areas are more subjected to floods. -**Other:** Different indicators were used to represent a wide range of shower events. -A linear **function** was used as no indication was found to do otherwise. -**Projection:** Thiessen polygons were used to indicate climatic areas over Kigali and Huye based on the location of the rainfall stations. -**Other:** The probability indicates the % of flood events above the threshold of respectively 25, 50, 70, and 100 mm/day.
Probability of exceeding 50mm/day.	Probability of exceeding 50mm/day (%) (return period = 1.1 years).	Daily precipitation	-Frequency analysis -Thyssen polygons	Negative linear; [0.22, 0.74%]; A higher probability of rainfall events has a lower score.	
Probability of exceeding 70mm/day.	Probability of exceeding 70mm/day (%) (return period = 2.1 years).	Daily precipitation	-Frequency analysis -Thyssen polygons	Negative linear; [0.05, 0.25%]; A higher probability of rainfall events has a lower score.	
Probability of exceeding 100mm/day.	Probability of exceeding 100mm/day (%) (return period = 18 years).	Daily precipitation	-Frequency analysis -Thyssen polygons	Negative linear; [0.007, 0.118%]; A higher probability of rainfall events has a lower score.	

Frequency analysis:

Frequency analysis was performed on the data of eleven weather stations to calculate the probability of exceeding a rainfall event (Van Westen et al., 2011; Wagesho & Claire, 2016). Four events of 25, 50, 70 and 100 mm/day and respectively return periods of 0.2, 1.1, 2.1 and 18 years were chosen to deal with possible climatic differences. These flood events were based on newspaper reports (Mugisha, 2020b; Ngabonziza, 2020) and Rainfall Intensity-Duration-Frequency (IDF) curves for Rwanda (Wagesho & Claire, 2016).

The probability of exceedance is described in Van Westen et al., (2011):

$$P = 100\ x\ \frac{m}{n+1} \text{ (Eq. 2)},$$

with P the probability in %, m is the rank of the precipitation ordered from the highest possible rainfall to the lowest en n is the total number of data points.

SCS-method (CN-value):

The capacity of land-uses to retain water through soil infiltration was described by Curve Number (CN) values. The SCS-method inspired the use of this classification. This empirical method calculates the run-off from an area after a shower based upon a design shower and the CN-value (United States Department of Agriculture, 1986; Table 2.1). The method was developed by United States Department of Agriculture, (1986), and applied to indicate floodwater discharge in an SMCE study by Zarkesh, (2005). This study obtained the CN-values for different land-uses using the United States Department of Agriculture, (1986) classification, while considering hydrologic soil group D (most prevalent in Rwanda obtained from ORNL DAAC, 2018), assuming a poor hydrological condition and averaging CN-values for land treatment. Table 21 shows these CN-values.

Table 21: CN values to classify infiltration.

Land-use	**CN-value**
Wetland*	45
Other land*	45
Forestland	~70
Natural forest	45
Dense planted forest	50
Medium dense planted forest	60
Low dense planted forest	75
Very low dense planted forest and high dense shrub	80
Low dense shrub	85
Grassland	80
Cropland	85
Settlement	95

*Waterbodies and other land uses were assigned a value of 45 to indicate that these land-uses have a high value retaining water. However, conventionally immediate run-off of water in wetlands is assumed; appraising CN=100.

