ADAPTATION OF SPATIAL DEVELOPMENT FRAMEWORK METHODS FOR AGRICULTURAL VALUE CHAIN DEVELOPMENT.

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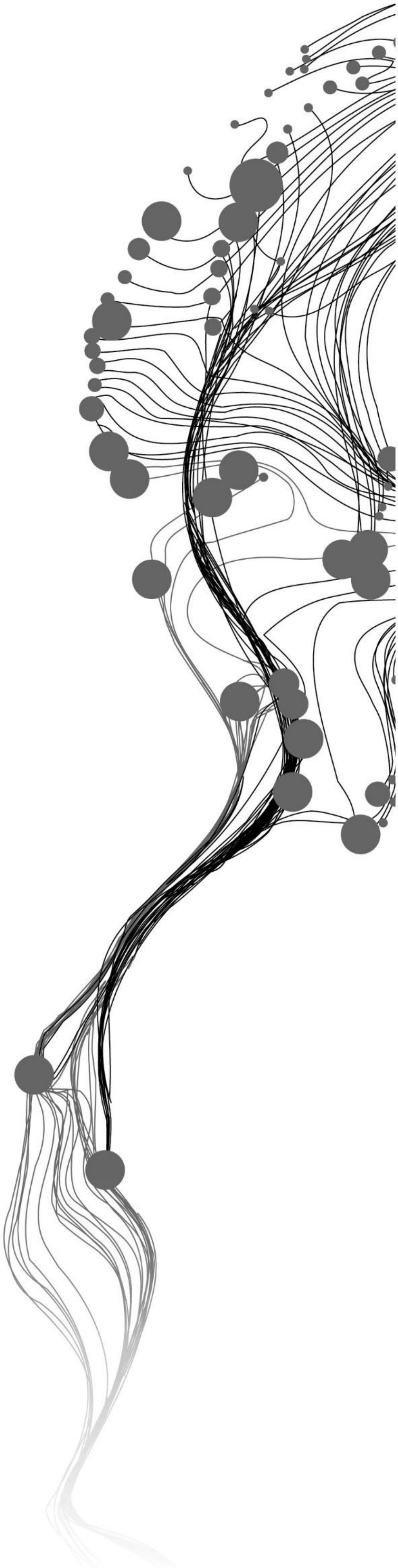

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ABSTRACT

Developing economies in sub-Saharan Africa (SSA) aim to break into global markets, by shifting from low productivity to high productivity and creating more jobs. They have had lessons from both policy successes and failures, as evidenced by the previous continental and regional economic strategies since independence. In the contemporary literature, various research advocates for adapting successful strategies applied in other fast developing economies, e.g. in East Asia, to facilitate the shift. However, to avoid duplicating externally designed strategies that lack endogenous characteristics, which have previously proven unsuccessful, development is to be guided by comparative advantages. Agriculture employs majority of SSAs working population, thus it offers a strength to the shift and job creation, through diversification of activities around it. Hence, national development strategies and plans need to integrate agricultural development initiatives.

To coordinate these strategies necessitates use of strategic planning tools at both national and local levels. The SDF methodology as used in Rwanda, facilitated a territorial understanding of regional development and complementarity of settlements within regions. It was also used to coordinate the allocation of interventions from national and local development strategies into regions, based on the territorial understanding. To further this research, this study adapted this methodology to prioritize industrial locations, by coordinating industrial and agricultural policy objectives. An agricultural commodity value-chain was analysed to identify relevant factors that complemented policy guidelines, to prioritize activities in special economic zones (SEZ).

To handle the variety of complex factors, spatial multi-criteria evaluation (SMCE) was used evaluate the suitability of the SEZs relative to the identified factors. This revealed that the selection of location factors was not exhaustive to select SEZ sites, and in addition identified the performance of SEZs based on agro-processing activities related to the analysed value chain. To simplify future site selection processes and activity allocation, a decision support model was developed in Scenario 360, an interactive GIS platform, using the factors from the SMCE to facilitate prioritization of activities in the SEZs. In conclusion, the developed model could be adopted to facilitate allocation of other activities in the SEZs, which in turn would facilitate prioritization of infrastructure investments. Moreover, as a recommendation, improved data availability and management would be beneficial for such a model to be more useful in strategic spatial planning.

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ABBREVIATIONS

DDS- District development Strategy

MINAGRI – Ministry of Agriculture and Animal Resources, Rwanda

MINECOFIN- Ministry of Finance and Economic Planning, Rwanda

MINICOM- Ministry of Trade and Industry, Rwanda

MoF – Matrix of Functions

NISR- National Institute of Statistics, Rwanda

NSAP- National Strategic Action Plan

NST1 – National Strategy for Transformation, Rwanda

RLMUA- Rwanda Land Management and Use Authority

SDF- Spatial Development Framework

SEZ- Special Economic Zones

SMCE- Spatial Multi-criteria Evaluation

SSP – Strategic Sector Plan

UNIDO- United Nations Industrial Development organization

VC – Value chain

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1. Introduction

1.1. Background

The integration of urbanization, industrial and agricultural policies in the contemporary sub-Saharan Africa economies, is essential to promote structural transformation (shifting from low-productivity[1] activities to high-productivity activities) and job creation. According to van Neuss (2019), structural change is measured by the contribution of sectors to economic growth, commonly through employment and value-added. Various researchers argue that structural transformation can spur African economies to break into the global markets for manufacturing, agro-industry and trade (Aryeetey & Moyo, 2012; Lin, 2018; Monga, 2012; Page, 2011) using procedures such as territorial planning (Nogales & Webber, 2017), strategic planning, integration of policy instruments and stakeholder engagement (McCormick, Anderberg, Coenen, & Neij, 2013).

The close relation between urbanization and sustainable development dimensions (economic, social and environmental), calls for adequate management of urban expansion, sustainable production and consumption patterns, since the high rate of urbanization and population growth in developing countries is constantly straining the available limited resources (Wohlmuth, 2013). For instance, 55% of the world's population, and 43% of Africa's, lived in urban areas in 2018, and projected to be 68% globally (United Nations, 2019) and 70% in Africa by 2050 (Stiglitz et al., 2017). This urban population depends on rural areas, especially in supply of agricultural products, amidst the diminishing natural resources and climate change constraints. It is also expected to sustain the demand for manufactured goods, based on contemporary consumption patterns (Stiglitz et al., 2017). Therefore, understanding the relationship between urban and rural areas would play a role in promoting their integrated and sustainable development.

1.1.1. Economic policy implications in post-independence Africa

Tacoli (1998) expounds that traditional post-independence African policies tended to neglect the rural-urban interactions, which had negative implications on economic development. Rural areas were mostly defined as agriculture-based, while urban areas by their reliance on industrial production and services. For instance, some urban policies neglected the need of diverse income sources for low-income earners e.g. via urban agriculture. Likewise, some rural policies mainly promoted agricultural production but did not consider off-farm activities like agro-processing. Some of these policies contributed to imbalance of economic growth by promoting urbanization and industrialization, at the expense of agricultural development. Amongst the significant economic policy actions include the unsuccessful import-substituting initiatives-1960s and Structural Adjustment Programs -1980s, and contemporary national development policies based on sectors -21st century (Clark, 2019).

Moreover, industrial performance indicators in sub-Saharan Africa (SSA), between 1995-2008, as discussed by Söderbom (2012) implied that manufacturing sector had not yet taken-off compared to other non-manufacturing industrial sectors like construction. This was substantially a result of approaches such as Africa's reliance on externally designed models which didn't consider characteristics of the individual

[1] Productivity ; measures the amount produced by a target group (country, sector, industry etc.) given a set of resources and inputs (FAO, 2017).

countries, and top-down development approaches that lacked citizen participation (UN-Habitat, 2014). In addition, the approaches were significantly facilitated by African economies lacking economic and social transformation in their political agendas (UN-Habitat, 2014), corruption, and foreign aid coupled with conditions that suppress endogenous approaches (Moyo, 2009).

1.1.2. Industrialization strategies in sub-Saharan Africa

Sub-Saharan Africa generally de-industrialized since the 1980s and could be over-dependent on agriculture and extraction of natural resources in future if this trend cannot be reversed. This is partly evidenced by the share of manufacturing value to SSA's Gross Domestic Product reducing from 15% to around 11% over this period, dependency on services [2] (Clark, 2019), and windfall earnings - e.g. minerals, oil (Wohlmuth, 2013). In particular, African post-independence (1960s &1970s) governments opted for state-led and import-substituting industrialization to boost economic growth, most of which failed due to their un-competitiveness, and governments' interventions that supported selected sectors - some of which defied comparative advantages (Ajakaiye & Page, 2012). Subsequently, Structural Adjustment Programs (SAP) promoting trade liberalization were advocated by IMF and World Bank in the 1980-90s to increase competition and technical efficiency. On this note, Behuria (2019) argues that despite the associated labor-intensive manufacturing the SAPs were also unsuccessful, since the existing industries could not compete in the global market due to reduced government support (tariffs). This resulted in further deindustrialization and economic crises. The author gives an example that SAPs contributed to the decline of Africa's textile industry partly due to increased imports of used clothing (cheaper than locally made because of high production costs).

Various action plans, with mixed outcomes, were also discussed at continental level via initiatives such as; Conference of African Ministers of Industry (CAMI) established in 1971 and organized every 2 years thereafter; New Partnership for Africa's Development-NEPAD (2001); African Productive Capacity Initiative- APCI (2004) and; Plan of Action for Accelerated Industrial Development of Africa (by African Union-2008). A significant outcome of the continental cooperation would be CAMI conferences as at 2008, that proposed some priorities to boost industrialization in Africa which included value addition and processing of agricultural and mineral resources, development of support infrastructure for industries, private-sector involvement, improvement of human capital- via education and health, and adaptation of technologies and research development to increase competitiveness (Marti & Ssenkubuge, 2009). Moreover, export oriented policies are favored in 21st century policy making (Behuria, 2019) supported by state-led interventions and comparative advantages (Stiglitz et al., 2017) towards the shift to higher productivity.

1.1.3. Structural transformation of agriculture in sub-Saharan Africa.

Aryeetey and Moyo (2012) refer to structural transformation in agriculture as "shifting from low-level agricultural production to industry, including tradable services and agro-industry". Monga (2012) argues that structural transformation results in job creation and income diversification, which are central to the development agenda of lower-income countries. Monga further suggests a development pattern whereby developing economies exploit the late-comer advantage in regional markets, by learning (rather than copying) from more advanced countries with endowment structures (e.g. cheap labor, economic drivers & activities) that are similar to theirs. Moreover, sub-Saharan Africa economies could also learn from "late-

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[2] Services: Intangible products that include accounting, banking, cleaning, consultancy, education, insurance, expertise, medical treatment, tourism, or transportation. Public services are paid for via taxes and other legal means. (http://www.businessdictionary.com/definition/services.html)

industrializing" East Asian countries, like Singapore, Japan, Korea, and Malaysia, that applied state-led interventions for structural transformation. These economies engineered high level technological and economic growth, by transitioning from low-value agricultural production to high-value industrialization, using low-cost & low-skill manufacturing (UN-Habitat, 2014).

UN-Habitat (2014) suggests state-led interventions that include developing strong and efficient national development planning institutions, training civil servants, and using the private-sector as an engine of growth. In particular, the structural changes to drive transformation require high-level leadership - by the national governments, and stakeholder involvement. The governments should work with the markets to address physical, institutional and knowledge limitations and also support continental economic growth efforts (Ajakaiye & Page, 2012). UN-Habitat (2014, p. 15) also emphasize that,

> "…those African countries that have developed a clear industrial policy that is consistent with their comparative advantage, invested heavily in infrastructure, upgraded their human capital through skills training and maintained a competitive and enabling business environment would be the ones who benefit from the changes in the global production system brought about by advances in information technology and rapidly declining transport cost."

However, the low-income economies face among other difficulties, identification of market limitations, stakeholder coordination mechanisms, framing of development issues, and disintegrated utilization of intra-country cross-border resources (Okereke et al., 2019), which necessitates approaches such as good institutional capacities and strategic planning.

1.1.4. Strategic spatial planning

Albrechts (2015) argues strategic planning as "a set of concepts, procedures, and tools that must be tailored carefully to the situation at hand if desirable outcomes are to be achieved." The author also presents a strategic spatial planning approach that involves regional coproduction and adaptation to contextual conditions to deal with increasing development complexities. In other words, it needs to be adaptive to changing circumstances, such as new knowledge and technology, as well as changing contexts. Moreover, a supportive political environment should enhance strategic planning to complement other planning tools - such as land-use and sector plans (Albrechts, 2015) in managing development complexities.

Additionally, Geertman (2008) presents planning support systems as strategic planning tools, used to deal with complexities in planning practice, such as handling knowledge through information management and scenario analysis. They entail use of geographic information systems (GIS)-technology, for data collection, analysis, and visualization of spatially distributed phenomena (Nyerges & Jankowski, 2010).

Hence, building on earlier mentioned constraints in SSA, this study seeks to further adapt a strategic spatial planning tool to support industrial planning; the Spatial Development Framework(SDF)- discussed in section 2.

1.2. Research gap

Location of industries is a strategic spatial decision that has impacts on firms' supply chain performance (Rikalović, Ćosić, Popov, & Lazarević, 2013), and is dependent on various spatial and non-spatial factors. In some developing economies, government and political directives, economic and technical criteria by entrepreneurs have mainly been considered to select project locations, occasionally inconsistent with policy recommendations (Stiglitz et al., 2017). Consequentially, some negative implications such as high costs of infrastructure investments, and environmental effects (Salari, Shariat, Rahimi, & Dashti, 2019) have necessitated various approaches such as strategic spatial planning (Oliveira, 2015). Due to existence of comparative advantages in different geographical areas, location factors vary, for instance based on access to market, labour, infrastructure, and economic activities amongst others.

Oliveira (2015) commends strategic planning (a set of tools, concepts and procedures tailored to situations), as a prerequisite for governments to prioritize developments. For instance, place branding (a strategic planning concept) as used in the National Urbanization Policy for Rwanda secondary cities' economic development, and the SDF methodology (a strategic spatial planning tool) that complemented the policy by identifying regional potentialities and locating strategic interventions (UN-Habitat, 2016, 2019). However, a research gap emerges in the methodology, regarding the suitability of spatial locations for the proposed interventions.

Meanwhile, according to the Special Economic Zone Policy of 2018 – a revised version of the Special Economic Zones Policy of 2010 - the Government of Rwanda earmarked special economic zones (SEZ) in secondary cities of the country. These were meant decentralize industrial development initiatives from Kigali SEZ, deconcentrate urban growth from Kigali capital city to other regions, and support industrial growth through initiatives such as the "Made in Rwanda" policy of 2017 (MINICOM, 2018). Through concentration of industrial activities, the SEZs would facilitate exploitation of economies of scale, ease infrastructure provision, facilitate cluster development, and address other local business constraints like land access (MINICOM, 2010). Therefore, the government plans to reduce operational costs by servicing the zones with infrastructure to attract investors (MINICOM, 2018).

According to UNIDO (2015) in their review of the SEZ policy of 2010, the superficial feasibility studies conducted rather than market demand analysis, during the establishment of the SEZs, would probably limit the achievement of the desired policy objectives. This insight was based on their international experience whereby the strategy of "build it and they will come" for industrial decentralization and regional development had failed elsewhere. On a related note, a local news article reported some industries closing or relocating from Huye district - although not clarifying the reasons-, amidst the plans for an industrial park and optimism from local authorities (The New Times, 2014). Following the review, the revised SEZ policy of 2018 set out guidelines for designation of new zones, which included robust market demand assessments, and a feasibility study defining infrastructure needs. However, development on the earmarked SEZs would proceed with a few improvements such as regulation and monitoring (MINICOM, 2018).

Therefore, as part of this study, the spatial locations of existing SEZs were evaluated against the SEZ policy of 2018, and National Land Use Planning Guidelines of 2017. In addition, an agricultural commodity value chain was mapped, to identify local economy factors that would affect the SEZs spatial locations. This was meant to address the gap as to how processing activities could be satisfactorily distributed to the SEZs based on comparative advantages and policy guidelines, to promote the desired regional economic development.

1.3. Research objective

The main objective of this study was to adapt the SDF methodology for satisfactory spatial distribution of agro-industries, based on existing relevant functions[3] and policies. The Northern Urban Corridor of Rwanda was used as a case study region, a growth corridor identified in phase B of the SDF methodology.

Research sub-objectives and questions

The study commenced with selection of a priority agricultural commodity, that has a potentiality of higher productivity and job creation. Then, a value chain mapping process - for the selected commodity- ensued for a better understanding of activities affecting the flow of products, as well as their respective locational factors. The next step entailed identification of the recommended Special Economic Zones (SEZ) location factors, as per policy documents. The acquired location factors informed criteria formulation, that enabled evaluation of the spatial locations of the existing Special Economic Zones. The final step entailed development of a decision support tool to support industrial site selection, using spatial suitability analysis.

These research questions were used to answer the relevant sub-objectives.

1) To map the post-harvest product flow of an agricultural commodity value-chain (VC).
   a) Which agricultural products have a high value across the secondary cities?
   b) How is the flow of the selected product across the value chain?
2) To evaluate the performance of existing industrial parks
   a) What spatial factors influenced the location of existing VC activities and industrial parks?
   b) How suitable are the existing industrial park locations, relative to policy guidelines and the value chain activities?
3) To design a decision-support tool to match industrial parks to agro-processing activities.
   a) How can the agro-processing activities be satisfactorily distributed amongst the existing industrial parks?

1.4. Thesis structure

This study consists of 6 chapters, introduction, literature review, research design and methods, results, discussions, and conclusions. The introduction gives a background to the efforts of sub-Saharan economies towards structural shift in their economies. Chapter 2 gives a brief explanation of industrial planning in SSA, and how comparative advantages can be used to promote the success of industrial policies. Chapter 3 explains the research methods as used for to answer the research questions. Chapter 4 presents the results of the research questions after applying the methods. Chapter 5 discusses the results in view of the literature, and finally chapter 6 describes the study conclusions and recommended research direction.

[3] Function: every service, equipment, activity, and facility which has an economic, administrative, social or cultural function in a given human settlement (UN-Habitat, 2016).

2. Literature review

This section explores how industrial planning can promote the structural transformation agenda in SSA, including some limitations and Special Economic Zones as an approach to manage them. Comparative advantages are then discussed as an approach of promoting SEZ success, with agriculture as a comparative advantage in SSA. The industrial planning sector in Rwanda is then discussed, including how the country is using the SDF methodology as a planning an approach.

2.1. Industrial Planning in sub-Saharan Africa

Several sub-Saharan African countries developed industrial policies with specific guidelines, statements and regulations to speed up the structural transformation process, such as Botswana, Cameroon, Ghana, Kenya, Rwanda, Mauritius, South Africa and Uganda; as reviewed by Marti & Ssenkubuge (2009). Implementation of such industrial policies in 21st century SSA has had significant success, as Stiglitz et al. (2017) elaborate in a composite African Development Bank Group report. They present some examples of success stories such as textile industry in Mauritius, cotton in Burkina Faso, mangoes in Mali, flowers from Ethiopia amongst others. A common trend could be observed whereby each government prioritized on relevant infrastructure provision informed by strengths of the specific sectors, and optimal locations for public services due to limited resources. Despite some critiques that the industrial policies approach is vertical- favoring only a selected priority sectors, rather than horizontal – concentrating on general business environment, they argue that its complicated for such interventions to be restricted to the specific sectors, since other sectors also benefit indirectly, e.g. from improved infrastructure.

Stiglitz et al. (2017) further highlight administrative capacity, to design and implement industrial policies, as a weakness in SSA economies. This is worsened by unhealthy politics, corruption, market failures, and shortage of private-sector entrepreneurship, occasionally necessitating government intervention, for instance to improve institutional capacities. They also concur with Monga (2012) on utilizing the 'late-comer' advantage of developing economies to learn from more developed economies with economic structures like theirs. Moreover, they argue that in recent years, governments in developing countries have developed institutions to promote industrialization, that attract investments and promote exports. Special economic zones, as part of industrial parks, are an example of such institutions.

Special Economic Zones

UNIDO (2019) defines an [4]industrial park as "a tract of land developed and sub-divided into plots according to a comprehensive plan with the provision of roads, transportation and public utilities, sometimes also with common facilities, for use by a group of manufacturers." They are amongst the instruments used by governments to attract and concentrate investments (such as FDI- foreign direct investment), towards enhancing value addition, job creation, increased exports, and market provision for producers. They have also been a way of influencing location decision of private firms using some predominant pull factors; access to markets, raw materials, transportation and energy (Nogales & Webber, 2017). The term however represents various concepts such as free-trade zones, export-processing zones, special economic zones, high-tech zones, free ports and enterprise zones (UNIDO, 2019). Like industrial policies, industrial parks have also had mixed outcomes in the context of developing countries.

[4] For this study, SEZ or industrial park was used in the general form as in the SEZ Policy of Rwanda-2018, and as defined by UNIDO (2019).