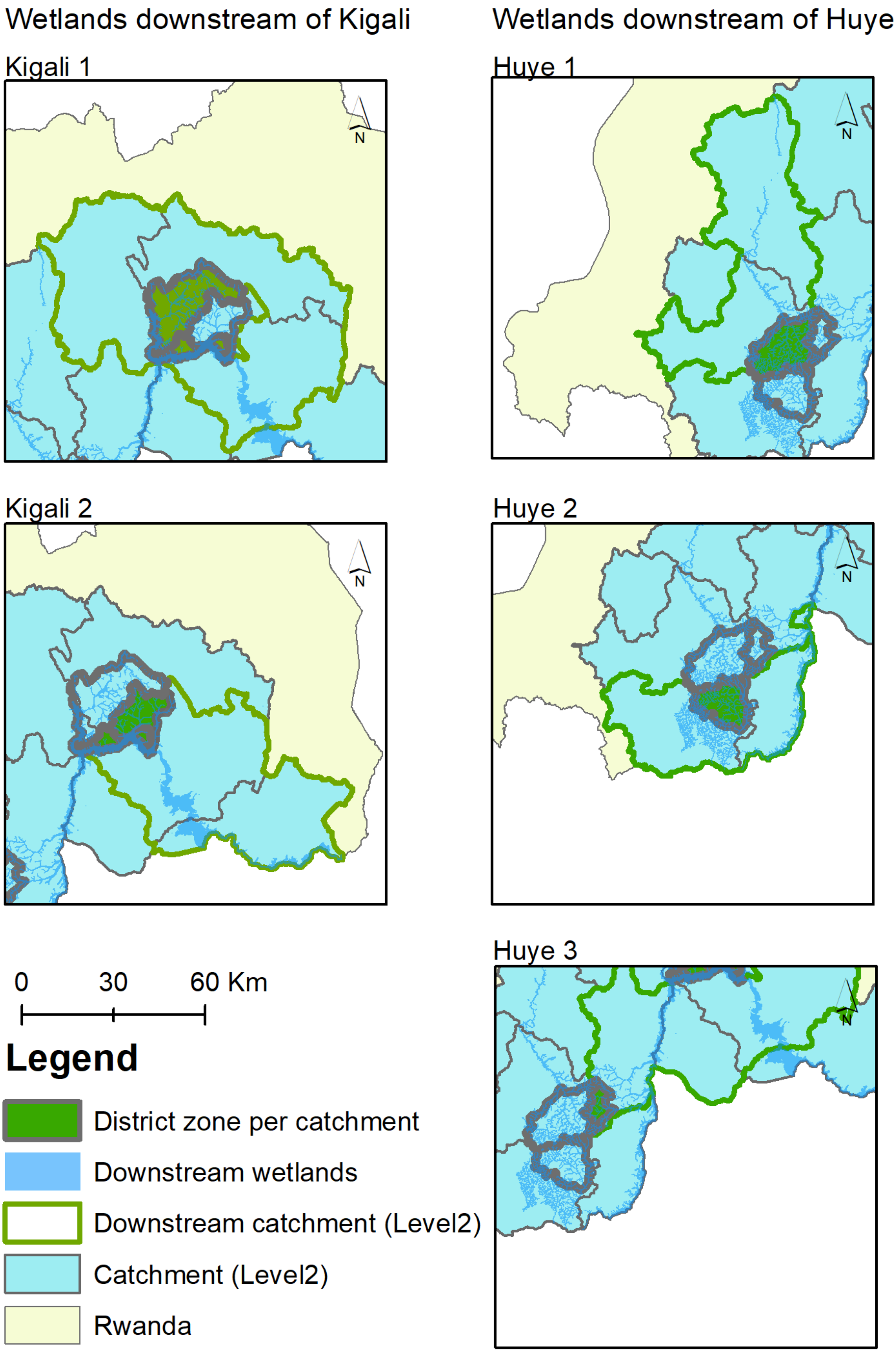

Figure 27: Five district areas (Huye 1, 2 & 3 and Kigali 1 & 2) with water flowing to different catchments downstream to describe indicators in theme 4: 'Vulnerable assets'.