According to Newman and Page (2017), many African economies are relatively [5]latecomers to the adoption of SEZs, partly influenced by incentives like the United States-Africa Growth and Opportunities Act (AGOA), and it appears the zones are functioning well in terms of occupation by firms and job creation. However, Farole and Akinci (2011) argue that SEZs in Africa still attract low FDI compared to non-African zones, occasionally as a result of poor investment climate. On a similar note, Saleman and Jordan (2015) highlight some general performance related problems facing SEZs in developing countries as follows; they are either not built, or attract little demand from firms to locate there, or create demand but with few [6]cluster effects, or they succeed but have neutral or negative side effects (spill overs) on investment climate outside the park. The negative spill-overs occur since SEZs are often established with limited links with firms outside the parks, thus overlooking domestic value chains (Newman & Page, 2017). This is to say that despite provision of infrastructure and good investment climate, location factors and market characteristics should also be a consideration during establishment of SEZs. For instance, focusing on comparative advantages, accompanied by a contextual understanding (e.g. via domestic value chains' analysis) could be an important factor for the success of SEZs in SSA.

2.2. Comparative advantages and structural transformation of agriculture in SSA.

Few sub-Saharan African countries can equate their recent economic growth to structural change towards manufacturing (Rodrik, 2016). Stagnation of agricultural and decline of manufacturing sectors' contribution to sub-Saharan Africa's GDP, and marginalization of trade in manufactured exports are some major economic problems facing Africa. These problems are also prevalent in agricultural value chains, undermining Africa's comparative advantage in land and agricultural resources (Wohlmuth, 2013). Economic development has thus been mainly dependent on services. Consequentially many sub-Saharan Africa economies have been exposed to shocks and volatility of growth rates, in addition to relying on low-value export commodities (Ayentimi, Burgess, & Brown, 2018).

Lin and Monga (2010) recommend a practical procedure to identify and facilitate growth by governments, i.e.; identifying tradeable industries that have worked in more developed economies with a similar endowment structure to theirs; identifying and acting on technological constraints facing existing private domestic firms in the industrial sector; attracting foreign direct investment (FDI), for instance from the earlier identified more developed economies; supporting spontaneous private industrial innovations in their countries; use of special economic zones or industrial parks to attract FDI; and temporary tax and subsidy incentives for pioneer firms.

However, Lin et al. (2011) warn of some issues to be considered beforehand by the developing economies which included; the varying growth trends over time influenced by technological improvements, change in demand, contextual differences such as in geography or institutions, and choice of policy instruments to adopt. This supports integrating a country's comparative advantages to lessons learnt from others for local economic development, and integrating the spatial dimension of sectoral policies through a territorially based strategy (Nogales & Webber, 2017). Such an approach concurs with the argument that market-oriented practices need to consider endogenous practices for local economic growth (Peredo, Montgomery, & McLean, 2017), rather than the earlier-unsuccessful approach of adopting externally designed models that do not consider local economic characteristics (UN-Habitat, 2014). Hence, McMillan and Headey (2014) suggest government strategies that support rural investment for income

[5] Established in late 1990s and early 2000s.

[6] "By clustering, enterprises are able to overcome constraints in capital, skills, technology, and markets"(Zeng, 2008) .

diversity, since small-scale agriculture is the main employer of most working population in sub-Saharan Africa.

2.2.1. Agriculture as a comparative advantage in sub-Saharan Africa

Agriculture employs the majority of the working population in sub-Saharan Africa, making it the major potentiality for pro-poor development (OECD/FAO, 2016). Learning from the East Asian developing economies, this potentiality can be explored through diversification economic activities around agriculture, such as via value addition using agro-processing and increased market-oriented practices. Wohlmuth (2013) argues that linkages between agriculture and agro-industries in Africa could be promoted by measures such as; value-chain (VC) developments of specific agricultural products and, promotion of efforts to translate spatially comparative advantages into competitive advantages, for instance as in the emergence of cut-flowers' industry in Ethiopia (Iizuka & Gebreeyesus, 2017).

Ethiopia flower industry enjoys a cool tropical climate with diverse range of altitudes, cheap labor, proximity to major markets, and an airport close to production areas (Gebreeyesus & Iizuka, 2010), creating over 100,000 jobs consisting 70% as women (Iizuka & Gebreeyesus, 2017). According to Iizuka and Gebreeyesus (2017), the flower industry in Ethiopia emerged in the 1990s and grew to be the 2nd largest flower exporter in Africa after Kenya, by 2015. This is despite some initial constraints that led to collapsing of the pioneer industries, that included high competition from the neighboring Kenyan market, unfavorable investment climate, inappropriate choice of production sites, and limited expertise in the business. The introduction of FDI from 1999 largely contributed to revivification of the industry, with the new investors improving on the failures of the earlier investors, such as by locating on better production sites (Melese & Helmsing, 2010). FDI also contributed to diversification of activities around the flowers' value chain, as well as transfer of technology and knowledge to emerging local firms. Moreover, the potentiality observed influenced government support, in 2002, to facilitate cheaper transportation costs, availability of state-owned land for cultivation, and credit availability (Iizuka & Gebreeyesus, 2017).

Hence, Lin (2012) argues that similarities in low income countries, such as having large share of the population living in rural areas and employed in agriculture - often subsistent, calls for the basic starting point to be a transformation via agricultural activities in rural areas. This transformation, characterized by entry into higher value markets, requires building on a sufficient understanding of activities and dynamics in the agricultural sector, achievable via value-chain development.

2.2.2. Agricultural Value chain development

Value-chain analysis is important for entry into global markets (Kaplinsky & Morris, 2001), and organizing value chain (VC) activities to promote formulation of competitive strategies (Ensign, 2001) to support endogenic economic growth (Peredo et al., 2017). A value chain "is the full range of activities required to bring a product or service from conception, through the different phases of production, transformation and delivery to final consumers and to final disposal after use" (Kaplinsky & Morris, 2001, p. 4). VC analysis defines relationships between VC actors, traces the flow of products, services, information and payment, and helps to identify entry points to improve the value chain (Lundy et al., 2014). In other words, it outlines transformation of resources using infrastructure, within constraints and opportunities of institutional environments, to produce value-added products and services for a market (Trienekens, 2011).

Since agriculture offers an economic growth potential to most sub-Saharan economies (Kozul-Wright & Fortunato, 2019), value chains can be seen as a means by which new forms of production, technologies, logistics, labour processes and organizational relations and networks are introduced (Trienekens, 2011) towards transformation. Moreover, Trienekens (2011) relates value added to quality, cost, delivery flexibility, and innovativeness, determined by the end-customer's willingness to pay. Therefore, mapping (conceptual and spatial) an agricultural commodity value chain would facilitate identification of actors, their interactions and other dynamics affecting the flow of products. This understanding would enable the addressing of constraints and building on opportunities that affect the flow of the commodity at different links of the chain. On this note, Bammann (2007) argues that the value chain concept has proved useful in identification of opportunities, as well as formulation and development of strategies and projects for rural and agricultural development. Such strategies and projects are characterized by reduced losses and transaction costs, improvement of quality and delivery, and improving the returns or earnings of actors.

Moreover, crop value chains are based on spatial relations ranging from local to global scale (Nier, Klein, & Tamásy, 2019) that partly determine the end-customer's willingness to pay, by influencing the utility of the products (e.g. via price or quality). These relations range from quality improvement activities such as processing, to accessibility concerns, access to available knowledge and technologies for innovativeness, and market access (Trienekens, 2011). Therefore, it is necessary to ensure that the spatial locations of these activities are appropriate to achieve the agreeable effect. Strategic planning tools- such as SMCE and GIS- have proved useful for satisfactory site selection, due to complexity of factors considered in the spatial decisions (Sarath, Saran, & Ramana, 2018).

2.3. Spatial Multi-Criteria Evaluation for site selection

Site selection can be defined as a complex process of identifying the most satisfactory locations for establishing projects based on environmental and socio-economic conditions (Ruiz, Romero, Pérez, & Fernández, 2012). The complexity is characterized by multiple objectives and stakeholders, influenced by trade-offs, legal regulations, risk and impact assessments amongst others (Rikalović et al., 2013). However, governmental and political directives, economic and technical criteria have recently been used for locating projects in many developing countries, unlike contemporary practices affected by environmental, social and economic criteria imposed by legalities and regulations (Stiglitz et al., 2017). It is such complexities that necessitated multi-criteria decision making.

Meanwhile, multi-criteria decision analysis presents a broad and formal analysis process developed within the "Operational Research/Management Science community" to evaluate a set of feasible or alternative actions in a decision problem, and its application is now adopted in various societal domains. In particular, multi-criteria decision making methodologies were incorporated in policy implementation to integrate scientific knowledge in public choice framework (Falcão, Machete, Castilho Gomes, & Gonçalves, 2019).

Spatial multicriteria analysis is one of the adoptions of these methodologies for site selection as a spatial planning support tool, to address the complexities associated with spatial planning decisions. It involves multi-criteria decision analysis and GIS-based spatial analysis (Sugumaran & DeGroote, 2011). In addition, spatial analysis refers to methods that use geographic referencing of each data case, to draw assumptions or conclusions describing spatial interactions between the data cases (Rikalović et al., 2013). Ruiz et al. (2012) applied multi-criteria analysis to develop a decision support system for planning sustainable industrial areas, which they argue was beneficial to manage the complexity of criteria required in the decision-making process. However, some issues were highlighted such as the need for more integration of vector and raster data in spatial multi-criteria analysis since raster data has been used in most occasions (Arabsheibani, Kanani Sadat, & Abedini, 2016), and the much time needed for data collection and analysis that could be reduced by better data infrastructure (Ruiz et al., 2012).

**Henceforth, this study used the agro-industrial planning sector in Rwanda, as a case study, to develop on a strategic planning tool. It integrated the concepts of SEZs, agricultural value chain development and spatial planning support tools.*

2.4. Industrial planning in Rwanda

Like other sub-Saharan Africa countries, post-independence economic policies did not advocate for optimal utilization of Rwanda's comparative advantages. Moreover, the success of Rwanda's policies in the 21st century has been limited by volatile trading environment, regional competition, over-dependence on individual firms and weak institutional capabilities (Behuria, 2019). Additionally, the underdeveloped agro-processing sector, coupled with poorly integrated markets, poverty, inadequate infrastructure and low productivity contributed to underutilization of resources, and low quality products (MINICOM, 2015b).

According to Jones (2006), post-war[7] Rwanda gradually progressed economically against great odds, amidst major poverty reduction efforts, for instance via the 2002 Rwanda Poverty Reduction Strategy Paper (PRSP), Economic Development and Poverty Reduction Strategies of 2007 and 2013 (EDPRS 1&2 respectively), various sector strategic plans (SSPs), 7-year Government Programs (7YGP) and Visions 2020 & 2050. These policies commonly highlighted recommendations such as making the private sector a driver of economic growth and poverty reduction, and investment in appropriate skills especially on the youth to improve their productivity. The country also integrated Agenda 2030 and Sustainable Development Goals through upgrading Vision 2020 to Vision 2050, and the EDPRS 2 to the 7YGP-National Strategy for Transformation(NST 1), as well as within SSPs (Bizoza & Simons, 2019).

The Vision 2020 adopted in the year 2000, was one of the key aspirations for attaining socio-economic transformation in post-war Rwanda. The vision was supported by a sequence of poverty reduction and economic development strategies that included the National Urbanization Policy-NUP (MININFRA, 2015), SSPs and district development strategies (DDS). This would be followed by a Vision 2050 aiming for high quality and high standards of life for Rwandans, with some targets by 2035 such as attaining middle-income-country status. In addition, the 7-year National Strategy for Transformation (NST1) would act as the implementation instrument towards Vision 2050 from Vision 2020, using economic, social and governance transformations as priority pillars (MINECOFIN, 2017).

The economic transformation pillar of NST1 aims at increased productivity and accelerated private sector-led economic growth through job creation, accelerating sustainable urbanization, establishing a knowledge-based economy, promoting industrialization and structural transformation, promoting investments, modernized agriculture and livestock productivity, and promoting sustainable environmental and natural resource management (MINECOFIN, 2017). Each of these priority initiatives was also linked to relative SSPs and DDSs.

Particularly, the industrialization and structural transformation priority, as relative to this study, is linked to SSPs such as NUP, National Agricultural Policy-NAP (MINAGRI, 2018a), National Industrial Policy (MINICOM, 2011) and the Industrial Masterplan for the Agro-Processing subsector (MINICOM, 2015b). The implementation instrument for NAP was the 7-year Strategic Plan for Agricultural Transformation-2018 to 2024 (PSTA4). PSTA4 purported to increase the share of in-country value added, by facilitating private sector investment in processing and value addition of agricultural commodities in selected value chains. For example through Made in Rwanda initiative (MINAGRI, 2018b), which was described as a "holistic roadmap aimed at increasing economic competitiveness by enhancing Rwanda's domestic market through value chain development"(MINICOM, 2017). In addition, the full potential of the agro-processing subsector as an engine for economic development is yet to be realized (MINICOM, 2015b).

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[7] Period following 1994, when the genocide in Rwanda ended (History.com Editors, 2014)

MINECOFIN (2019) projected some transformation as a result of NST1 in the period 2017-2024, with the share of industry in GDP rising from 16.5% to 21.8%, and the share of agriculture falling from 29.6% to 22.9% and a slight rise in share of services from 47.7% to 48.3%. This is anticipated to accelerate the GDP growth in average to [8]9.1% over the 7-year period. The improvement in the industrial sector was anticipated to be driven by industrial parks in secondary cities, especially via textile and agro-processing industries. Meanwhile, Government of Rwanda earmarked 9 additional Special economic zones (SEZ) to complement Kigali SEZ under the SEZ policy of 2010. This was aimed at supporting small and medium sized industrialists to access the zones and mainstream the 'Made in Rwanda' initiative. (MINICOM, 2018).

Moreover, since Rwanda aims to boost economic growth using urbanization, an approach to manage the urbanization process was adopted. It would enhance physical connections between resources and markets, to support the network of urban areas based on the uniqueness of each urban area. It was also adopted to coordinate development initiatives across districts with the national development strategy. The approach was to use a strategic spatial prioritization methodology; the Spatial Development Framework(SDF) (MININFRA, 2015).

2.5. Spatial Development Framework methodology in Rwanda

The Spatial Development Framework (SDF) methodology was developed in 2011 by UN-Habitat, and initially applied for territorial reconstruction after the war in Darfur, Sudan, between 2011 and 2013. It was later adapted by Rwanda between 2014 and 2016 to complement the implementation of the National Urbanization policy (NUP). Particularly, it was developed to support fast urbanizing countries with weak planning systems, to implement spatial development strategies (Boerboom, Gibert, Spaliviero, & Spaliviero, 2017; Spaliviero, Boerboom, Gibert, Spaliviero, & Bajaj, 2019).

The SDF complemented NUP to provide direction for better understanding and coordination of urbanization, and to set principles for integrated development of urban settlements. Additionally, it would provide a framework for implementation of various regulatory policies adopted by Rwanda. The constrained business enabling environment in Rwanda was attributed to lack of economic specialization and cooperation between districts, prompting the use of SDF to identify unique opportunities and comparative advantages, growth complementarity between the districts and investment attraction (UN-Habitat, 2016). It was adapted in Rwanda in 2 phases.

2.5.1. Phase A

The initial phase was meant to understand the territorial structure, by identifying a well-structured system of urban settlements to accommodate and supply needs of the future population. This phase consisted of the matrix of functions (MoF), consultative workshops and spatial multi-criteria evaluation (SMCE)-(see figure 1).

The MoF was used to strategically categorize urban settlements based on availability or absence of key functions[9]. As a result, sets of functions in settlements, a functional hierarchy of settlements, priority investment areas, spatial linkages amongst settlements, and networks of settlements emerged. The consultative workshops were then used to explain the use of the methodology, validate the findings of the MoF and support the ranking of settlements by their urban and socio-economic development potentials.

[8] The most recent available GDP growth average was 8.6%, for 2018 (The World Bank, n.d.)

[9] Function: every service, equipment, activity, and facility which has an economic, administrative, social or cultural function in a given human settlement (UN-Habitat, 2016).

This resulted in a spatial structure consisting of settlements and spatial linkages; the so called 'emerging spatial structure'- see fig. 2 (In reality, these settlements lie in different administrative provinces).

Phase A finalized with spatial multi-criteria evaluation (SMCE) that enabled evaluation, comparison, and prioritization of spatial alternatives. It was used to measure present progress of the settlements in relation to the policy pillars (translated to objectives) as defined by the National Urbanization Policy (NUP), and other relevant policies and laws. It was structured in 4 main objectives, derived from the 4 pillars of NUP: coordination, densification, conviviality and economic growth (UN-Habitat, 2016).

The emerging spatial structure revealed that every settlement in the country played a role in the urbanization process due to their interdependence, contrasting the NUP's model of Kigali and the secondary cities as the growth poles (UN-Habitat, 2019).

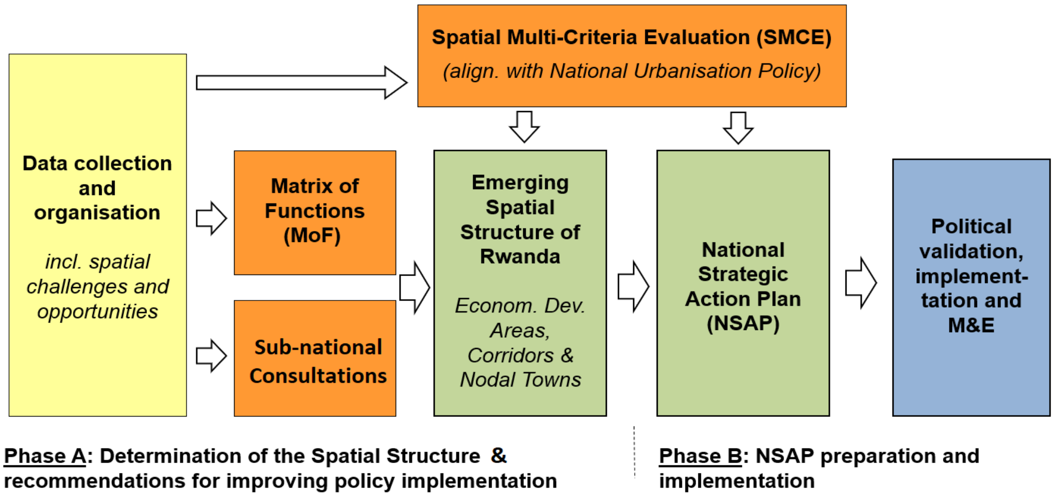


Figure 1; The SDF Methodology of Rwanda, adopted from (UN-Habitat, 2016).

2.5.2. Phase B

This phase entailed the National Strategic Action Plan (NSAP)- see fig. 1, a strategic action planning tool to align spatial planning horizontally (coordination among districts), and vertically (coordination among ministries, national government agencies and districts). The National Strategy for Transformation (NST1), being the current implementation instrument for vision 2020 and the first 4 years of vision 2050, was evaluated against the 'emerging spatial structure' (UN-Habitat, 2019).

Moreover, clusters of districts were identified using the 'emerging spatial structure' (spatial structure and potentials), as listed in table 1. The clusters were analyzed using the MoF (2nd round of MoF), with respect to manufacturing and industrial functions. This revealed 3 types of industrial areas; the so called 'economic specialization areas' (fig. 3 shows one cluster with the distribution of economic specialization areas- the Kivu belt region). Table 2 presents the main characteristics of the areas, based on the type of settlements and their socio-economic development. These areas were then used to allocate interventions proposed in the NST1 to the administrative areas of Rwanda. In addition, MoF and NSAP were used to review planned manufacturing and industrial activities in DDSs that could benefit from regional coordination. Furthermore, the NSAP would benefit from collaboration with agriculture and industry agencies to maximize spatial specialization and optimize infrastructure development. Hence, the SDF methodology "provides the more sophisticated understanding of the territory for forthcoming policies related to urbanization and national transformation"(UN-Habitat, 2019).

Table 1; Clusters of districts identified from the 'emerging spatial structure' (adopted from UN-Habitat, 2019)

District cluster	Districts in Rwanda
Central corridor	Bugesera, Kamonyi, Nyarugenge, Kicukiro, Gasabo, Rulindo, Gicumbi
Eastern Economic Development Area	Kirehe, Ngoma, Kayonza, Rwamagana, Gatsibo, Nyagatare
Kivu Belt	Rusizi, Nyamasheke, Karongi, Rutsiro, Ngororero
Northern Corridor	Rubavu, Nyabihu, Musanze, Burera, Gakenke
Southern Economic Development Area	Nyaruguru, Gisagara, Huye, Nyamagabe, Nyanza, Ruhango, Muhanga

Table 2; Economic specialization areas resulting from the analysis on industrial and manufacturing functions (adopted from 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**

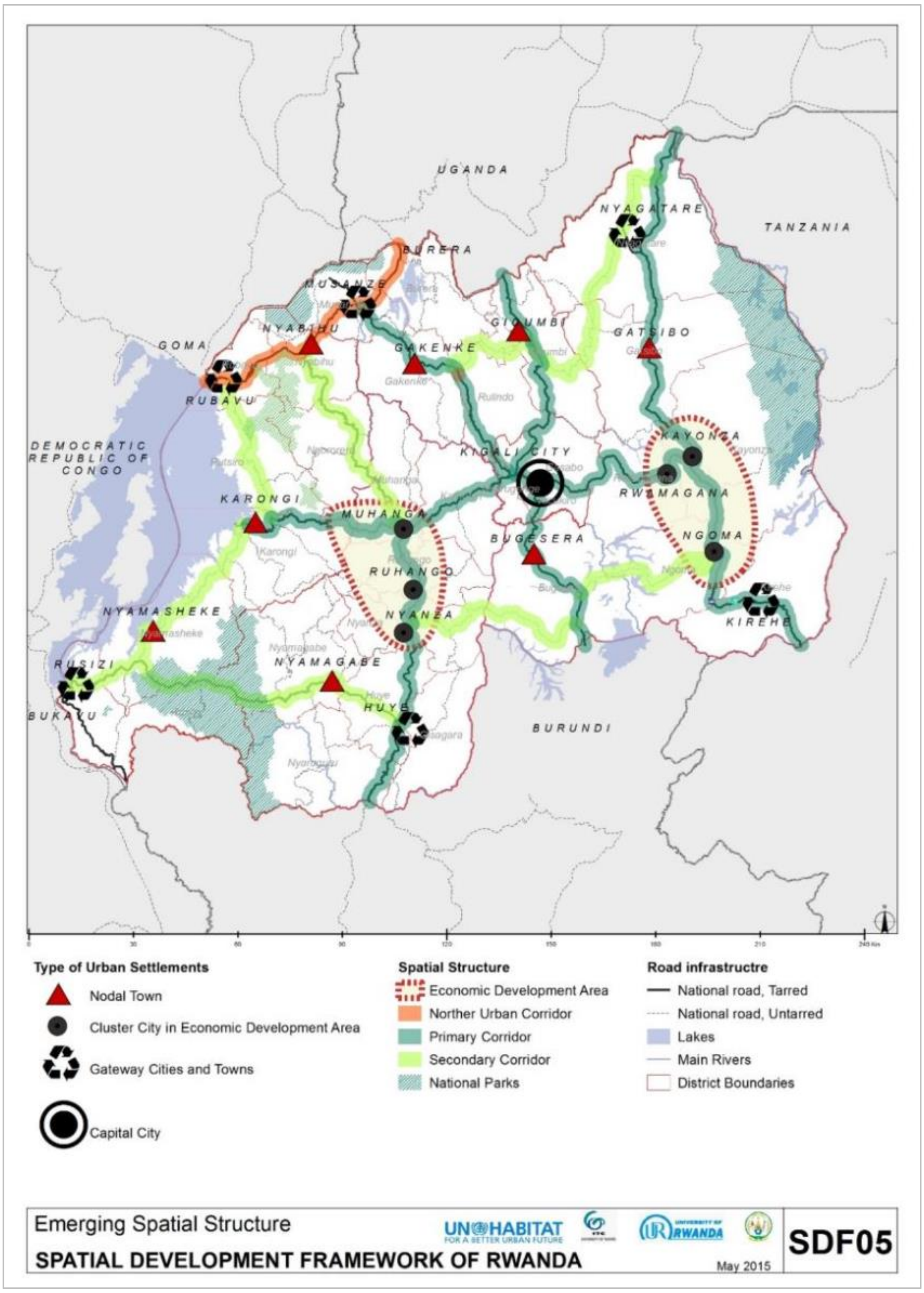


Figure 2; The emerging spatial structure of Rwanda, 2015 (adopted from UN-Habitat (2016))

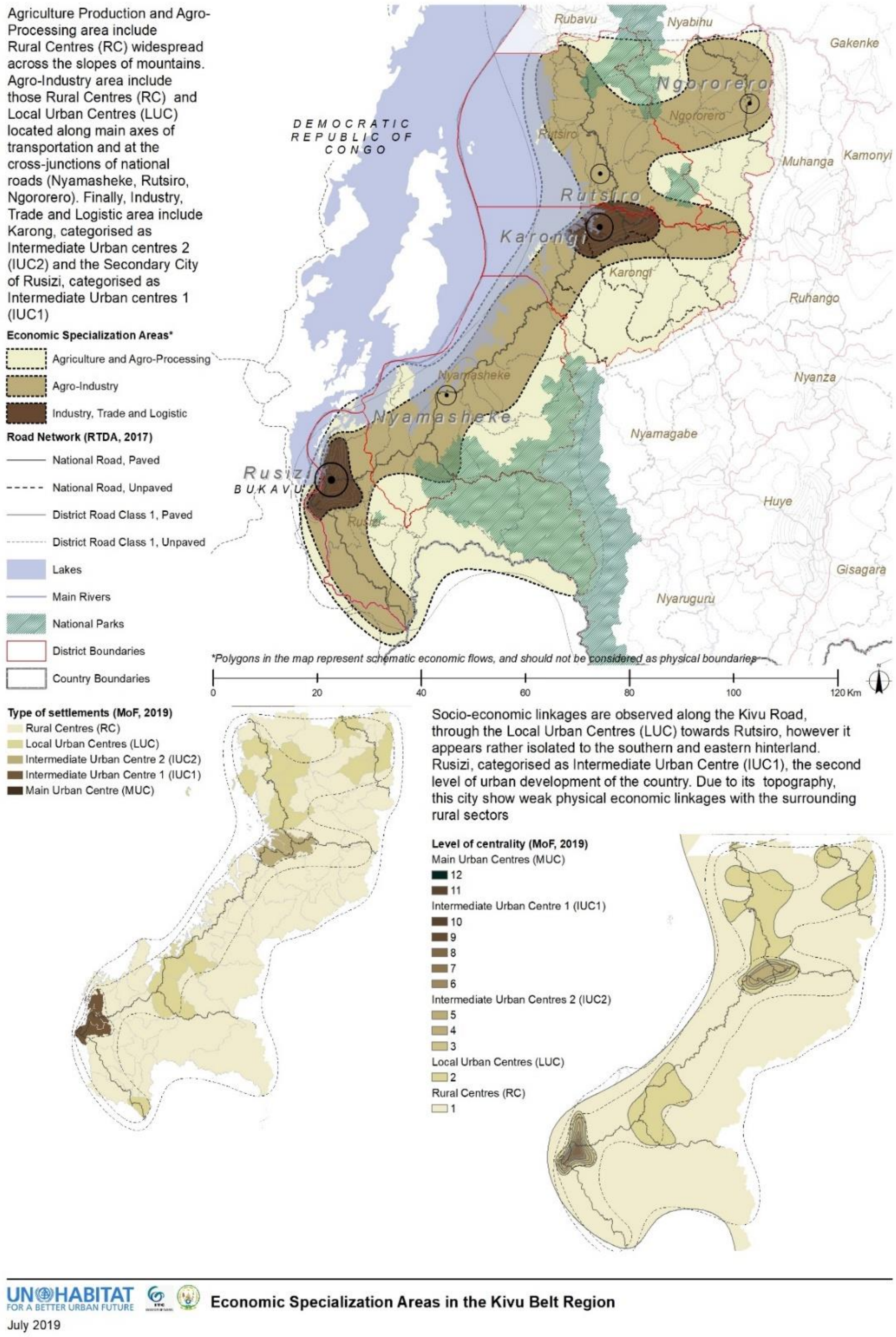


Figure 3; Spatial distribution of the economic specialization areas in the Kivu Belt Region (adopted from UN-Habitat (2019))

3. Research design and methods

This chapter discusses the research methodology for the study. The main aim being to adapt the SDF methodology for agricultural value chain development, in the context of sub-Saharan Africa. This is motivated on the region's high dependence on agricultural activities, which employ the highest proportion of working population. Therefore, agricultural development holds a high potentiality for economic growth and job creation. With this in mind, Rwanda presents a valid opportunity to conduct the research. With approximately 72% of the population employed in the agricultural sector (FAO, n.d.-a), the country has made significant steps in promoting agriculture transformation for economic growth, as described in section 2.4. Additionally, it has a practical advantage in the region, having recently adopted the SDF methodology to manage its economic development process.

3.1 Research design

In the latter phase of the methodology, UN-Habitat (2019) recommends adapting the methodology to support economic planning by improving the spatial component, for instance via collaboration with agriculture and industry agencies to maximize spatial specialization and optimize infrastructure development. Henceforth, this study used one of the economic specialization areas as a case study area. The study then focused on adapting the SDF methods for satisfactory spatial distribution of agro-industries, based on existing relevant functions and policies. Accordingly, an agricultural commodity value chain was used to obtain criteria for evaluating existing industrial parks/SEZs, and to model how agro-industrial locations could be more satisfactorily located in accordance with policy requirements and stakeholders' preferences.

A mixed methods approach was adopted for qualitative and quantitative data collection and analysis methods to complement each other (DeCuir-Gunby, 2008) in addition to spatial analysis. Quantitative data included agricultural production statistics and the share of use at various links in the commodity value chain. In addition to policy documents, key informant interviews were used to obtain qualitative data. This included destinations and respective proportions of the commodity, factors considered for site selection of existing VC activity locations, and constraints and opportunities at each link. Spatial analysis also enabled evaluation of existing industrial parks and suitability analysis on a GIS interface. An overview of data used, and respective sources is available in appendix I.

Conceptual framework

The main concepts in the case study partly address the weak institutional capacities relative to policy implementation. They include relevant development policies and low value productivity as a result of insufficient implementation of the policies, the SDF methodology as an intervention to complement the implementation, expected to facilitate high value productivity- see figure 4.

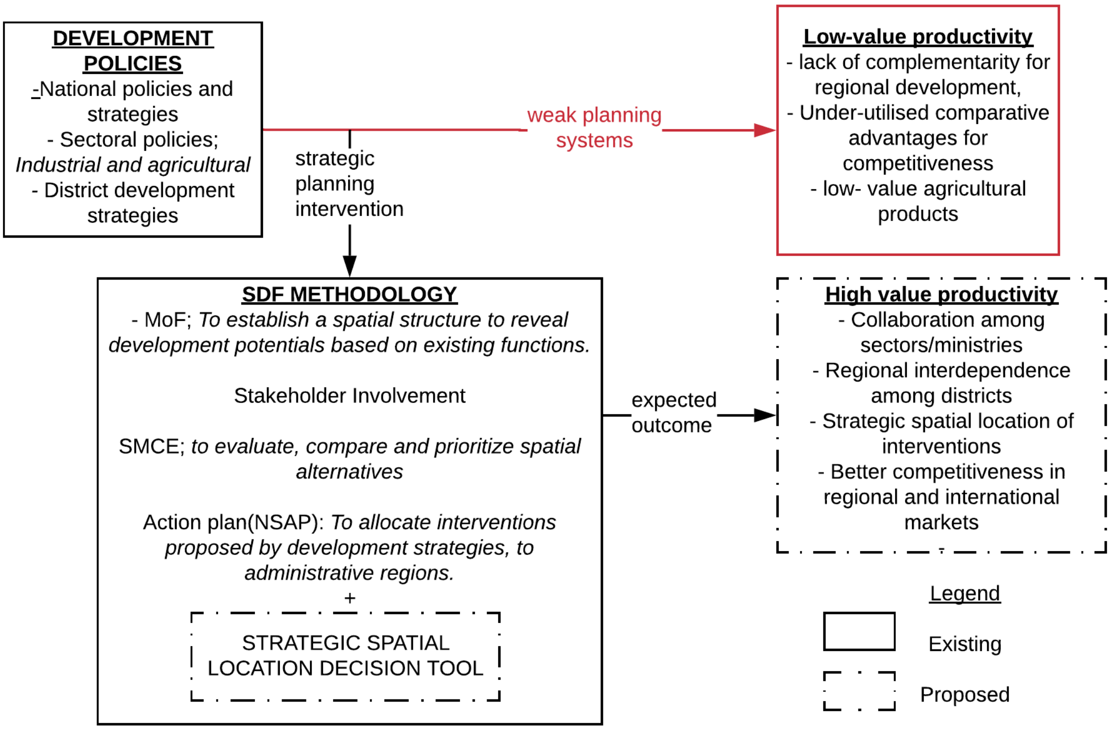


Figure 4; Conceptual framework of the case study.

Low value productivity in the agricultural sector is characterized by low-value products, such as raw materials instead of value-added products. As revealed by the SDF methods in UN-Habitat (2019), there is a lack of regional complementarity among Rwanda's districts in development projects, despite their shared potentialities. Examples include neighboring districts planning for similar projects, amidst limited financial resources, which would relatively prolong the time for implementation of such initiatives and their expected economic impacts. This means that shared advantages among such districts would probably be overlooked in the development process. In addition, the mainly subsistent agricultural production offers low value products to the market, amidst low infrastructure and technological development to support the sector (Bizoza & Simons, 2019).

Meanwhile, the Government of Rwanda is actively working to improve economic development through measures such as reforming financial and business sectors, improved agricultural production to achieve self-sufficiency, deepen democracy, strengthen inclusive citizen participation and accountability in governance (Promar Consulting, 2012; UNDP, n.d.; USAID, 2019) using various development policies. Accordingly, effective implementation of these policies based on a territorial understanding would firmly support their success.

The SDF methodology then provided an approach to achieve a territorial understanding to implement policy initiatives; first, using the matrix of functions (MoF) and relevant-stakeholder consultations, to reveal the existing spatial structure (of regions) and regional potentialities among districts. Secondly, the

SMCE evaluated the progress of settlements against the main urbanization policy-NUP, to prioritize spatial alternatives (UN-Habitat, 2016). Third, the NSAP was involved to allocate spatial interventions to the districts, as proposed by the NST1, as well as identify other projects proposed by the districts that could benefit from regional complementarity (UN-Habitat, 2019).

In addition, among the outputs of this study is a planning support tool, developed in a GIS platform to model how agro-industrial locations could be more satisfactorily located (using suitability analysis) in accordance with policy requirements and stakeholders' preferences. This was to complement the methodology, to promote high value productivity in the agricultural sector.

As a result of the SDF methodology intervention, the collaboration among districts (in the same cluster) to build on the existing regional comparative advantages, would promote regional interdependence. Moreover, spatial locations of interventions would be more satisfactorily prioritized, and consequently their support infrastructure. Policy objectives to promote diversification around agricultural activities would also be complemented, to promote production of high-value agricultural products. In general, this would concur with the example by Aryeetey and Moyo (2012) on how resource-based, labor-intensive manufacturing constantly upgraded towards more technology-intensive and higher value-added activities, enabled transformation of East Asian economies, paving way for other developing economies to learn from. The availability of agricultural resources and cheap labor in sub-Saharan Africa economies (e.g. Rwanda) thus provides an opportunity for economic transformation.

3.2 Research methodology

This section explains the methods used in the study. It begins with the study area selection, followed by the agricultural value chain mapping, then spatial multi-criteria evaluation, and finally the development of a spatial planning decision support model.

3.2.1 Study area

The SDF methodology in Rwanda enabled the identification of Economic Specialization Areas (ESA), during 'Phase B' of the methodology (fig.1). The Northern Urban Corridor was used as a case study region for this study, which lies in 5 districts (Rubavu, Nyabihu, Musanze, Burera & Gakenke), as shown in figures 5 and 6. The region contributed 17.7% of Rwanda's urban population in 2012 (NISR, 2014), making it the 2nd most urban populated region of the ESAs after the Central Corridor (Kigali region).

According to UN-Habitat (2016), Rubavu had the largest urban population with 149,209 persons in 40.55km² of urban area, then Musanze with 68,930 people in 21.85km² urban area, Nyabihu with 15,101 persons in 12.1km², and Burera with 2,389 people in 1.25 km² of urban area. This information was not provided for Gakenke urban settlement, although it is considered a [10] 'local urban centre' alongside Nyabihu and Burera district towns.

Rubavu and Musanze are international cross-border towns to DRC and Uganda respectively, as well as the central places for functions and services in the region – "intermediate urban centres 1" (UN-Habitat, 2019). Being among the 6 secondary cities to Kigali, Rubavu and Musanze were experiencing annual population growth rates of around 5.5% and 4.1% respectively, between 2012 and 2015 (Rajashekar, Richard, & Stoelinga, 2019).

Moreover, Rubavu and Nyabihu districts lie in the western province, while Musanze, Burera and Gakenke lie in the Northern province. Tourism plays a significant part in the region's economy with Lake Kivu - south of Rubavu, Volcanoes national Park in the North of the region, Rwanda Cycling Team base in Musanze and, Lakes Ruhondo and Burera in Burera district. Moreover, the region has large industries such as Braliwa Breweries in Rubavu, Mukamira dairy plant in Musanze, and KivuWatt- a methane gas power project in Rubavu (Government of Rwanda & GGGI, 2015). National and district roads link the region with other secondary cities and urban centres, Kigali, DRC and Uganda, (UN-Habitat, 2019).

Moreover, the relatively high agricultural productivity of the area (NISR, 2019) presents a strength to explore agriculture-led development, for regional cooperation and complementarity between settlements to maximise on infrastructure investments. This high agricultural productivity in the region results from favourable agroclimatic zones, characterized by fertile volcanic soils and reliable rainfall patterns (Ephraim & Murugesan, 2015). Figure 6 also describes the 3 economic specialization areas, as in phase B of the SDF methodology.

[10] Categorized under a functional hierarchy of human settlements based on level of socio-economic and urbanization development; "Local Urban Centres" (LUC) being the least developed, the "Intermediate Urban Centres" (IUC) and the "Main Urban Centres" (MUC) being the most developed

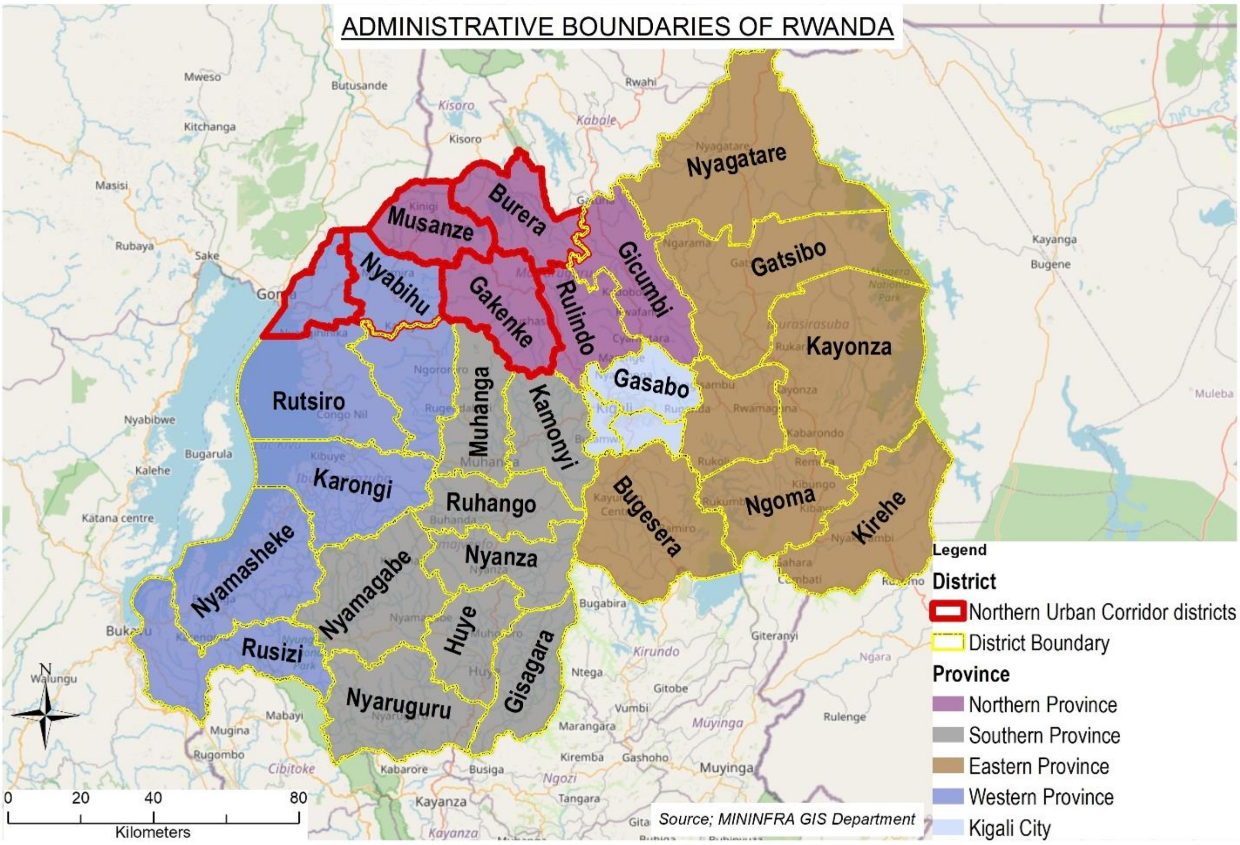


Figure 5; A map of Rwanda's Districts, highlighting the study area (Northern Urban Corridor) and the associated provincial boundaries. *Source; MININFRA GIS Department,2020.*