Appendix VI: Session outlines & Consent forms

This appendix provides an overview of the session outlines that were used to structure the interviews. These guidelines described the session objectives, content, logistics and guiding questions to ensure that all the topics were covered during the interviews. Within the guidelines, example questions are mentioned that were optional to ask. The interviews covered four topics: consideration environmental information (See Session outline 1: Explanatory intake meeting & consideration of environmental information.), environmental issues (See Session outline 1: Explanatory intake meeting & consideration of environmental information.Session outline 2: Environmental issues, Criteria tree & Data collection), weighting & visions (See Session outline 3: Weighting and design visions), and evaluation of the case study (Session outline 4: Evaluation case study). Although it was intended that the four topics were covered in different interviews, in practice, the interviewees could address each topic. Furthermore, throughout the fieldwork, sessions were combined or shortened based on the circumstances and time available.

Before the first interview: an one-pager, an information sheet on consent and a consent sheet were send to the interviewee (See Appendix VII: Information sheet consent interview). Additionally, before the final evaluation interview, the proceedings of the case study were presented. Although the focus of these materials was on the integration of different tools and their applicability in decision-making, most of their output could still be used.

a) Session outline 1: Explanatory intake meeting & consideration of environmental information.

Participants[1]	MoE, REMA, RWB, RLMUA, CoK, Huye
Materials needed[2]	-Audio recorder -Presentation about the research and NSAP method -One pager
Logistics needed[2]	-Quiet room -One pager sent beforehand -Consent sheet sent beforehand -Laptop -Presentation of SDF and my research, beamer
Planned date[2]	7th till 10th Jan.
Planned duration[2]	60min

1) Only the participants that were involved in the topic; consideration of environment are mentioned.
2) In reality, these materials, logistics and timelines were different per interview. The description provides what was aimed for.

<u>Content of the session</u>

Session objectives	-Create engagement and trust -To get to know and expectation setting -To acquaint the participant with the research -To discuss the current consideration of environment. -Develop new research ideas, hypothesis and concepts to adjust the research to the Rwandese environmental and governance context. -Identify key environmental issues caused by industrial development -Scheduling follow-up meetings
Research question	Question 1.1: How do policy and plans that guide the decision-making process of industrial development locations include the consideration of the environment? Question 1.2: What is the role of environmental policy in locating industrial development? Question 1.3: Which key environmental issues are caused by industrial development?
Main messages to transmit	-Their valuable contribution to the research
Previous sessions	-
Prepare before session	-One-pager with information on the research -Consent sheet
Output materials	-Dates follow-up meetings and timeline -Clarity on the current consideration of environment. -Reflect on Rwandese culture, to adjust interview style.
Other remarks	-This meeting is mainly to get to know and has an unstructured approach that should be able to touch upon many topics. -The intakes also serve to create engagement and trust. This is related to getting to know the Rwandese culture. Culture observations in the first week might help to understand the context in which environment is considered.

Flow of the session:

Main Content	Duration (min)	Objective	Delivery method and description	Other
Opening	5	To explain the purpose of this session Set expectations.	Purpose: explain that this meeting is to get to know each other and the research better. Ask if they had questions about the one-pager or the consent form.	
Consent	5	To inform the participant on how the interview data is used. To gain trust	Form of consent and explain that they are recorded as a representative.	
Get to know	10	To investigate the job of the participant To gain trust To get to know	Unofficial talk about the research and the activity of the person. Ask about their experience in the field, daily work life. What drives them to participate?	
Explain research	25	To acquaint the participant with the research. To create engagement	-Presentation about the SDF if needed, the research and the role of the participant in the research. -Discuss the steps that are followed. Ask in which steps they would like to be involved and explain very clearly why I would like to involve them in which step. Explain that I would like to have the same people involved during the process. Informal so allow questions during the presentation. - Ask about their initial impression. How and if the participant can contribute. What do they think?	
	15	Consideration environment.	Do they think environment is considered enough in spatial planning? How is environment considered? What are the main issues?	
Develop research	5	Develop new research ideas, hypothesis, and concepts to adjust the research better to the Rwandese context.	Ask how this research fits in the Rwandese context	
Debrief	5	To summarise the outcome and evaluate the use of the session. To schedule follow-up	Talk about the next steps. Talk about their contribution in this session and schedule the next meetings.	If staff members of an organisation are being interviewed, ordinarily, top managers can assist in setting up the interviews.
Total	60			

Questions

Assessing the difference in value and norms between participants helps to understand the principles behind the answers. To understand how people think and feel about the topic of environmental impacts from industrialisation.