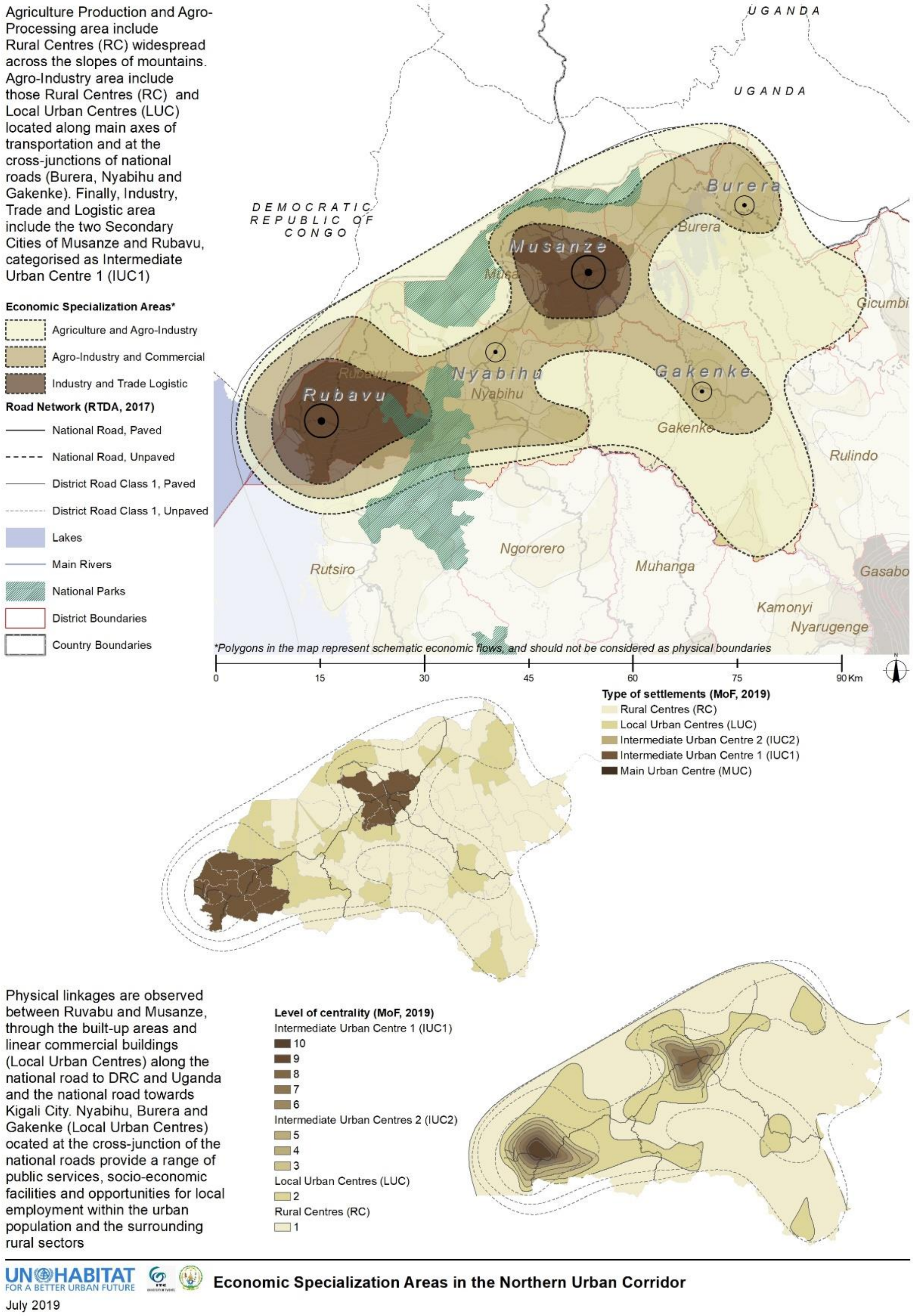


Figure 6; Spatial distribution and descriptions of the economic specialization areas in the Northern Urban Corridor, adopted from UN-Habitat (2019).

3.2.2 Agricultural commodity value-chain mapping.

This section entailed a description of the selection of a priority agricultural commodity, and the subsequent value-chain mapping process.

3.2.2.1 Selection of a priority agricultural commodity.

To identify the dominant comparative advantage of the study area, the selection of a priority sample crop for value chain analysis was conducted. This selection criteria was used; a crop that is commonly grown in all the districts with a relatively high production nationally, by small scale farmers (to support poverty eradication), and a priority for improved productivity by the district plans. This was achieved through analysis of the crop production statistics in 2019, and district development strategies (DDS) of the 5 districts.

3.2.2.2 Flow of Irish potatoes along the Value Chain

Value chain flow mapping was mainly conducted to acquire spatial factors for the location of existing value chain activities. It entailed identifying VC actors (direct and indirect) and their relationships, as well as flow of products and information from [11]production to consumption, as illustrated by the adopted link methodology by Lundy et al. (2014), in figure 7. Spatial flow maps were then used to visualize the geographical movement of products across the various locations, using GIS.

The 2019 seasonal agricultural survey (SAS) annual report, by the National Institute of Statistics Rwanda (NISR), provided crop production data. These included 2019 production statistics at district level, as well as the share of use of the produce, at national level. Additional statistics were obtained from the other relevant stakeholders, as described in section 4.1.2.

The commodity trade value chain specialist (at MINICOM), provided an overview of the value-chain activities, and identified some stakeholders that would be relevant as key informants. Key informant interviews were then conducted using semi-structured questionnaires (see appendix I), to provide more information (including statistics where possible) on the flow of the priority crop. This method was appropriate to allow free listing (Weller & Romney, 1988) and capture any unanticipated information.

[11] Relative to the study objectives of evaluating existing sites and allocating activities to SEZs, it was relevant to consider the post-harvest section of the value-chain (rather than including the production process), and mainly focus on the direct actors. The external influences, fig. 7, were also not discussed in this study.

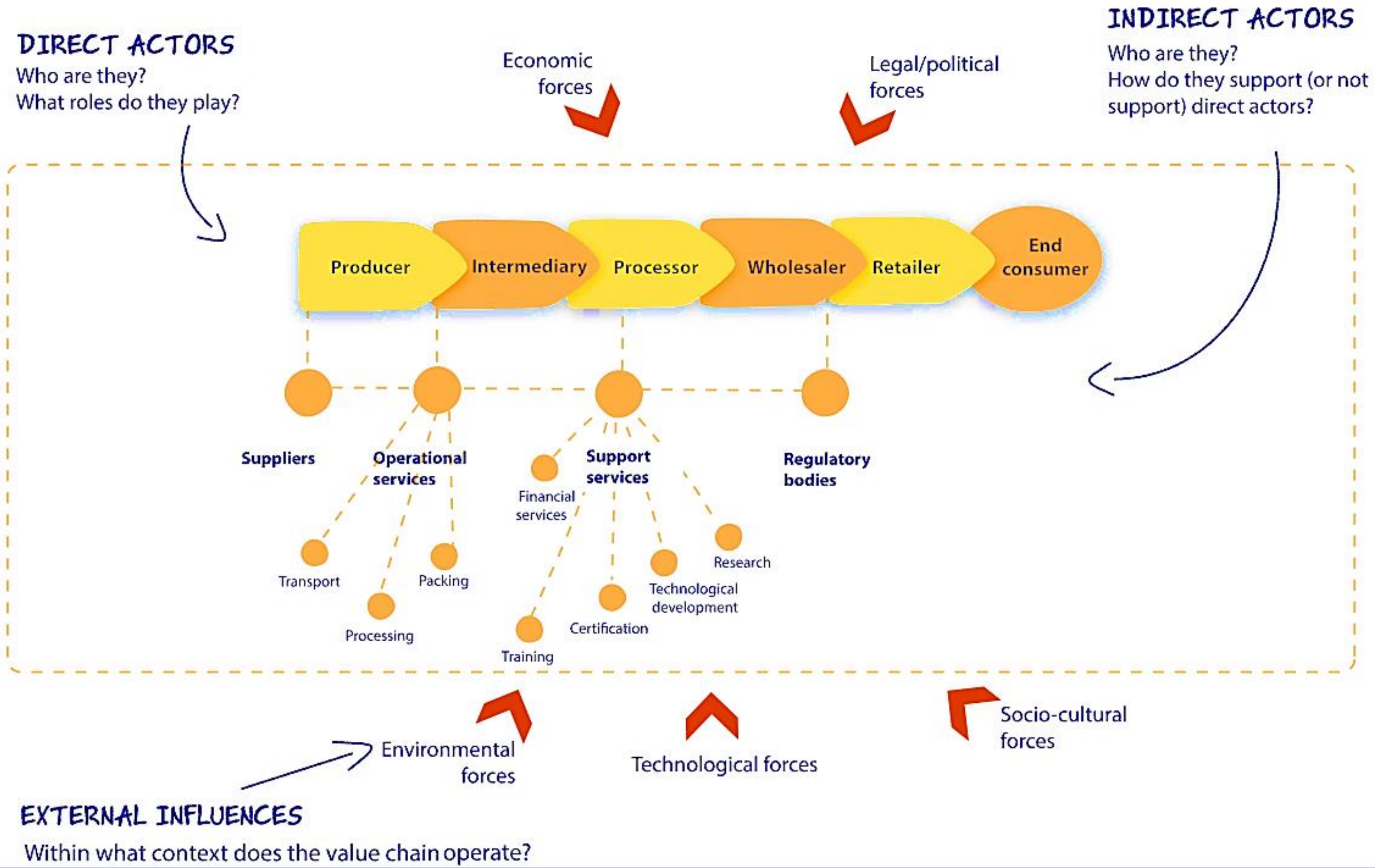


Figure 7; Link methodology of Value chain mapping. (adopted from 'Link Methodology' by Lundy et al., 2014).

3.2.3 Spatial Multi-Criteria Evaluation of existing industrial parks,

The evaluation exercise was conducted to analyse the performance of existing industrial parks in relation to relevant policy guidelines, and factors derived from the value-chain mapping. This was meant to analyse whether the site selection process of existing industrial parks was in accordance with the set regulations, and in addition, how efficient they were to support value-chain development of the priority crop. The process involved obtaining factors from policy documents as well as key informant interviews. The two relevant policy documents used were the Special Economic Zones Policy (MINICOM, 2018) and National Land Use Planning Guidelines (RLMUA, 2017). Key informant interviews provided additional information on the criteria used for selection of activities related to agro-processing in relation to the value-chain.

The identified factors were then used to formulate criteria for spatial multicriteria evaluation (SMCE) of the industrial parks, and GIS was used to quantify the criteria via spatial measurements. Next, the indicator values were normalized on a 0 to 1 scale (Nevill & Holder, 1995), before calculating an arithmetic mean of all the normalized values for each industrial park to create a cumulative perfomance index.

Decision support model, for strategic spatial allocation of activities to industrial parks

Following the SMCE, a suitability model was developed to support the allocation of the VC development (agro-processing) activities to the SEZs. As a strategic planning tool, it would support future site selection decisions, by managing the complexity of factors involved in the decision process. For instance, not only in designating new industrial parks, but also allocating activities to the industrial parks based on a local understanding.

The SMCE was adapted to develop the GIS-based suitability model in an interactive platform, to assess and visualize the impacts of criteria, and rank the existing industrial parks (based on suitability). The evaluation criteria were adapted as independent variables in the model, to evaluate the suitability of each industrial park.

Scenario 360 extension in ArcGIS was used to develop the model. It offers an interactive platform for analysing both vector and raster data, and a suitability wizard that can be manipulated to the user's preference. It also offers an flexible weighting option with the ability to view impacts dynamically in pre-formulated charts (City Explained, n.d.). In other words, the user can adjust the weight of any of the suitability factors used in the model, and subsequently view the impacts in a chart(s) after running the simulation.

4. Results

This section presents the results of the methods applied in the study, beginning with the findings of the value-chain mapping, the spatial multi-criteria evaluation, and development of the strategic planning tool.

4.1 Agricultural commodity value-chain mapping.

The selection of a priority agricultural commodity facilitated the study to focus on a comparative advantage of the study area, in relation to other regions in the country. This was accompanied by a value-chain mapping exercise for a better understanding of the post-harvest activities on the selected commodity.

4.1.1 Selection of a priority agricultural commodity.

The priority crop selection commenced with two steps: first, ranking the [12]main crops in Rwanda, using 2019 production statistics, as in fig 8. This was aimed at identifying the high production crops in the country, of which bananas, sweet potatoes, cassava, Irish potatoes, and beans ranked top 5, respectively. Secondly, the crop production in the 5 economic specialization areas (ESAs-identified by SDF) was compared using the top 5 highly produced crops, fig.9. This enabled the identification of the strengths of each of the regions, relative to crop production. Some significant observations in fig 9 indicated that the Eastern Region had the highest production of bananas and beans, while the Northern Urban Corridor distinctively led in Irish potato production contributing 69% of the national total, and the Southern Region had relatively higher production of cassava and sweet potatoes.

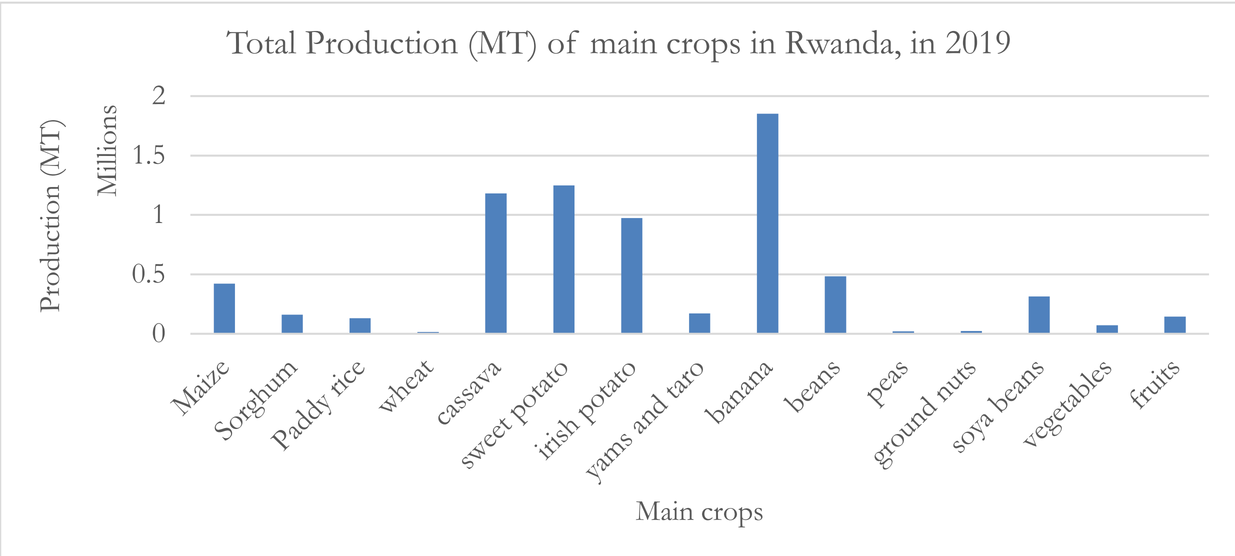


Figure 8; Total production (MT) of main crops in Rwanda, 2019. *Source; NISR (2019)*

[12] The 2019 seasonal agricultural survey listed the crops shown in fig.8 as the main crops produced in Rwanda.

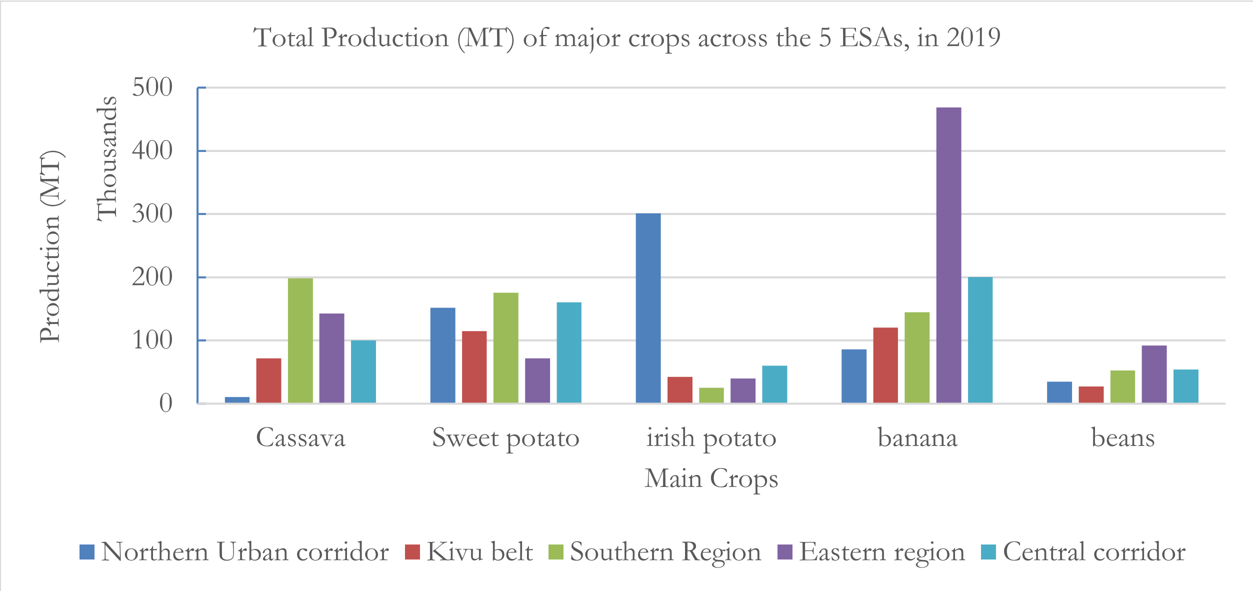


Figure 9; Total production (MT) of the 5 highest produced crops in Rwanda-2019, relative to ESAs. *Source; NISR (2019)*

Moreover, analysis of the 7-year district development strategies (DDS) in the study area (5 districts) was performed to identify priority projects relative to improving crop productivity. This revealed that within the 5 DDS reports, only Irish potatoes had at least one project in each district, towards improved productivity, see table 3. Notably, 4 of the DDS had measures to improve yields, 3 aimed to improve post-harvest handling by collection or storage, while 1 -Musanze- planned for a factory (table 3). However, there was no indication of coordinated projects among any of the districts, despite the shared advantage in Irish potato production. For these reasons, Irish potato was selected as the priority crop for the study.

In particular, the Northern Urban Corridor region features favourable agro-climatic conditions with highly fertile volcanic soils for production of Irish potatoes, and characterized by mainly small-scale production plots (Ephraim & Murugesan, 2015; USAID, 2013). The small-scale farming presents a potentiality for improvement of rural livelihoods, for instance via initiatives such as the [13]land consolidation plans in Gakenke district, see table 3. Moreover, Irish potatoes are the 2nd most important staple food in Rwanda (MINICOM, 2015b), and one of the six priority crops in the "Crop Intensification Program(CIP)" (FAO, n.d.-b). Notably, Rwanda was also, on average, the 5th largest producer of Irish potatoes in sub-Saharan Africa between 2010 and 2018 (FAO, 2018), with an Irish potato per capita consumption of 125 kg/year (Nkurunziza, 2019). According to PotatoPro (n.d.), in 2017 Rwanda produced 846,184 tonnes of potatoes at a yield of 90,028 hg/ha compared to Africa's 25 million tonnes at 132,154 hg/ha, and global production of 388 million tonnes at 201,108 hg/ha.

[13] Land consolidation in Rwanda entails small scale farmers combining their land to benefit from economies of scale; reduced production cost and increased yields (Alinda & Abbott, 2012)

Table 3;District Development Strategy initiatives for Irish potato value chain development.

DISTRICT	Irish potato development initiatives – DDS 2024 Targets
Burera (Burera District, 2018)	• "Construction of link roads to I. Potato growing areas, • 22 I. Potato collection points constructed, • 11 Seeds warehouses rehabilitated and constructed for Irish Potatoes."
Gakenke (Gakenke District, 2018)	***"Economic transformation pillar, Goal 1, Activity 3***; Land use consolidation of main crops on 45515ha (maize, beans, wheat, cassava, Irish potatoes) per year."
Musanze (Musanze District, 2018)	• "Develop Irish potato starch (amidon) factory, • Construct and upgrade Irish potatoes collection centers and new store houses, • Targeted improvement in production from 29.53 to 32 t/ha."
Nyabihu (Nyabihu District, 2018)	• "Greenhouses constructed for Irish potatoes seeds multiplication, & model seed storehouses, • Construction of 2 Cold storage rooms for harvested Irish potatoes, • Targeted improvement in production from 27 to 35 t/ha."
Rubavu (Rubavu District, 2018)	***"DDS Priority 6.2***; increasing improved seeds produced at local level by establishing Irish potatoes minitubes greenhouses from 5 to 10, ***DDS Priority 6.3***: Increase the average productivity of key and high value crops (Maize, Irish Potatoes, Beans, Coffee, Tea and Pyrethrum) with production target aimed to have multiplied by 4 in 2024, Targeted improvement in production from 32.3 to 34 t/ha."