1. Ask about their experience in the field, daily work life.
2. What is their role in environmental planning?
3. What environmental issues, related to forest or wetlands are important to consider in spatial planning? Why?
4. How is environment currently considered in spatial planning? Should it be done differently? Is there a difference on a national or local level?
5. How does this research fit in the Rwandese context of industrialisation and decision-making?
6. What would be required to integrate environment in national spatial plan-making?, why?
7. What would the requirements of a spatial tool be? The preferred output?

b) Session outline 2: Environmental issues, Criteria tree & Data collection

Participants	MoE, NGO, RLMUA, RWB, REMA, MININFRA, RHA
Materials needed[1]	-Audio recorder -Predefined wetland themes -Markers -Paper -Map of the area -Criteria tree outline
Logistics needed[1]	-Quiet rooms -Laptop, preferably beamer
Planned date[1]	8th – 14th jan.
Planned duration[1]	90min

1) In reality, these materials, logistics and timelines were different per interview. The description provides what was aimed for.

Content of the session

Session objective	To establish SEA-objectives and criteria that measure the state of wetlands.
Research questions	Question 1.3: Which key environmental issues are caused by industrial development? Question 2.1: Which flood issues are influenced by industrial development? Question 2.2: Which SEA-objectives address these issues? Question 2.3: Which criteria, indicators and data measure the performance of these objectives? Question 2.4: What is the spatial influence of each criterion?
Main messages to transmit	-How the input of the participants is going to be used
Previous sessions	-Intake meeting
Prepare before session	-Themes from pre-investigation issues. -Premade example criteria tree. -Map of the area.
Output materials	-List of environmental objectives, criteria, measurable indicators and thresholds to be used in the assessment (criteria). -Locations vulnerable areas. -Indication of what issues are important according to each interviewee.
Other remarks	-The possibility exists to build upon the example criteria tree that was defined

	beforehand, if this is the preference of the stakeholder. However, the results so far should not be shared in this stage, to avoid that the interviewee's perspective is manipulated. -It is possible to strengthen each indicator by clearly describing the story of each indicator. How does the story work spatially? Is it a cost or benefit? Is it linear or non-linear? -Follow-up is presented to the participants in the form of value functions during the weighting & visions interview and/or evaluation interview.

Flow of the session:

Main Content	Duration (min)	Objective	Delivery method and description
Opening	5	To explain the purpose of this session and set expectations.	-Explain that today will be about identifying issues and setting spatial indicators to reflect the objectives. Give an example. -Explain what an environmental issue is: An environmental problem, something that is not liked and needs to be addressed. -Reflect on the intake meeting; are there any additional questions?
Issues	30	To establish environmental issues in the themes wetlands related to industry expansion and NSAP.	Discuss: 1) What issues does the participant see in relation to wetlands and industry? 2) Make sure the underlying assumptions, discourses below the issues are known by asking; Why is it an issue? And how they relate? What are the driving forces and the outcome? When will it stop being an issue? How does this issue show in practice? 3) What issues did wetlands experience in the past? Do you have an example? How did that influence decision-making? What are the economic and social consequences? Who is affected most by the degradation of wetlands? 4) Why built-in wetlands? When is it allowed and when not? What is the ideal state of a wetland? 5) At the end of the meeting, ask about the remaining issues I found in the literature and in other sessions. Does the participant agree?
	5	To point out areas where environment is under pressure[1]	-Ask where the participants think environment is under pressure? Why? -Let people point out places on the map where environment is impacted.
Baseline	10	To understand the current performance of each issue	-Ask for clarifications of the issues. How would the participant describe the state of each issue as it is now? And when is it an issue, and when not? What is the threshold?
	5	To collect spatial data	-For each issue, ask how it can be measured. Collect spatial data, restricted areas i.e. nature parks, water bodies, wetlands.
Criteria tree[1]	25	To develop a criteria tree depicting the objectives and corresponding criteria, indicators and thresholds	-Develop criteria tree by drawing it on a paper, describe the linkages and describe how each criterion can be mapped. Use the example tree if difficulties arise.
Debrief	10	To summarise the outcome and evaluate the use of the session.	-Summarise the result of the criteria tree. Stress that the outcome is going to be used to indicate how environment is performing and to show how it is spatially impacted.
Total	90		