4.1.2 Flow of Irish potatoes along the Value Chain

The value chain mapping process used information from 2019 seasonal agricultural survey report and [14]key informant interviews. In essence, the pre-harvest activities of the value-chain were not considered relevant for this study, in relation to the main objective that entailed suitability of SEZs to agro-processing activities. The indirect actors and the external influences were not discussed as well.

According to IABINYA Union President (2020), the Ministry of Trade and Industry (MINICOM) encouraged the empowerment of cooperatives, that manage collection centres, to facilitate price control and formalize marketing of the potatoes. The cooperatives collect the produce and repackage into standard-sized sacks for the wholesale market or sell to processing companies and retailers. They are occasionally stored in the cooperatives' warehouses (if available) awaiting buyers, some of which are under construction under the 'Climate Resilient Post-harvest and Agri-business Support Project (PASP)' by MINAGRI. Moreover, most of the wholesale traders are based at the Kigali Irish potato wholesale market (established in 2015), where approximately 80% of the collected quantity was sold in 2019. The potatoes were then distributed to other markets/towns to retailers nationwide, since cross-border trade with Uganda and Burundi was limited by their political tensions with Rwanda (at the time of fieldwork). Additionally, it wasn't clear how much Irish potatoes were imported, although USAID (2013) indicate that some imports used to originate from Uganda, Burundi, DRC and Tanzania; via both formal and informal trade.

Production statistics, as illustrated in fig 10, respectively rank the districts as follows; Nyabihu with the highest, then Rubavu, Musanze, Burera and Gakenke with the least production. Notably, Gakenke district with its relatively low production, did not have any development initiatives related to post-harvest activities in the DDS. This was confirmed by Mukamurenzi (2020) indicating that the district was not officially considered, by the ministry, a high production zone for irish potatoes.

However, there was a mismatch between NISR and the cooperatives' production statistics, which could be attributed to poor record keeping by the cooperatives (Mukamurenzi, 2020). NISR data is also estimated based on survey samples in farms (NISR, 2019), which could be affected by heterogeneity of farms and farming methods. Moreover, although the collection centres have been useful in regulating the marketing process, they experience insufficient storage constraints (Mukamurenzi, 2020) which would have contributed to post-harvest losses.

Meanwhile, crisps production was the main processing activity, with a community processing center (CPC)- (*Nyabihu Potato company*) and a private company (*Hollanda Fairfoods Ltd*) being the main processors countrywide. The CPC was established under the 'Domestic Market Recapturing Strategy' to promote local production for the domestic market (MINICOM, 2015a). In addition, the crisps produced are sold locally to supermarkets mainly in Kigali, and to other urban centers-fig.13. Hollanda Fairfoods Ltd mainly market their products via distribution centers in Kigali and Kampala, Uganda, with plans to spread their market to other East African nations.

[14] a list of key informants is availed in appendix II - data sources.

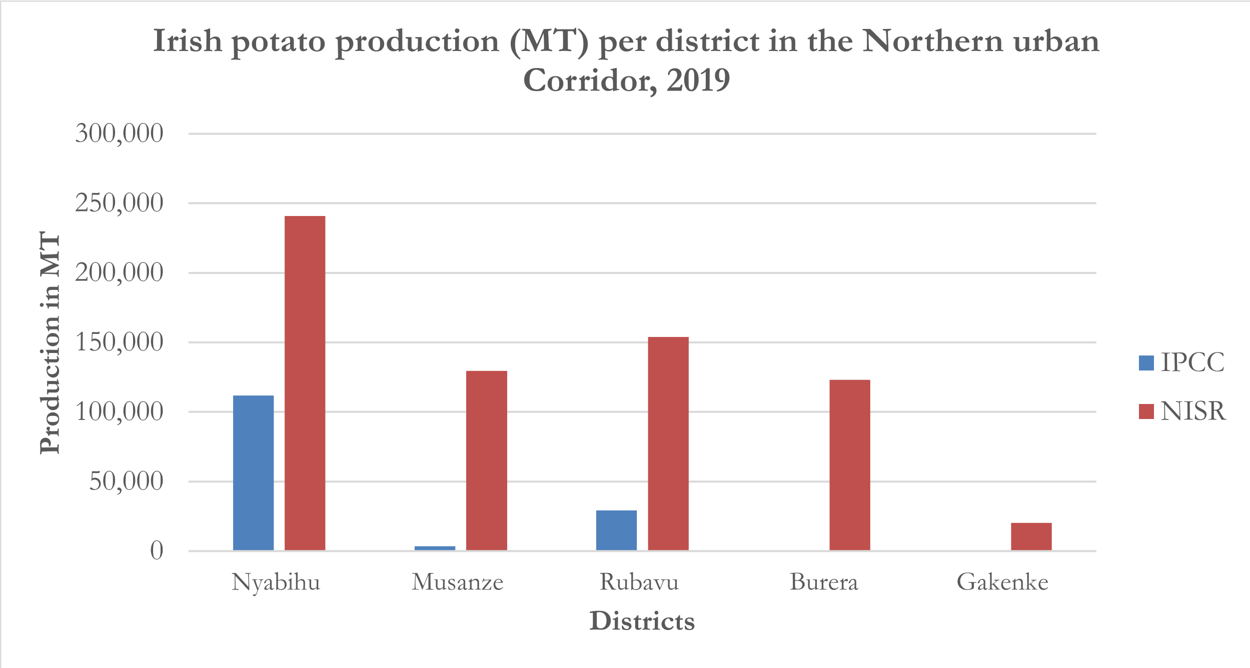


Figure 10; Irish potato production statistics (MT) per district in the Northern Urban Corrridor,2019; *source National Institute of Statistics Rwanda (NISR, 2019) and Irish potato cooperatives(IPCC).*

Figures 11, 12 and 13 show generalised views of the flow and spatial distribution of Irish potatoes at the various links as per NISR (2019) seasonal agricultural survey, and key informant interviews with IABINYA Union president, commodity trade value chain specialist-Mukamurenzi (2020), food crops production specialist at MINAGRI, and representatives of the 2 crisps processing companies. Farmers retained approximately 20% of the produce as seeds (input) for the following season, since the improved seeds are unaffordable to most of the small scale farmers (CTA, 2018). In addition, approximately 66% of the remaining produce was sold, after domestic consumption, labour, rent, fodder, gifts, and post-harvest losses. A more detailed flow map, data sources-table 9, and list of key informants can be found in appendices.

Hence, the commodity distribution takes place in 2 main chains. In the first chain-figures 11 & 12, farmers deliver their produce at the collection centres, where the quantity is recorded for temporary storage, sorting, and packaging. The cooperative in charge of the collection centres then seeks for clients, mainly from the wholesale market in Nzove, Kigali, where approximately 80% of the produce is sold to wholesalers. The wholesalers then distribute to retailers in other towns nationwide.

In the second chain-figs.11 & 13, the cooperatives sell the produce to the 2 main crisps processing companies: Hollanda Fairfoods Ltd, and Nyabihu Potato Company. Occasionally, the companies contract some farmers to grow a specific variety called "*Kinigi",* which they consider high quality for crisps. This is still done with the knowledge of the respective cooperatives that the farmers are members to. In other instances, the companies contract some cooperatives to outsource for the specific variety of potatoes from their farmer members. Moreover, some retailers may purchase the potatoes from the collection centres for the local markets.

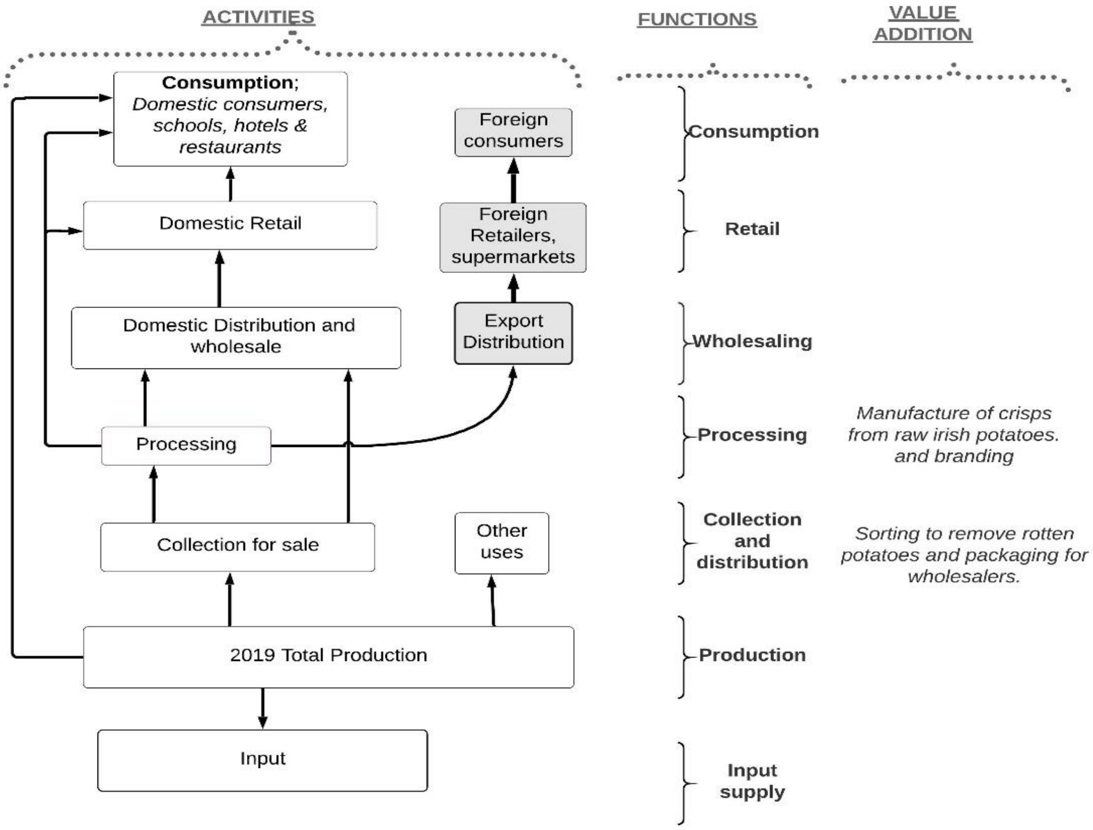
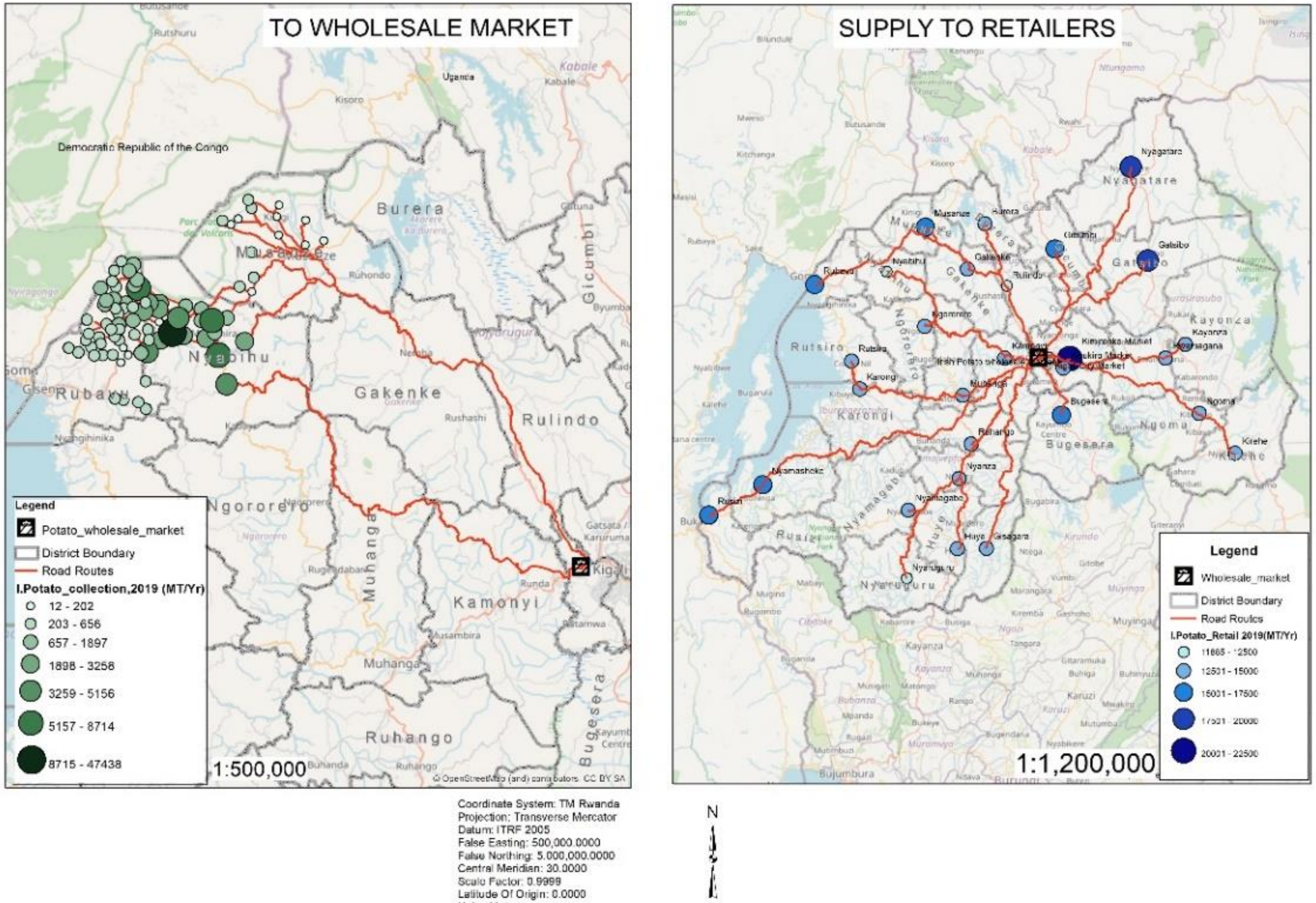


Figure 11; A summarized [15]flow of Irish potatoes, after production to consumption. (*Source*; *NISR 2019, Key informants*).

The spatial flow was visualized using the [16]major roads as the transportation network. Fig.12 shows spatial flow from the collection centres to the main wholesale market in Kigali, and from the wholesale market to other towns in Rwanda. Due to unavailable data on distribution quantities to other towns, population distribution per district was used to estimate the market quantities of Irish potatoes to the district markets (considering potatoes are a staple food in Rwanda). Fig. 13 then shows spatial flow from the collection centres to the 2 processing companies (factory locations), and subsequently to their respective distribution centres.

[15] The arrow points to the direction of flow of products.
[16] National and district roads.



Coordinate System: TM Rwanda
Projection: Transverse Mercator
Datum: ITRF 2005
False Easting: 500,000.0000
False Northing: 5,000,000.0000
Central Meridian: 30.0000
Scale Factor: 0.9999
Latitude Of Origin: 0.0000
Units: Meter

Figure 12; Spatial flow of Irish potatoes; from collection centres to wholesale market, and from wholesale market to district markets.

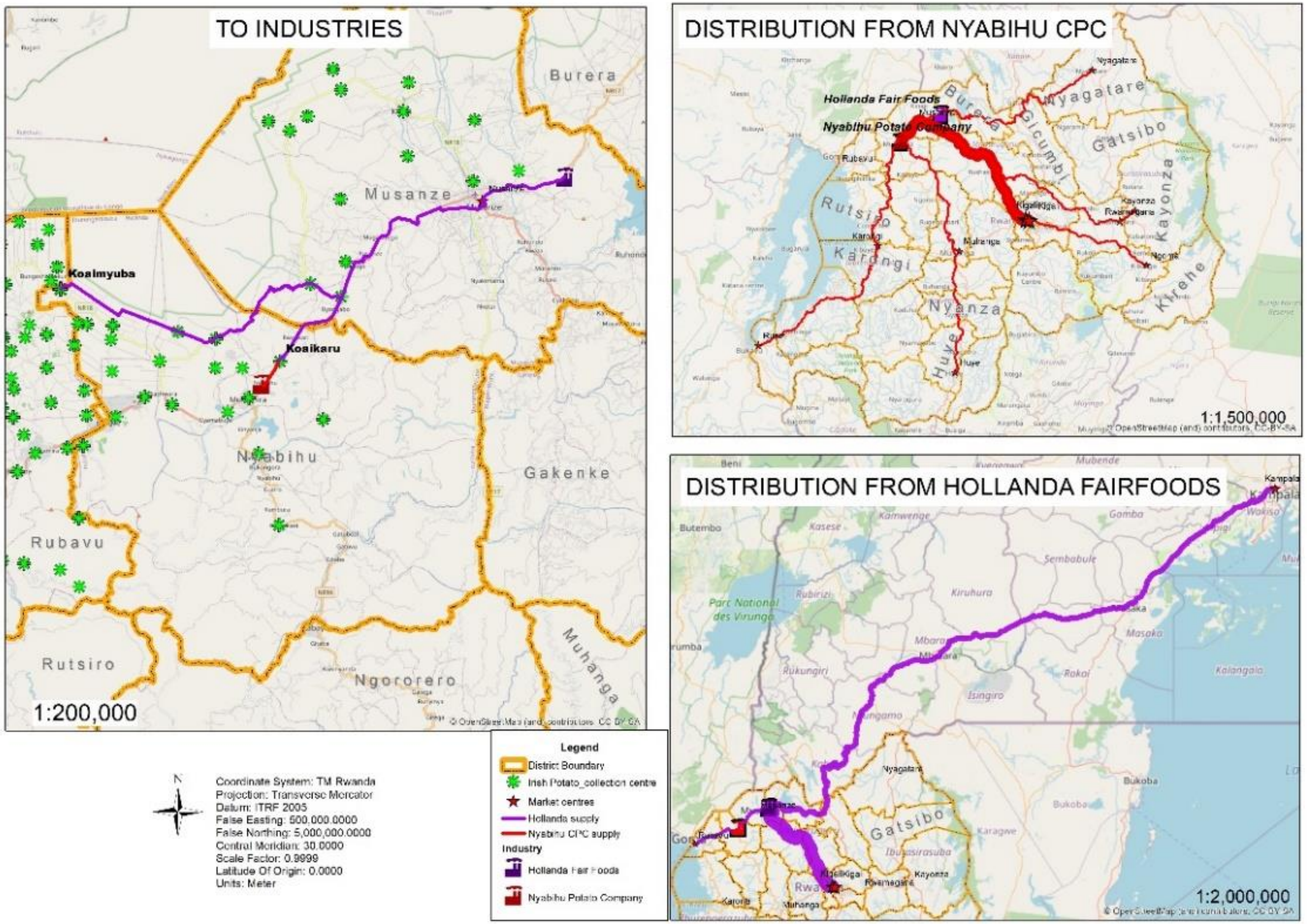


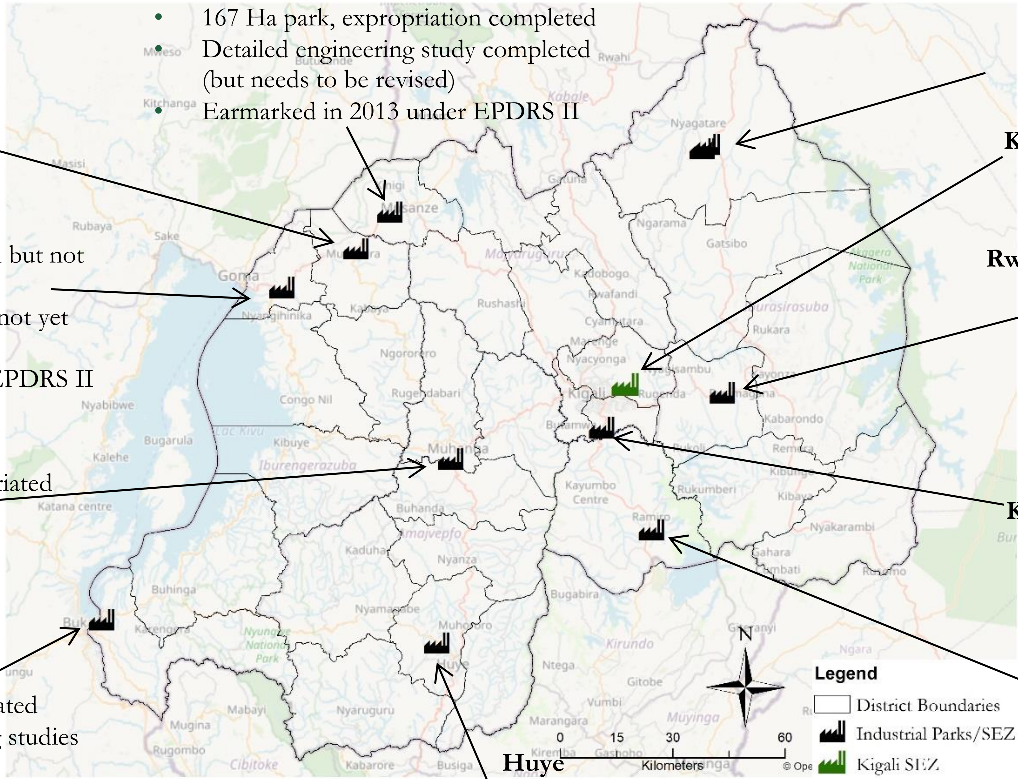
Figure 13; Spatial flow of Irish potatoes; from collection centres to industries, and from industries to distribution centres.