1) These steps were often not performed, due to time issues.

c) Session outline 3: Weighting and design visions

Participants	MoE, REMA, RWB, RLMUA
Materials needed[1]	-Audio recorder -criteria tree printed -value functions printed -Laptop with running ilwis system
Logistics needed[1]	-quiet room -Laptop
Date[1]	20th to 22nd Jan.
Duration[1]	120min

1) In reality, these materials, logistics and timelines were different per interview. The description provides what was aimed for.

<u>**Content of the session**</u>

Session objectives	To evaluate value functions To weight criteria To formulate visions.
Research questions	Question 2.4: What is the spatial influence of each criterion? Question 2.5: Which visions distinguish different options on where to locate industrial sites and areas?
Main messages to transmit	-Make clear how the visions are being used in spatial planning.
Previous sessions	1. Intake meeting 2. Environmental issue, baseline, data, objectives, criteria and indicators.
Prepare before session	-Print criteria tree -Value functions of each criteria. Drawn spatially. -ILWIS system running and premade composite index map of equal weighting.
Output materials	-Validation of each criteria and description of the standardized value functions. -Visions representing different stakeholder perspectives.

Flow of the session:

Main Content	Duration (min)	Objective	Delivery method and description
Opening	5	To explain the purpose of this session and set expectations.	Explain that today will be about the validation of the value functions, followed by the weighting of criteria and the co-design of alternatives to represent different stakeholder perspectives'
Value functions	30	Evaluate value functions	Go over each value function and ask if they agree and how the value functions can be improved. Use a spatial description of the criteria and drawings.
Process description	20	To explain the purpose of this session and set expectations.	Explain the purpose of this session: weighting and the co-design of alternatives. And explain (repeat) how this can be used in the construction national spatial plans. Answer questions.
Weighting	5	To assign weights to each criteria	Let participants indicate which SEA objectives and which criteria are more important.
	10		Follow-up with asking why some indicators are more important than others. Ask them to illustrate the choices for weights.
	5		Show how the weighting influences the map by running Ilwis. [1]
Co-design alternative visions [2]	40	To co-design alternative visions (max 4)	workshop with 2 representatives from both MoE and MININFRA. Explain that the visions should become significantly different from each other to see difference in the mapping. First, compare the weighting and discuss why there is a difference. Ask how an environmentall friendly vision would look like according to them. Then ask how an economic or social vision would look like. Ask them where they would locate industry, and why? And which effects would they expect on environment? Facilitate the discussion between MININFRA and MoE. Make sure the participants argue clearly why these decisions are made.
Debrief	5	To summarise the outcome and evaluate the use of the session.	Summarise the results. Explain the next steps. Remind the participants of the evaluation interview
Total	120		

1) This was not performed with RLMUA and MoE.

2) This was not performed with stakeholder groups, because it was not possible to arrange having multiple stakeholders participating in one session. Instead, semi-structured interviews were conducted with single representatives.

d) Session outline 4: Evaluation case study

Participants	MoE, REMA, RWB, Huye, MININFRA
Materials needed[1]	-Audio recorder -Interview questions -Presentation on the case study so far, Presentation should be the same for everyone.
Logistics needed[1]	-Quiet room -Laptop
Date[1]	7th till 14th feb.
Duration[1]	90min

1) In reality, these materials, logistics and timelines were different per interview. The description provides what was aimed for.