4.2 Spatial Multi-Criteria Evaluation of existing industrial parks.

This section elaborates the evaluation process for the existing industrial parks/ SEZs, based on factors from key informants and 2 policy documents. The key informants provided factors that were considered for site selection of existing activities- table 4. The analysis of 2 policy documents was then aimed at obtaining location factors as recommended by government regulations - table 5. Factors from both sources would then inform criteria (table 6) to evaluate the existing SEZ locations. It was expected that some of the spatial factors from the existing activities (e.g. processors) would complement government regulations, by providing some endogenous understanding of the local agricultural sector.

According to MINICOM (2018), Government of Rwanda appropriated 9 special economic zones in secondary cities to complement Kigali SEZ, see fig 14, in promoting industrial development e.g. via the Made in Rwanda initiative, as well as promote regional development. This was in accordance with SEZ Policy of 2010 and EPDRS II of 2013.

Despite being out of the study area, all industrial parks were considered in the suitability calculations. This was based on the assumption that investors may consider some factors more important than others based on opportunity costs. For instance, a SEZ in a capital city may offer proximity to markets, but an investor may prefer a smaller city due to cheaper land rates or cheaper labour costs. For this reason, all SEZs could be potential locations.



Nyabihu

- 44 Ha park, site earmarked
- Earmarked in 2011 under 2010 SEZ policy.

Rubavu

- 50 Ha park, land earmarked but not yet expropriated
- Detailed engineering study not yet available
- Earmarked in 2013 under EPDRS II

Muhanga

- 63 Ha park, not yet expropriated
- Detailed engineering study complete
- Earmarked in 2013 under EPDRS II
-

Rusizi

- 45 Ha park, fully expropriated
- Feasibility and engineering studies complete
- Zoning and demarcation complete
- Earmarked in 2011 under 2010 SEZ policy.

Musanze

- 167 Ha park, expropriation completed
- Detailed engineering study completed (but needs to be revised)
- Earmarked in 2013 under EPDRS II

Huye

- 50 Ha park, fully expropriated
- Feasibility and engineering study complete
- Zoning and demarcation complete
- Earmarked in 2011 under 2010 SEZ policy.

Nyagatare

- 50 Ha park, land earmarked but not yet expropriated
- Detailed engineering study not yet available
- Earmarked in 2013 under EPDRS II

Kigali SEZ

- Established in 2009 after merging Kigali Free Trade Zone and Kigali Industrial Park

Rwamagana

- 80 Ha park
- Detailed engineering study complete
- Expropriation completed
- Ring road developed
- Internal marram roads under development
- Established to support demand in Kigali SEZ

Kicukiro SME Park (Gahanga SEZ)

- Detailed engineering study complete
- Construction of murram roads were stopped at 10%.
- Established to support demand in Kigali SEZ

Bugesera (Rweru SEZ)

- 330 Ha park, fully expropriated
- Detailed engineering study complete
- Construction of phase I, 100 Ha is at 55%
- Earmarked in 2011 under 2010 SEZ policy.

Figure 14; Status of proposed special economic zones in Rwanda under SEZ Policy of 2010 (adapted from UNIDO (2015)and (Industrial Infrastructure Policy Specialist, 2020))

4.2.1 Spatial factors that influenced the location of current Irish potatoes value chain activities, and industrial parks

The spatial factors illustrated in table 4, were obtained for the main activities as per the value-chain mapping. These activities included potato collection, processing, and marketing[17]. IABINYA Union president and 3 cooperative representatives provided information on spatial factors leading to current locations of collection centres, while 2 representatives of the processing companies provided information on their respective factory locations. Next, the Industrial Infrastructure Policy Specialist (2020) provided factors that informed the spatial locations of the appropriated SEZs.

Proximity to raw materials/farms was identified as the main factor for spatial locations of both existing industries and collection centres, followed by accessibility[18] of the locations. Accessibility concerns were mainly related to quality of (mainly seasonal) feeder roads to the farms. Proximity to major roads and access to land (availability and affordability) were also a consideration for the 3 activities. The existing industries also considered cheap labour as one of the location factors. The main spatial factors that led to site selection of existing industrial parks was land availability and proximity to existing industries. The government acquired land close to existing industries, which was meant to improve amenities and support existing industries (Industrial Infrastructure Policy Specialist, 2020).

Table 4; Factors considered for the spatial locations of existing activities (*Source; Key informant interviews*)

Irish potato collection	**Existing crisps processing companies**	**Existing SEZs/industrial parks**
Proximity to farmers/raw materials	Proximity to raw materials	Proximity to existing industries
Access to land; affordability and availability.	Access to land; affordability and availability.	Land availability
Accessibility by farmers and clients (road quality)	Accessibility; road quality	Accessibility of the SEZs
Proximity to major roads	Proximity to major roads	Proximity to major markets; (urban areas)
Electricity supply	Availability and proximity to cheap labour. labour in current locations was cheaper than Kigali.	Environmental impacts of the parks

*Overlapping factors are highlighted with the same colour.

[17] Information could not be obtained about the main wholesale market activities in Kigali.
[18]Adopted from Brussel et al. (2019) Accessibility was used for indicators that combine transport and land-use systems.

4.2.2 Factors to be considered for location of new industries and industrial parks in Rwanda.

The factors, in table 5, obtained from the land use planning guidelines (RLMUA, 2017) and the SEZ policy (MINICOM, 2018) were used to inform evaluation criteria for the existing industrial parks. The 2 policies had some overlapping factors which included provision of utilities, environmental considerations, and good accessibility.

Table 5; Factors recommended for locating SEZs. *[Source*(MINICOM, 2018; RLMUA, 2017)*]*

Land Use Planning Guidelines (RLMUA, 2017)	**Special Economic Zones Policy** (MINICOM, 2018)
Industries to be in industrial zones	Feasibility analysis
Flat land or large flat terraces	Availability of waste management infrastructure
Adequate provision of utilities	Reliable utility connectivity
Easy road or rail access	Access to infrastructure, like roads
Good access to major traffic routes	
Slope gradient (below 20% rise)	
Distance from residential areas to protect them from pollution	
Distance from water sources and water bodies	
Suitable distance from environmentally sensitive areas	Distant from environmental sensitive areas to limit pollution

*The overlapping factors are highlighted with the same colour.

4.2.3 Evaluation of existing industrial parks

The factors presented in tables 4 & 5 were used to formulate the criteria in table 6, based on rationale from the respective sources of the factors used. Spatial data acquired from GIS department at MININFRA was then used to measure the relation of each criterion to the existing industrial parks in ArcGIS. The value of each indicator was then normalized, before creating a cumulative performance index.

Moreover, criteria weights were not acquired for this case study due to the additional time that would be required to acquire more stakeholders' input. In particular, the different sources of factors would have required a second round of interviews informed by the criteria in table 6, targeted at stakeholders such as the existing processing companies, and relevant government agencies. For this reason, all criteria carried the same weights in the evaluation. However, the strategic planning tool developed after the evaluation, used an interactive software that allows the user to dynamically vary the weights of criteria and subsequently view the impacts.

Inadequate data limited the use of additional factors, such as distance from residential areas prone to pollution, and access to waste management infrastructure. Moreover, distance to major roads, distance to water pipelines, and distance to electricity criteria were not considered, based on observations (using layers in GIS) that all industrial parks were next to major roads (national and district roads), and already had medium power lines[19] and water lines, as a means of attracting investors (MINICOM, 2015b). Hence, only five criteria were used as shown in table 7.

Distance along the major road network layer was used to extract data values related to the collection centres and district markets criteria, while for the waterbodies a straight-line distance to the nearest point from the SEZs was used. A digital elevation model was processed in ArcGIS to produce a slope percentage raster layer, from which average slope values were extracted per industrial park (for the slope indicator).

In addition, linear normalization was used to reclassify values for each factor on a 0 to 1 scale, due to the different units for each criterion. A value of 1 represented highest performance while 0 represented least performance (Nevill & Holder, 1995). A cost-benefit formulation complemented the normalization, based on the positive or negative influence of the criteria. A compensatory approach was then used to compute the arithmetic mean, whereby weak performance of the SEZs in some criteria was complemented by high performance in others (Falcão et al., 2019), to establish the cumulative performance index. On this note, slope, distances to rivers and wetlands were calculated as costs since they negatively influence suitability, while other 2 criteria were calculated as benefits, since they improve amenity of the industrial parks (Mouter, Annema, & Wee, 2013)

[19] Industries require by medium voltage powerlines (Industrial Infrastructure Policy Specialist, 2020).

Table 6; Criteria used for evaluation of industrial parks [Source; MINICOM, 2018; RLMUA, 2017 and Key informant interviews.]

Criteria	Rationale	Factors used from key informant interviews (A) and policies (B)	Data layers used
Distance to medium voltage powerlines	Reliable connectivity to utilities creates a good investment climate.	Adequate access to utilities like water and energy. (A) & (B)	Medium voltage power lines
Distance to water pipelines			Water pipelines
Average distance to collection centres	Proximity to raw materials is recommended to ease on transportation costs and other related post-harvest losses.	Proximity to raw materials (A)	Irish potato collection centres, major roads
Average distance to district markets	Convenient access to business centres in existing urban areas for input acquisition and market access. (*District capitals were used to represent market locations per district.*)	Proximity to major markets (A)	Markets, major roads
Distance to waterbodies (rivers and wetlands)	Industrial activities should be restricted to areas with low risk of pollution runoff to water bodies depending on distance to water bodies and land gradient (buffer distance between 100m up to 1500m). They should also be distant from flood prone areas and steep slopes.	Distance from environmentally sensitive areas (B)	Wetlands, rivers
Slope		Slope gradient (B)	Digital Elevation Model

Despite having the lowest score for the slope factor –i.e. highest slope percentage rise of 11.61, Musanze SEZ scored highly for other indicators to emerge with the highest performance index. RLMUA (2017) however allows for construction of permanent structures on slopes of up to 20 percent rise. This makes Musanze SEZ the relatively best location for an industry. Rweru SEZ also scored very low in relation to collection centres but highly for other indicators. This would mean that despite Rweru SEZ being relatively the 2nd best location of the industrial parks, establishing an Irish potato factory there would incur additional costs e.g. on transportation and preservation of the potatoes. Being within the Northern Urban corridor, Musanze, Rubavu and Nyabihu industrial parks were the closest to the potato collection centres.

Notwithstanding their good proximity to collection centres, Nyabihu and Rubavu industrial parks are relatively less suitable than Rweru SEZ in overall performance, due to their low performance against the other criteria, such as being below the average score (0.5) to wetlands and rivers. However, their proximity to collection centres and their low slope percentages compensated to place them amongst the top half performers.

It is worth noting that despite a site having a high overall suitability, some industrial parks could still not be feasible for new industries as per the policy guidelines. For instance, only 2 industrial parks are located above the 1500m buffer distance from wetlands, and 1 other -Masoro SEZ- being below the 100m minimum buffer distance. At the same time, only 4 of the industrial parks are located above 1500m from rivers (RLMUA, 2017), as illustrated in table 7. These findings indicate that additional measures against environmental degradation would be required at such sites. Moreover, Rusizi as the lowest performing site, would be characterized by relatively higher investment costs for establishing new industries, for instance on product transportation due to distant markets, or relatively low returns on investments.

Table 7; Spatial multi-criteria evaluation of existing industrial parks in Rwanda.

Industrial Park	Average distance to collection centers (Km)	**Normalized Score**	Average distance to District markets (Km)	**Normalized Score**	Distance to rivers (Metres)	**Normalized Score**	Distance to wetlands (Metres)	**Normalized Score**	slope (%)	**Normalized Score**	***cumulative performance index***
Musanze SEZ	30.027	0.94	111.755	0.73	6272.55	0.73	4891.71	1.00	11.61	0.00	**0.68**
Rweru SEZ (Bugesera)	169.261	0.14	102.311	0.82	8497.14	1.00	2151.76	0.44	5.66	0.70	**0.62**
Nyabihu industrial park	18.718	1.00	117.862	0.68	1201.24	0.13	1494.85	0.30	4.17	0.88	**0.60**
Rubavu SEZ	22.410	0.98	128.610	0.58	482.43	0.04	858.95	0.17	3.16	1.00	**0.56**
Gahanga SEZ	132.989	0.35	84.325	0.98	1721.49	0.19	890.25	0.18	4.56	0.83	**0.51**
Muhanga industrial zone	108.908	0.48	82.375	1.00	238.75	0.02	74.22	0.01	7.01	0.54	**0.41**
Masoro SEZ (Kigali)	130.602	0.36	85.089	0.98	644.82	0.06	18.79	0.00	8.51	0.37	**0.35**
Nyagatare SEZ	168.707	0.14	140.710	0.47	4369.46	0.51	119.04	0.02	6.50	0.60	**0.35**
Rwamagana industrial site	161.492	0.18	103.079	0.81	742.08	0.08	449.12	0.09	6.89	0.56	**0.34**
Huye industrial park	164.901	0.16	111.664	0.74	111.88	0.00	207.19	0.04	7.11	0.53	**0.29**
Rusizi SEZ	193.742	0.00	193.101	0.00	250.42	0.02	103.88	0.02	9.54	0.24	**0.06**

4.2.4 Decision support model, for strategic spatial allocation of activities to industrial parks.

The SMCE findings in the previous section are a valid justification to explore alternative means of decision making. A decision support model was developed in Scenario 360, as an extension in ArcGIS, to facilitate allocation of activities to industrial parks, based on the complexity of factors to be considered.

4.2.4.1 Decision problem

Allocation of spatial interventions during phase B of the SDF methodology of Rwanda was informed by presence or absence of manufacturing and industrial functions, complementing the NST1 strategy. Additionally, various development strategies and policies in the country aim at developing the agro-processing sector, such as in DDSs and the Industrial Masterplan for the Agro-Processing Subsector (MINICOM, 2015b). Moreover, SEZs were established in secondary cities to support local manufacturing (MINICOM, 2018).

Site selection of these SEZs was mainly influenced by land availability and location of existing industries (Industrial Infrastructure Policy Specialist, 2020). Moreover, as Stiglitz et al. (2017) argue, industrial site selection decisions require various complex considerations, that may be guided by relevant policies and stakeholder inputs. As evidenced by the evaluation in section 4.2.3, some of the selected locations were not in accordance with the recommended policy guidelines, such as the recommended buffer-distance of industrial activities from waterbodies between 100m and 1500m – see table 7 (RLMUA, 2017).

4.2.4.2 Model aim.

The NSAP, in the SDF methodology, facilitated the revelation of economic specialisation areas, to allocate interventions of the NST1 and DDSs to these areas. However, this action planning was not detailed enough for specific industrial activities. To examine this, the SMCE in table 7 evaluated the current spatial locations of industrial parks in relation to policy guidelines and Irish potato value chain factors.

Correspondingly, this model was designed to simplify the action planning process and complexities associated with suitability analysis. Thus, the criteria used for the SMCE was adopted to develop the model. It is expected that the model can be useful to support the satisfactory distribution of activities in the industrial parks, based on comparative advantages and stakeholders' input.

4.2.4.3 Model design

The software used, [20]*Scenario 360*, can accommodate both vector and raster data formats, and requires the spatial data to be projected to a uniform coordinate system before the analysis, see fig. 15. The industrial parks layer (.shp format) was used as a dynamic layer (dependent variable) while the layers of the criteria were used as independent variables influencing the suitability of the industrial parks.. The suitability wizard as shown in fig.16 was configured, to include a weighting factor and scale (fig.17), and an option to use or omit each criterion. The weighting scale enables the user to change the weight of each factor as desired, and subsequently run the simulation to view the impacts.

Moreover, unlike the cumulative performance index of the SMCE, the suitability score was based on a scale of 0 (least suitable) to 100 (most suitable)-fig 18, and the most suitable site scores 100 while the least suitable scores 0. The suitability wizard performs an automated normalization of raw values, and subsequently computes the suitability score, both on a scale of 0-100. These calculations are stored on dynamic attributes, in the attribute table of the dependent variable (industrial parks in this case), that are updated every time a simulation is run.

[20] See interphase in appendix III

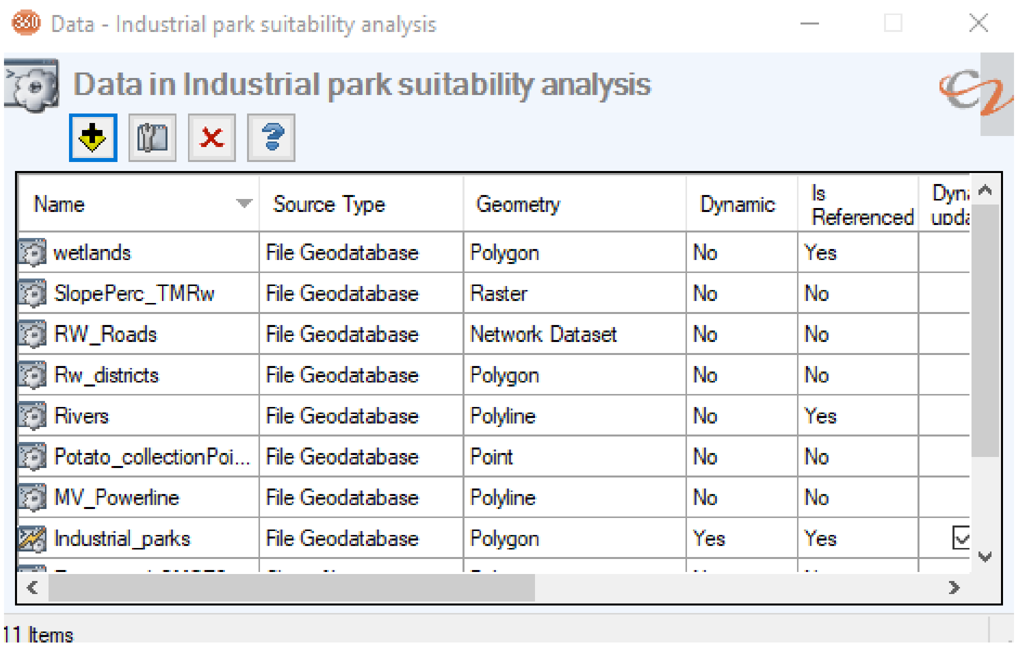


Figure 15; A snapshot of some of the spatial data used in the scenario 360 model.

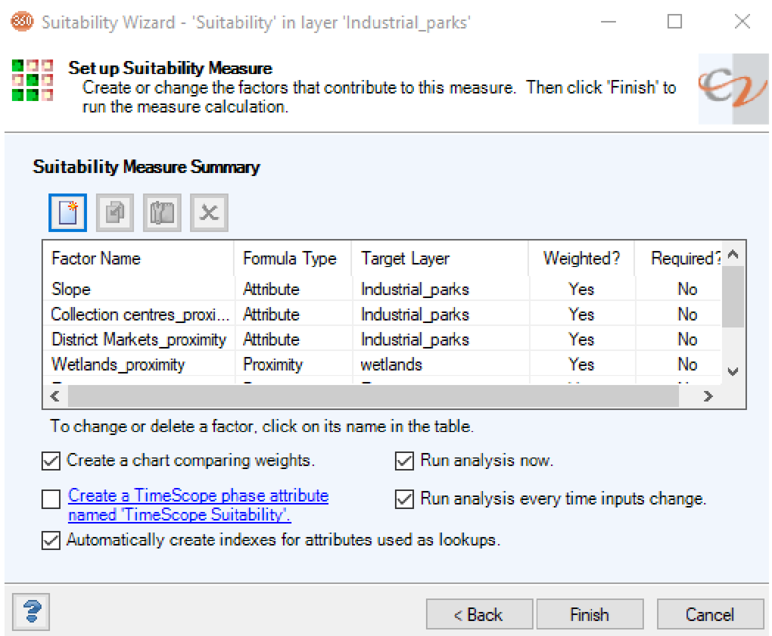


Figure 16; A snapshot of the suitability wizard used for the analysis.

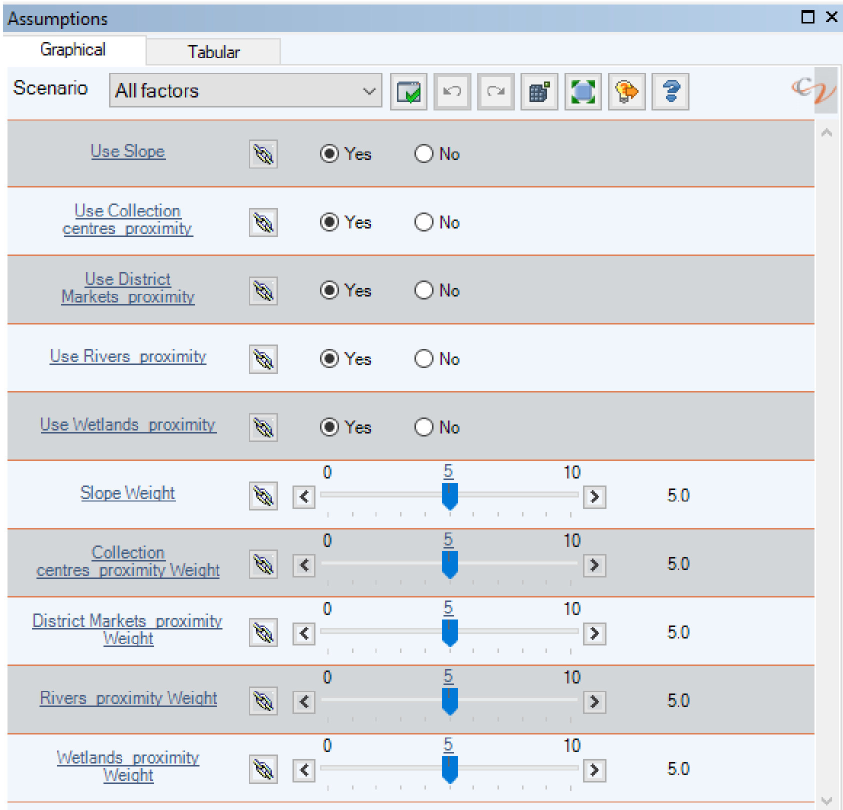


Figure 17; A snapshot of the assumptions window showing the criteria used and weight options.

4.2.4.4 Model outputs and evaluation

The results of the suitability model were visualized and evaluated using indicators calculated as dynamic attributes in the industrial parks layer. The indicator in figure 18 shows the overall suitability scores, echoing the cumulative performance index of the SMCE in table 7, although on a different but proportional scale. Criteria weights were not obtained, as earlier explained, so the simulation in the model used similar weights for all criteria.

In addition, policy guidelines defined criteria limits for only the slope, rivers, and wetlands criteria, i.e. the recommended slope gradient, and distances from water bodies for construction of industries or and other permanent structures. With this in mind, the evaluation indicators in figure 19 show how the model was used to evaluate the sites performance relative to specific policy guidelines, which can be done for any other user-defined indicators. In this case, despite some industrial sites being in relatively high-suitability locations, they were below the regulated distances from waterbodies (between 100 and 1500m), as per environmental protection regulations.

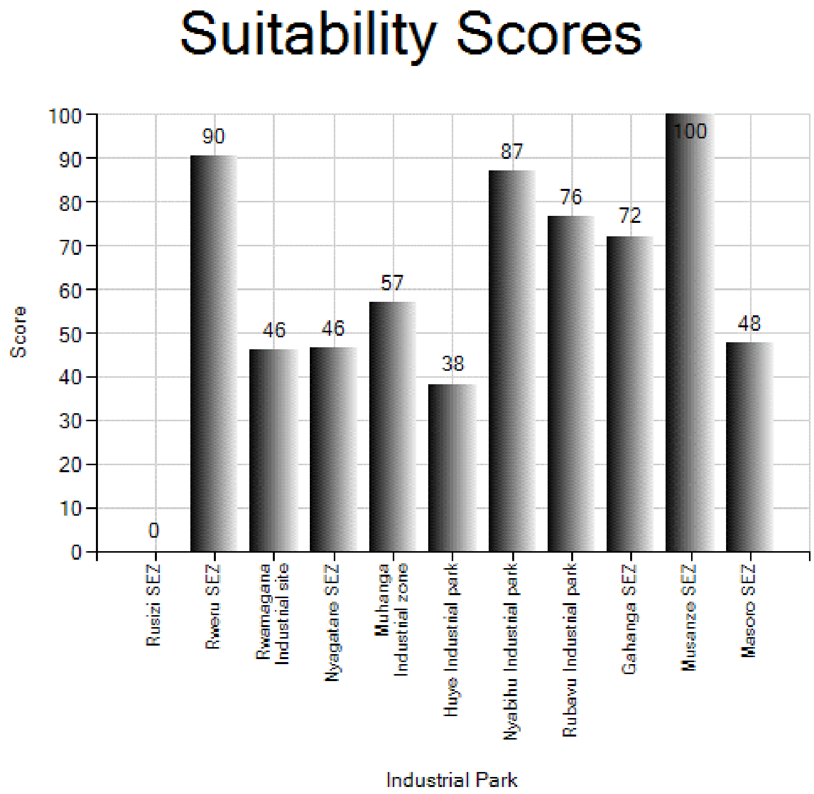


Figure 18; Suitability scores showing the performance of each industrial park.

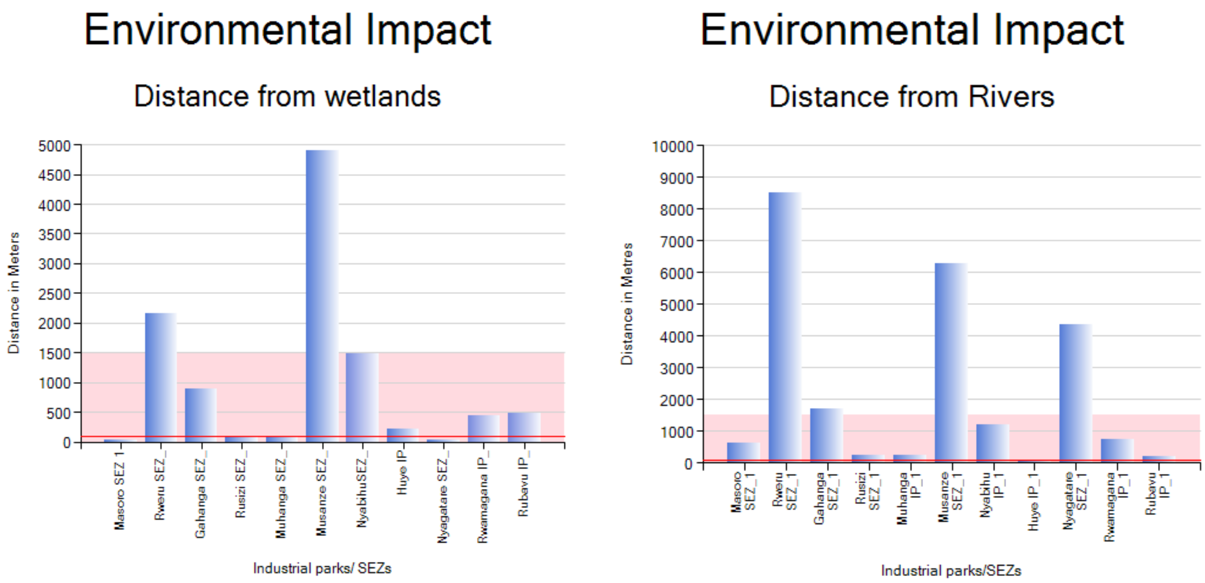


Figure 19; Distances of industrial parks to water bodies; indicating buffer zone limits as per land use planning guidelines.

5. DISCUSSION

UN-Habitat, (2019) recommended adaptation of the SDF methods by different ministries and agencies in Rwanda, to promote integrated decision making across ministries as well as administrative districts. Therefore, this study adapted the methodology to integrate local comparative advantages in strategic spatial planning. Agriculture being a major employer in Rwanda, presented a comparative advantage to promote economic development and regional interdependence, coupled with governmental efforts to use the agro-processing sector as a key driver of industrialization (MINICOM, 2015b). The value chain mapping conducted, on Irish potatoes as a model commodity, gave a clearer understanding of the flow as well as limitations and opportunities in the sector.

5.1 Adaptation of SDF methods.

In phase A of the SDF methodology, the existing spatial structure of settlements and regional potentialities were revealed, using MoF and stakeholder workshops. Subsequently, the SMCE was conducted to evaluate the performance of settlements against the 4 pillars of NUP. Relevant to this study are the NUP objectives of achieving economic-growth and off-farm job creation under the economic pillar, and ensuring appropriate urban planning and management tools under the coordination pillar.

[21]Four of the main settlements in the study area performed as follows against the economic pillar (on a 4-point scale with 'Very Low', 'Low', 'Moderate', and 'Good'); Musanze and Rubavu at 'Moderate', Nyabihu and Gakenke at 'Low'. Moreover, sub-objective 8 under the economic pillar was aimed at "developing urban centres as centres for innovation and entrepreneurship, to increase socio-economic services and off-farm job opportunities" (pg.55). Under this sub-objective, Musanze and Rubavu had 'Low' performance, characterised by relatively low increase in off-farm jobs, while Nyabihu and Gakenke had 'Very Low' performance, characterised by lacking concentration of specific activities to develop a "formal" economic sector. Meanwhile, under the coordination pillar of NUP, objective 2 aimed "to ensure use of appropriate urban planning and management tools, to improve implementation and regulation of the urbanization process" (pg.36) for instance by having clear prioritization of investment locations and projects. Musanze, Rubavu and Nyabihu had 'Very-Low' coordination, while Gakenke had 'Good' coordination (UN-Habitat, 2016). Hence, this evaluation revealed weaknesses and potentialities of the various settlements against a development policy.

The NSAP was then formulated to coordinate strategic planning both [22]vertically and horizontally. It was used as a tool to coordinate allocation of industrial interventions proposed by a national strategy (NST1) and respective DDSs, into district clusters that had complementary industrial and manufacturing functions. This allocation was conducted using the 3 ESAs (table 2), delineated using settlement hierarchies based on functions, socio-economic linkages, and manufacturing and industrial activities in each sector. However, to further develop on the prioritization of investments, a deeper understanding of the complementary economic activities and potentialities in the regions (ESAs) was relevant.

Therefore, this study sought to explore one of the district clusters to promote the economic goal increasing off-farm job opportunities; by analysing a crop value-chain (with a potential for higher

[21] Only the 4 settlements are used in the report, Burera was not included in the SMCE.

[22] Vertical; coordination between agencies at different levels e.g. national and district.
Horizontal; coordination between agencies at the same level, e.g. between district clusters

productivity) to identify factors that would be relevant to develop the value-chain (and diversify income-earning activities). It was also relevant to promote objective 8 under the coordination pillar, by developing a tool for allocating projects to satisfactory investment locations. SEZs in Rwanda were used as the investment locations.

5.2 Agricultural commodity value chain mapping

Irish potato as selected has a potentiality for rural development, due to the mainly small-scale farming with a relatively high production (NISR, 2019) on a continental level, and as a staple food in Rwanda. Although all the districts in the study area propose initiatives to improve potato productivity in the DDSs, there was no evidence observed of inter-district collaboration within these initiatives. This is despite Irish potatoes being a shared comparative advantage.

Moreover, despite Gakenke district being in the high production region i.e. Northern urban Corridor, its contribution to overall Irish-potato production was relatively low, further characterized by the purportedly[23] lacking collection centers. However, in the event that the land-use consolidation initiative (table 3) leads to future yield improvements, it would be expected to benefit from the prioritized agro-processing locations (as part of the Northern Urban Corridor).

As a result of price control initiatives by MINICOM (2015c), marketing of Irish potatoes was formalized through Irish potato collection centers managed by cooperatives. The cooperatives play a major role in management of collection centers and marketing on behalf of the farmers, although market overflow is a recurring problem during harvest period, especially due to insufficient storage facilities. For this reason, MINAGRI (2015) supported construction of storage facilities for the cooperatives under the PASP[24] project, which was ongoing during the fieldwork period.

The flow maps in figures 11 & 20 generally explain the existing situation in the Irish potato value chain in the study area, echoing some earlier findings by Maurice (2018) on the value chain activities in Musanze district, despite limited access to detailed data for this study. However, in contrast, international trade of potatoes from the area was informally exclusive with Goma, DRC, at the time of fieldwork, due to political tensions with Uganda and Burundi.

Value chains are often depicted as a vertical chain, although intra-chain linkages are most often of a two-way nature (Kaplinsky & Morris, 2001). For instance, the arrows in figure 11 only show the direction of product flow, although the flow of market information and income (money) occurs in the opposite direction. This relation may influence product flow in the following period, e.g. if quality from collection centres to processors was poor from the previous harvest, the processor may buy from the wholesaler in the following period.

Meanwhile, Kigali contributes 10.8% of the country's population, compared to 16.5% from the Northern Urban Corridor districts (NISR, 2014), but receives on average 80% of the total market quantity on wholesale. This produce is then distributed to other towns. This can be attributed to Kigali being the capital city, presence of the potato wholesale market at Nzove sector in Kigali, and other issues such as low increase of off-farm jobs at the study area urban-settlements -from SDF findings (UN-Habitat, 2016),

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[23] Evidence from MINICOM does not indicate of potato collection centers in Gakenke. However, Irish potato farmers are required to be part of cooperatives (IABINYA Union President, 2020).
[24] PASP- The Climate Resilient Post-harvest and Agri-business Support Project

poorly integrated markets across the country, and inadequate infrastructure in other towns (The World Bank, 2017).

5.3 Evaluation of existing industrial parks and strategic planning model

According to Feick (2010), spatial multicriteria evaluation (SMCE) is well suited to semi structured problems that may require input from several individuals or sectors to choose from a set of alternatives, despite uncertainties on how possible solutions should be generated or evaluated. These alternatives are often characterized by a diverse range of factors dependent on the individuals or sectors. The SMCE approach thus complements GIS capabilities in data management, spatial analysis, and map-based visualization with MCDA techniques that incorporate user judgment into evaluation processes. In this study, this approach was applied to evaluate appropriated site locations of SEZs, relative to policy guidelines and relevant stakeholders' input.

Saleman and Jordan (2015) argue that lack of demand from firms to locate and invest in industrial parks, is amongst the main causes of their failure in developing countries. As a recent addition to the industrial development tools in Rwanda, it would be thus beneficial to learn from failures elsewhere, to promote success of the SEZs. This would mitigate some issues such as unused investments, and high investment costs to compensate for unavailable comparative advantages. Hence, despite allocating SEZs in secondary cities to facilitate regional development (MINICOM, 2018), endogenous economic activities (advantages) would be quite relevant for their success.

Moreover, land access and proximity to existing industries were the major factors for industrial parks' site selection (Industrial Infrastructure Policy Specialist, 2020), which would explain the low performance of some industrial parks against the selected criteria-table 7. Stiglitz et al. (2017) argue that different factors (spatial and non-spatial) need to be considered for industrial site selection, based on local comparative advantages (Lin et al., 2011). This way, amidst limitations like inadequate infrastructure or unestablished markets, development guided by local potentialities would have a higher chance of success to prioritize investments, or even attract more FDI and government's interest to grow the sector as in the case of flowers in Ethiopia. This could be compared to the 'build it and they will come' approach as argued by UNIDO (2015), that it had previously failed unless supported by robust demand and economic analytics. The SMCE findings affirm these arguments, for instance in the case of Rubavu and Nyabihu SEZ-table 7, which performed poorly under the distance to major markets criterion, but proximity to production areas (collection centers), elevated them above Gahanga SEZ, which is farther from collection centers.

Meanwhile, Talukder, W. Hipel, and W. vanLoon (2017) argue that by using the min-max normalization method, as in this study, data proportionality is not maintained. The range of minimum and maximum values thus highly influences the output. For instance, in table 7 under the distance to wetlands criterion, the big difference in min and max absolute values is not reflected in the normalized values. However, the method is beneficial to set data boundaries for easier comparison by having the uniform range of 0-1.

Furthermore, Talukder, W. Hipel, and W. vanLoon (2017) argue that compensability in arithmetic mean as an aggregation technique, may result in low performance in some significant criterion being compensated by high performance in another. For instance, in table 7 Rweru SEZ is far from collection centers, but it has the 2nd best cumulative index due to compensation by other factors. Considering in this study weights were not used; this significant criterion could be overlooked in the SMCE if the focus was on the cumulative index. For this reason, the capability of the decision model to display selected indicators in charts (e.g. fig 19), presents an advantage to monitor some effects of criteria that could be overlooked in suitability analysis.

The Rwanda Industrial Masterplan for the Agro-Processing Subsector of 2015 (MINICOM, 2015b) aims to promote cleaner production for better environmental sustainability. However, as evident from table 7 and figure 19, some SEZ locations were not in accordance with the national land use regulations. Therefore, establishment of industrial activities in these SEZs, would either necessitate further prioritization to allocate non-polluting activities, or other approaches like sustainable waste treatment as proposed by El-Haggar (2007), that involves treating industrial waste as by-products that can be recycled. However, this would necessitate additional research on impacts of the SEZs on the environment.

Moreover, the decision support model simplified the complex process of suitability analysis using an interactive tool in GIS, as explained in section 4.2.4. Besides integrating vector and raster data formats as recommended by Arabsheibani, Kanani Sadat, and Abedini (2016) for future SMCE approaches, the interactive and dynamic capabilities of the software gives room for multiple stakeholders to input more factors and their relative weights, run the simulation in an automated normalization process, and subsequently view the impacts.

6. Conclusions and recommendations

This section presents the conclusions of the study, recommendations, and directions for further research on the SDF methodology.

6.1 Conclusions

The main objective of this study was to adapt the SDF methodology for satisfactory spatial distribution of agro-industries, based on existing relevant functions[25] and policies. This was achieved by building on previous research on the SDF methodology and using Rwanda as a case study country in SSA. Besides having earlier adopted the methodology, Rwanda also presented an opportunity to explore how agricultural strategies could be integrated with industrial strategies towards promoting structural transformation. This is because Rwanda, like many other SSA developing countries, has agriculture as a major employer of the working population, and is faced with a weak planning system in relation to coordination of development strategies both vertically and horizontally. Therefore, a cluster of districts in the Northern Urban Corridor (identified by SDF), that share a common advantage in functions and economic activities, was used to achieve the study objective.

Irish potatoes were identified as the priority crop for value-chain development in the region, based on the high production, and the respective districts' plans of improving the crop's productivity. As a comparative advantage for the region, it also presented an opportunity to promote regional complementarity among the districts. Value chain mapping was then conducted to identify actors in the sector, their relationships, and the flow of the potatoes from harvest to the different markets. This enabled identification of location factors of existing activities, which were adapted to evaluate how future industrial parks' activities could be prioritized.

Meanwhile, Rwanda adopted special economic zones as tools for managing industrial development in the country. However, location factors as recommended by relevant policy guidelines were not appropriately considered as evidenced by the SMCE in this study. The policy guidelines were complemented by location factors from the value-chain mapping, to form criteria for evaluation of the SEZ spatial locations. Notably, 2 of the top 5 performing SEZs violated the recommended distances to water bodies. In such a case, contingency measures would be necessary since development steps have commenced in the SEZs. This could either be in accordance with national environmental regulations, or prioritization of activities to establish only non-polluting industrial activities.

Following the SMCE, a decision support model was developed that simplified the suitability analysis process, using an interactive platform that can accommodate multiple stakeholders at a time in a decision process. With this in mind, the model outputs (e.g. the suitability score) would be quite useful, not as an end to the decision process, but rather support a participatory decision-making process. The model can also be adopted for prioritizing sites in other location-allocation decision problems, by changing the input data and using relevant monitoring indicators.

[25] Function: every service, equipment, activity, and facility which has an economic, administrative, social or cultural function in a given human settlement (UN-Habitat, 2016).

6.2 Study limitations and recommendations for future research.

The study commenced with value-chain mapping of a priority crop, which was faced by inadequate data and some data inconsistency as the main limitations. This was in part influenced by unresponsiveness of some key informants coupled with a language barrier, thus the researcher had to rely on limited key informants. Moreover, spatial data limitations restricted use of some criteria, for instance regarding location of residential areas in relation to SEZs. Therefore, use of a reliable data infrastructure by government agencies would be useful in embracing innovations in technology to solve development problems. To echo the recommendations of Ruiz et al. (2012), the data limitations could be addressed by formalized data collection, storage, and sharing across government agencies, also to promote integrated planning of development initiatives from the various agencies.

As UNIDO (2015) observed, special economic zones can prevent or delay economic reforms rather than catalysing them, if they are not developed as part of broader strategic structural reforms. Hence, besides satisfactory locations and allocation of activities, further research could explore the contemporary and expected impacts of SEZs as part of broader national and regional strategies in SSA. Such impacts would range from emerging cluster effects, to local investment climate, and complementary regional economic growth. In the view of the developed decision support model, further research can be done on how such a model could add value to decision-making processes using different stakeholders.