<u>Content of the session:</u>

Session objectives	-To understand how the participants value environment, more specifically wetlands. -To evaluate the general support for the environmental objectives and the correctness of data, issues and indicators. -To improve the method
Research questions	Question 2.2: Which SEA-objectives address these issues? Question 2.3: Which criteria, indicators and data measure the performance of these objectives? Question 2.4: What is the spatial influence of each criterion? Question 2.5: Which visions distinguish different options on where to locate industrial sites and areas?
Main messages to transmit	-Improvements to the method can still be made
Previous sessions	1. Intake meeting 2. Environmental issue, baseline, data, objectives, criteria and indicators. 3. Validate value functions, assign weights and co-design visions Time in this session can be limited by giving them more insight in the process in previous workshops and by sending the output materials beforehand.
Prepare before session	-Presentation using the composite index maps
Output materials	-The support for the research output (the objectives, indicators and the data used) -Improvements method -Discussion points (e.g. application elsewhere, the alignment with SEA requirements, the use in the SDF-method and the potential benefit to the environment).

Flow of the session:

Main Content	Duration (min)	Objective	Delivery method and description
Opening	5	To explain the purpose of this session and set expectations.	The purpose of this session is to evaluate the tool. Ask the background control questions.
Recap	15	To repeat the steps followed	Presentation including: -SDF context. -steps followed shortly -use of the method -Compliance with SEA regulation -outcomes of the environmental impact prediction -overlay and slicing pillars and composite index maps.
Importance environment	5	Indication on the role of wetlands in environment	Ask how they think wetlands should be considered in policy making? What improvements can be made?
General questions	25	Exploration of applicability, capabilities, weaknesses and possible improvements method.	Start interview with general questions to explore broadly. Many of the questions will be answered already. Stripe off questions that are answered.
Support case study outcomes.	10	Indication of support for environmental objectives and data accuracy.	Ask the questions about set of objectives, indicators, data and/or representation in value functions.
	10	Suggested improvements and opportunities for the implementation	Ask open questions about where to apply elsewhere and how? And what to improve?
Concluding questions	5	To address forgotten questions	Ask if they want to share anything else deemed relevant for the evaluation of the method and the development of the tool.
Debrief	5	To summarise the outcome and evaluate the session.	Thank the participants, tell when the research is done.
Total	120		

QUESTIONS

Importance environment

Assessing the difference in value and norms between participants helps to understand the principles behind the answers. To understand how people think and feel about the topic environmental impact on wetland. And if there is a bias among participants.

1. Ask how they think wetlands should be considered in policy making?
    a. What improvements can be made?

General questions

Start with general questions that will most likely answer some of the specific questions below. This identifies what the method does and what it is capable of.

1. What is your first impression of the method? Is it helpful? Why? How?
2. How can the method be improved? What are the potential challenges?
3. Would you use the method elsewhere? Why? Where? How? What should be changed?
4. (How) does the method improve the consideration of environment in spatial plan-making guided by the SDF?

Support case study outcomes

The outcome can be less useful due to a wrong set of objectives, indicators, data and/or representation. Therefore it is asked: how well the maps inform considering the issues, indicators, data and correctness.

1. Did the SMCE give realistic results? Why?/why not? What could be improved?
   a. Does the information adequately describe the risk on floods in wetlands?
   b. Do the indicators adequately describe their contribution to flood effects in wetlands?
   c. Is the data quality sufficient? Are their data gaps?
   d. Is the outcome simple to understand and apply in decision-making?
   e. Does the method increase understanding of the relation between industrial development and environment (floods)?

Other

Do you want to share anything else deemed relevant for the evaluation of te method and the development of the tool?

Appendix VII: Information sheet consent interview

Research objective: Exploring the integration of environmental considerations in spatial planning guided by the Sustainable Development Framework.

This sheet includes information about the purpose, the benefits and risks, the use of data and the procedures for participating in the workshops and interviews. Attached to this document, you can find a consent form to participate in this study.

Aim of the research

To explore how to integrate environmental considerations in spatial plan-making on a national level aiming to prevent irreversible damages and (environmental) costs in the future. During a case study, environmental criteria are assessed and depicted spatially on their performance using a Spatial Multi-Criteria Evaluation. These criteria are related to the enhancement of flooding in wetlands. The outcome serves to be used as a guiding tool to determine where large scale industries can be developed. This research investigates the usefulness of such tool; assessing it on the use in decision-making procedures and Strategic Environmental Assessment practices. It evaluates the implementation, the applicability and the support among stakeholders to integrate the environmental considerations using the case study. The aim is to find out how environment can be best integrated with existing decision-making procedures.

The following applies when participating in this research:

- The interviews are conducted starting from 07-01-2020 till 20-02-2020.
- The participant participates in an interviews to evaluate the usability and implementation of the case study: Exploring the integration of environmental considerations in spatial planning guided by the Sustainable Development Framework.
- The data collected is used to evaluate the case study on its implementation, applicability and support.
- The workshops and interviews are recorded using an audio-recorder and are transcribed to text.
- Data recorded is retained till the defence of the research approximated in May 2020.
- The transcribed data is anonymised and archived. It can be used for an MSc report, scientific publications, follow-up studies and the assessment of environmental issues in Rwanda.
- The participant has the right to view the data obtained during the workshops and interviews. Statements made during the interviews may be adjusted if provided with a clear statement of the reasoning.
- No personal data other than a name and the represented organisation is collected during the interview. During the processing, personal data is pseudonymized. Participants are referred to as representatives of an organisation.
- The research has been reviewed and approved by the Ethics Committee of the Faculty of Geo-Information Science and Earth Observation (ITC) at the University of Twente.
- The participant has the right to withdraw from the study at any moment of the research. Data collected can still be used in the research.

Contact details:

Researcher: Anne Mossink a.s.mossink@student.utwente.nl

ITC Ethics committee: ec-itc@utwente.nl

Consent Form for "Exploring the integration of environmental considerations in spatial planning guided by the Sustainable Development Framework".

YOU WILL BE GIVEN A COPY OF THIS INFORMED CONSENT FORM

Please tick the appropriate boxes	Yes	No
Taking part in the study		
I have read and understood the study information dated 28-12-2019, or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	☐	☐
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	☐	☐
I understand that taking part in the study involves participation in workshops and interviews: -To evaluate the usefulness and implementation of the tool that integrates environment in spatial plan-making.	☐	☐
I understand that taking part in the study involves audio-recording of each workshop and interview, that the recordings are transcribed to text and that the transcribed data is archived.	☐	☐
Use of the information in the study		
I understand that information I provide will be used for an MSc Report and scientific publications, follow-up studies and the assessment of environmental issues in Rwanda.	☐	☐
I understand that personal information collected about me that can identify me, such as my name and email address will not be shared beyond the study team.	☐	☐
I agree to be audio/video recorded. Yes/no	☐	☐
Future use and reuse of the information by others		
I give permission for the anonymised transcripts that I provide to be archived in the repository of the ITC so it can be used for future research and learning.	☐	☐
I give the researchers permission to keep my contact information and to contact me for future research projects.	☐	☐
Signatures		
____________________ ____________________ ________ **Name of participant** **Legal representative** **Signature** **Date** ___________________		
I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.		
______________________ _________________ ________ **Researcher name** **Signature** **Date**		
Study contact details for further information: **Anne Mossink,** **a.s.mossink@student.utwente.nl**		
Contact Information for Questions about Your Rights as a Research Participant		
If you have questions about your rights as a research participant, or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the Secretary of the Ethics Committee of the Faculty of Geo-Information Science and Earth Observation: ec-itc@utwente.nl		