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Appendices

Appendix I; Value chain mapping

a) Interview guide for key informants

[26]Purpose of the research

I am Emmanuel Mutwiri, a MSc student at ITC, University of Twente-Netherlands. I am conducting a MSc. research titled *Adaptation of Spatial Development Framework (SDF) Methods for Agricultural Value Chain Development*. The study seeks to understand and address the mismatch between agro-processing industries and spatial locations of agricultural commodity value-chain activities. The Irish potato value chain in the Northern Economic Specialization Area (ESA) districts (Burera, Nyabihu, Rubavu, Musanze & Gakenke) of Rwanda, will be used for the study.

In a few words, the SDF in Rwanda is a spatial decision support tool that aims to address gaps in strategic spatial planning by grounding approved policies in territorial realities, i.e. to invest in comparative advantages of specific regions for economic development.

The main research objective is to adapt the SDF methods for satisfactory spatial distribution of agro-industries, based on existing functions and policies. Value chain analysis will be conducted to identify spatial factors, which shall inform criteria to evaluate the locations of existing industries & industrial parks. The study outputs include a decision support tool, to be used by MININFRA after the research, to match suitable industrial park locations with the relevant value chain activities.

As a respondent in agro-processing sector, your participation will contribute immensely to achieving the above goals.

Kind regards,

Emmanuel Mutwiri

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[26] 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

Interview guide for MINICOM /MINAGRI Representative

What kind of activities are present in the Irish potato value-chain, as from production to consumption?

- **a.** Where are the geographic locations of the major activities? E.g. Markets, factories, production areas.
- **b.** Who determines these locations? / how were they determined?
- **c.** How are the operations managed, public/private, e.g. collection centres, factories, markets?
- **d.** How can I access detailed information on each link of the chain? / who can provide it?
- **e.** How is data managed on these activities, such as quantities per link?
- **f.** What kind of limitations are present at the various links? (list separately)
- **g.** What kind of solutions do you think can be applied?
- **h.** What is your opinion on the idea of a decision support model as earlier describes?

Additional questions for industrial infrastructure investment specialist

What kind of industrial activities are in place relative to Irish potatoes?

How were the special economic zones established, and sites selected?

Interview guide for Irish potato Union

Brief description of union, regarding name, establishment time, activities, and member-cooperatives.

1) How many cooperatives do you manage, and where are they located?
2) How were the spatial locations of the collection centres selected?
3) What quantities were collected per cooperative in 2019?
4) What proportions were sold to which markets in 2019?
5) What constraints and opportunities are experienced by the union?

Interview guide for Irish potato cooperatives

Brief description of cooperative, regarding name, establishment time, activities, and members.

1) How many collection centres do you manage and in which cells and sector are they located, and serve?
2) What were the quantities per collection centre in 2019?
3) How were the locations for the collection centres selected?
4) How does the potatoes reach the collection centre, and the market?
5) What proportions of potatoes are sold to which specific markets in 2019?
6) What constraints and opportunities are experienced by the cooperative?

Interview guide for processing companies

1) *Brief description of the company. e.g. establishment date and activities engaged in.*
2) List sources of raw Irish potatoes and quantities per source in the year 2019 (*any additional support documents can be attached, farmers' names are not necessary, but cell and sector locations are.)*

   What reasons made you to prefer these sources/suppliers?

3) *Factory(ies)*
   a. *Name cell and sector locations of factories*
   b. *What factors influenced selection of these specific geographic locations? (list in order of importance)*
   c. *What quantity is produced per unit of time (day/week/month)*
   d. *What are the average monthly costs for processing a unit of potatoes (e.g. ton)?*
      i. *Electricity*
      ii. *Labor*
      iii. *Water*
      iv. *Transport to factory and to distribution centers*
      v. *Raw Irish potatoes*
      vi. *Other input materials (oil, salt, flavors etc.)*
      vii. *Rent/land rates*
   e. *What quantity of crisps is produced per unit (ton) of Irish potatoes?*
4) *Distribution*
   a. *Cell and sector locations of distribution centres*
   b. *Factors that influenced the spatial locations*
   c. *Quantities taken to each distribution centre / supermarkets/ institution/ others*
5) *What constraints are experienced at the various steps of;*
   a. *Raw material acquisition*
   b. *Processing*
   c. *Distribution and marketing*
   d. *Other?*
6) *How do you address the constraints?*
7) *What opportunities or plans does the company have in relation to development in the potato sector?*

b) Data collected

Fully acquired *Partially* *None*

Table 8; Overview of data collected

Data required	acquired?	Source	Constraint/Gap	Not acquired? contingency
District Irish potato production statistics for 2019	2019 Annual agricultural production report and table	National Institute of Statistics Rwanda. (Statistical reports)		
Sector /cell/ cooperative Irish potato production statistics for 2019 in the 5 districts	Production per Sector data acquired for Nyabihu and Musanze (Fig. 3)	District agronomists in Nyabihu and Musanze.	Production per Sector data not availed for Burera and Rubavu. Gakenke is not considered a high production area by MINICOM or have significant I. Potato priorities in DDS.	Estimate the 2019 production statistics using the proportions of harvested area per sector in Rubavu and Burera districts. *Gakenke district excluded;*
	Production per cooperative (and serviced cells) data acquired for Nyabihu, Rubavu and Musanze districts	IABINYA, RAPORO and UCOOPAMU Unions respectively.	Production per cooperative/ cells not available for Burera districts	Estimate the 2019 production statistics using the proportions of harvested area per Sector. (*see formula below table*)
Proportion/quantity of Irish potatoes per use	Percentage of Irish potatoes per use, at National scale	National Institute of Statistics Rwanda. (Statistical reports)	Only available at generalized National scale	Use the available data from NISR statistics report,2019, to estimate quantities per use/ function in the value chain
Quantities in and out of Kigali Irish potato wholesale market	No data		Unsuccessful attempts to get a response from City of Kigali authority. They oversee	

			operations at the market.	
Quantities in and out of the processing industries, sources, and destinations, respectively.	Supply quantity estimate and respective suppliers to Nyabihu CPC Distribution proportions and destinations from Hollanda Fairfoods Ltd.	Nyabihu Community Processing Centre (CPC) manager Sales representative, Hollanda Fairfoods Ltd.	Data on production costs and more statistics not yet availed No data received about raw materials acquired and their sources, or production costs.	

Estimation of production per sector and cooperatives

Estimated Harvested area/sector = total harvested area[27] *(arable land in sector/ total arable land)[28]
Estimated Production per sector= (estimated harvested area per sector / total harvested area) * total production in the district
Estimated Production per cooperative[29]= (estimated production per sector*65.87%) / total number of cooperatives in the sector

[27] Source; NISR 2019 agricultural survey report
[28] Source; Land use data from Rwanda Land Use management Authority.
[29] Only done for Burera district since cooperative data was not available. Assumption: production is distributed equally in all cooperatives in the sector. 65.87% represents the proportion of harvest sold (NISR, 2019).

Spatial constraints and opportunities experienced along the value chain?

Table 9; Opportunities and constraints experienced along the Irish potato value chain (Source, Key informant interviews and DDS)

CONSTRAINTS	OPPORTUNITIES
Lack of storage facilities and cold rooms at collection centres	Ongoing construction of storage rooms through support from MINAGRI. Cold rooms could help extend the shelf life of the potatoes.
Market overflow during peak harvest periods	Cleaning and packaging potatoes in mesh bags by the cooperatives (e.g. 5kg, 10kg,15kg) could help capture more clients and reduce rotting.
Changing weather trends and crop diseases affecting production	
Topography affects accessibility of collection centres by farmers	
Some roads are in poor condition, especially in rainy seasons	Planned projects to improve quality of feeder roads
The cooperative leaders need to travel far to get clients; wholesale market (Kigali) and other districts,	Use of technology, e.g. a union website where clients can place orders before and during harvest periods.
Political tension with neighbouring Burundi and Uganda limited international trade.	Rwanda as a member of East Africa Community has potential benefits for export and import trade.
Processors	
Market for processed crisps is mainly in Kigali city, less market demand in other towns	Prospects of spreading to other markets. Nyabihu CPC; diversification of products -French fries for restaurants and flavoured crisps Hollanda; Spread to other East African nations (*currently in Rwanda and Uganda*)
Low supply and higher prices of *Kinigi* variety of potatoes; they are considered best for processing	Hollanda; Cheap labour since their location is far from the city

c) Detailed value chain map of irish potatoes in the study area.

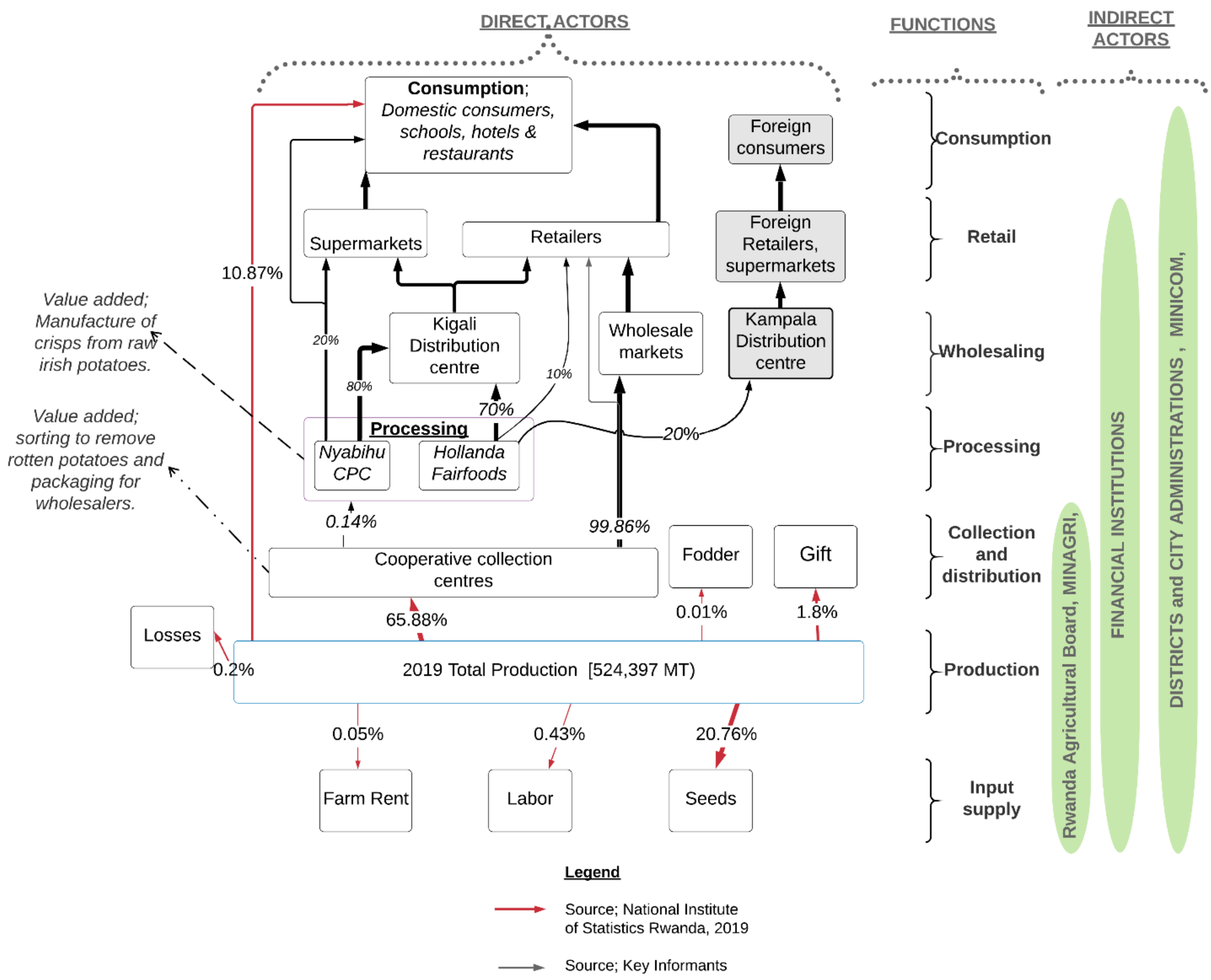


Figure 20; Flow map of Irish potatoes, showing direction of product flow after production to consumption.

Appendix II; Data sources

Table 10; Overview of data types used, their format, source, and date of acquisition.

Data type	Format	Date of data acquisition	Source
1. To identify spatial constraints and opportunities across an agricultural commodity value-chain			
Agricultural production statistics, 2019	Spreadsheet & report	September 2019	National Institute of Statistics Rwanda
District development strategies, Rwanda	Reports	September 2019	SDF project database
Locations of Irish potato collection centres, markets, crisps industries.	Key informant interviews	February 2020	Commodity value chain trade office.
Irish potato production statistics-District, sector & cooperative level	Spreadsheet	February & March 2020	NISR, District agronomists, Irish potato farmers Unions
Irish potato value chain spatial constraints and opportunities	Key informant interviews	February & March 2020	Key informants
2. To evaluate suitability of existing industrial parks			
Factors for spatial locations of existing I. Potato value chain activities	Key informant interviews	February & March 2020	Key informants
Policy recommendations for site selection of industrial and industrial parks.	Reports	March 2020	Rwanda Special economic zones policy, 2018. Rwanda land use planning Guidelines,2017.
3. To design a decision-making tool to match suitable agro-processing sites and their demand.			
Industrial parks locations	Shapefiles	Feb 2020	Rwanda Land Management and Use Authority (RLMA)
Slope/ DEM	Raster	Feb 2020	RLMA
Roads Rivers, wetlands, administrative boundaries, electricity, and water supply,	Shapefiles	Feb 2020	GIS Department, MININFRA

*Key informants used; Food crops production specialist (MINAGRI), Industrial infrastructure policy specialist (MINICOM), commodity trade value chain specialist (MINICOM), Private Sector Federation representative (agriculture chamber), IABINYA union president (Irish potato union), 3 Irish potato cooperative representatives and Hollanda Fairfoods sales representative (Irish potato crisps industry).

Appendix III; Strategic planning model details

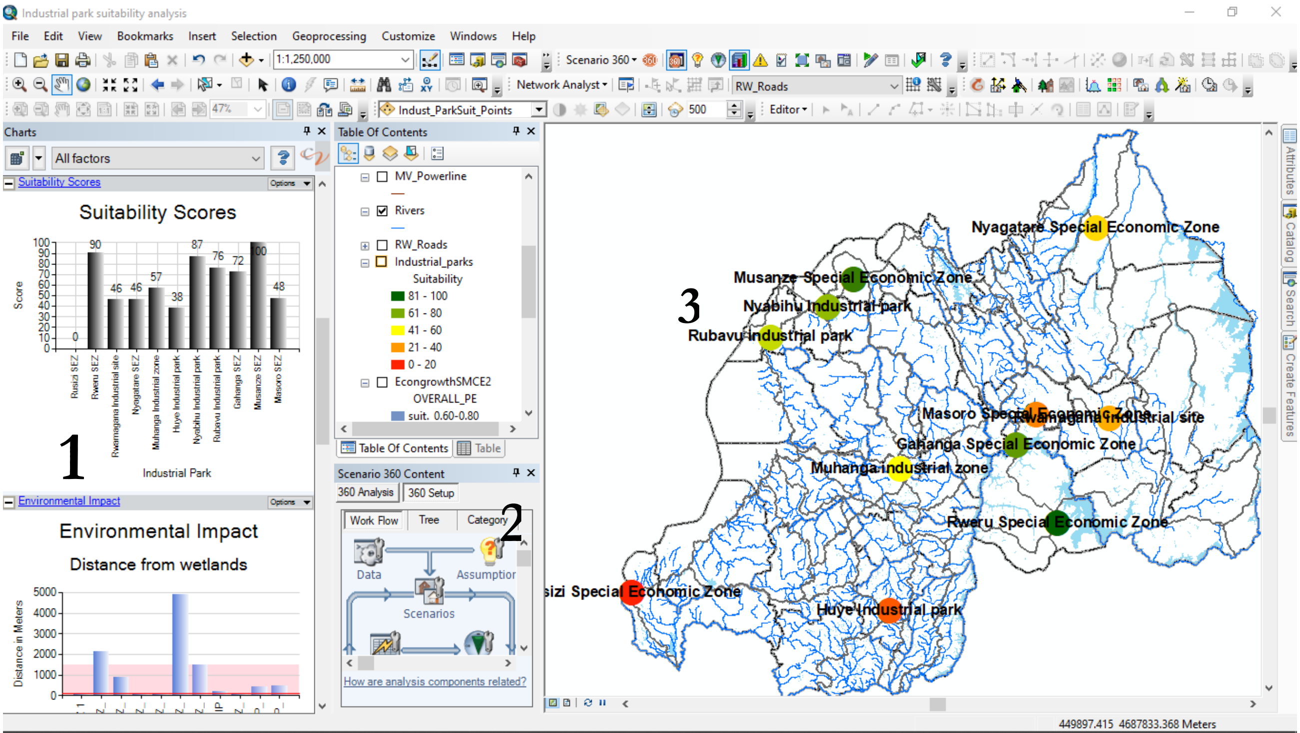
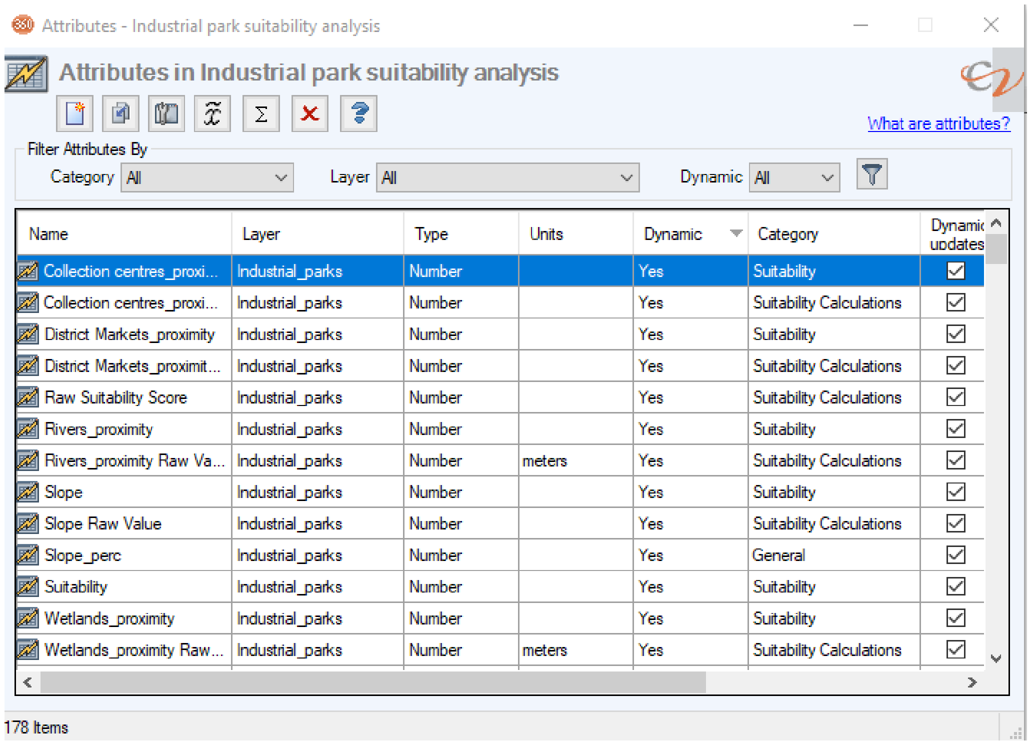


Figure 21; Model user interface in ArcMap ; 1)Impact assessment charts, ;2) Community Viz analysis and setup window,; 3) ArcMap data view interface showing suitability of the industrial parks



Name	Layer	Type	Units	Dynamic	Category	Dynamic updates
Collection centres_proxi...	Industrial_parks	Number		Yes	Suitability	☑
Collection centres_proxi...	Industrial_parks	Number		Yes	Suitability Calculations	☑
District Markets_proximity	Industrial_parks	Number		Yes	Suitability	☑
District Markets_proximit...	Industrial_parks	Number		Yes	Suitability Calculations	☑
Raw Suitability Score	Industrial_parks	Number		Yes	Suitability Calculations	☑
Rivers_proximity	Industrial_parks	Number		Yes	Suitability	☑
Rivers_proximity Raw Va...	Industrial_parks	Number	meters	Yes	Suitability Calculations	☑
Slope	Industrial_parks	Number		Yes	Suitability	☑
Slope Raw Value	Industrial_parks	Number		Yes	Suitability Calculations	☑
Slope_perc	Industrial_parks	Number		Yes	General	☑
Suitability	Industrial_parks	Number		Yes	Suitability	☑
Wetlands_proximity	Industrial_parks	Number		Yes	Suitability	☑
Wetlands_proximity Raw...	Industrial_parks	Number	meters	Yes	Suitability Calculations	☑

178 Items

Figure 22; Spatial indicators as dynamic attributes of the industrial parks layer.