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GIS-based optimal localisation of beekeeping in rural Kenya

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Contents: Page

List of images		vii
List of boxes		vii
List of tables		vii
List of figures		viii
Acronyms		ix
Preface		x
Acknowledgements		x
Abstract		1
Keywords		1
Chapter 1 - Introduction		1
Chapter 2 - Background		3
2.1	Context and theoretical framework	3
2.2	Study area	6
Chapter 3 - Methodology		11
3.1	A philosophical background	11
3.2	Geographic Information Systems and Multi-Criteria Evaluation	11
	3.2.1 GIS definition	12
	3.2.2 MCE definition	12
3.3	Flowchart research methods	13
3.4	Data collection	14
	3.4.1 Honey Care Africa Geo-database	15
3.5	The MCE and the steps of the analysis	17
	3.5.1 Definitions	18
	3.5.2 Data Modeling	20
	3.5.2.1 Establishing criteria and factors	20
	3.5.2.2 Distance tools	20
	3.5.2.3 Standardizing	22
	3.5.2.4 Weighting and normalisation	24
	3.5.2.5 Weight Sum Overlay	27
	3.5.3 Suitability	28
	3.5.4 Accuracy of the analysis	30
Chapter 4 - Results		33
4.1	Turkana	33
4.2	Samburu	35
4.3	Trans Nzoia	36
4.4	Nakuru	38
4.5	The south - The Masai Mara Reserve and Amboseli National Park	40

Chapter 5 - Discussion 43
5.1 The reliability of the results 43
5.1.1 Turkana 43
5.1.2 Samburu 44
5.1.3 Trans Nzoia 44
5.1.4 Nakuru 44
5.1.5 The south - The Masai Mara Reserve and Amboseli National Park 44
5.2 The conceptual model 45
5.3 The environment and the selection of relevant variables 49
5.4 The socioeconomic variables 51
5.5 Shortcomings and solutions 56

Chapter 6 - Conclusions 59

References 61
Appendices 69

List of images*

Photo 1: Honey Care honey Acacia type.

Photo 2: HCA bee-hive nearby Thika.

Photo 3: Small farm (15 hectare) tea plantation

Photo 4: House at a village near Lake Baringo

Photo 5: Honey collection at a village center near Lake Baringo

Photo 6: Traditional hive hanging at HCA's office in Nairobi

Photo 7: Traditional hive hanging from a tree nearby Lake Baringo.

Photo 8: Small farm (15 hectare) tea plantation

Photo 9: Langstroth hive hanging from an avocado tree at small field (5-10 hectares)

Photo 10: Agro-industrial enterprise - Avocado plantation, nearby Thika

Photo 11: Agro-industrial enterprise - Macademia plantation, nearby Thika

**All photographs were taken by the author of this paper unless indicated.*

List of boxes

Box 1: Flowchart of the research methods

Box 2: The fundamental scale of absolute numbers

Box 3: Calculation of the *Consistency Ratio*

Box 4: Illustration of *Sum Weight Overlay* calculation

List of tables

Table 1: Standardisation of criteria

Table 2: Pairwise Comparison Matrix

Table 3: Pairwise Comparison Matrix Sum Calculation

Table 4: Weight calculation after Pairwise comparison Matrix

Table 5: Table showing the values for the Random Consistency Index (RI)

Table 6: Table showing FAO's classification for Mozambique

List of figures*

Figure 1: HCA's distribution of beekeepers in Kenya.

Figure 2: Selected study area, Rift Valley, Kenya.

Figure 3: Study area districts Rift Valley

Figure 4: Study area Roads Rift Valley

Figure 5: Rift Valley, Cost distance to towns.

Figure 6: Rift Valley, Cost distance to protected areas.

Figure 7: Map resulting from the Weighted Sum Overlay Rift Valley

Figure 8: Suitability map of southern Turkana with high suitable Villages.

Figure 9: Detailed map with villages and high suitability areas at Samburu district.

Figure 10: Detailed Suitability map Trans Nzoia.

Figure 11: Suitability map Trans Nzoia without details.

Figure 12: Detailed map of suitability around the Lake Nakuru National Reserve where high suitable villages are located and labeled.

Figure 13: Map showing suitable villages in the Londiani area. The map shows the concentration of small crop fields and closed forest.

Figure 14: High suitability in the south of the study area.

Figure 15: Detailed maps of high suitable areas and villages.

**All maps were made by the author with ArcMap GIS Esri*

Acronyms

AHP	Analytical Hierarchy Process
BoP	Base of the Pyramid
CBFM	Community Based Forest Management
FAO	Food and Agriculture Organization (United Nations)
GDP	Gross Domestic Product
GIS	Geographic Information Systems
HCA	Honey Care Africa
IFPRI	International Food Policy Research Institute
IMF	International Monetary Fund
MCDA	Multi-criteria Decision Analysis
MCE	Multi-criteria evaluation
NGO	Non-governmental Organization
NTFP	Non Timber Forest Product
OECD	Organization for Economic Cooperation and Development
REDD	Reduction of Emissions Due to Deforestation
SDSS	Spatial Decision Support System
UN	United Nations
UNDP	United Nations Development Program
UNEP	United Nations Environmental Program
WB	World Bank

Preface

Honey Care Africa (HCA), to whom I am infinitely grateful, has served as a source of inspiration, and practical ground for the design and application of this research. Accordingly, the present research project has taken into consideration some of HCA's interests and goals. However, the design, development and results of this research do not represent neither HCA's official organizational profile nor its commercial and social strategies.

Acknowledgements

I would like to start thanking Honey Care Africa for sharing their knowledge, expertise and thoughts in an open and unconditional manner. Special thanks to my good friend Julio de Souza and his beautiful family, who's help, whether in Rwanda or Kenya, made this project possible.

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To my companion and my sons, for their infinite patience and understanding through the long hours I needed to fulfill this -personal- project.

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Abstract

A Geographic Information System (GIS) based multi-criteria site suitability evaluation provides the means to locate potential beekeepers in rural Kenya. The criteria considers specific environmental and socio-economic variables. The resulting location suitability maps consider several scenarios where environmental variables aim to favour the location of beekeepers close to protected areas and forests, while socio-economic variables target isolated villages, and small farmers.

Keywords

GIS based multi-criteria evaluation, beekeeping, poverty alleviation, forest preservation.

Study subject

Optimal localization of beekeepers with help of a GIS based multi-criteria site suitability evaluation.

Chapter 1 - Introduction

Honey Care Africa (HCA), a Kenyan based Non-Governmental Organization (NGO), is in need of a methodic approach regarding the location of potential new beekeepers in rural Kenya. The location of beekeepers needs to attend specific socio-economic and environmental variables. On the one hand, beekeeping should be an economic activity which helps lifting local rural populations out of poverty. On the other, beekeeping should contribute to preserve the local and regional eco-systems.

The present study subject and research realm takes HCA's decision-problem as an inspiration. Hence, the study subject comprehends the overlap of social and environmental variables necessary to locate beekeepers in Rift Valley, Kenya. This overlap has a geographical relevance, and therefore the convenience of the use of Geographic Information Systems (GIS) in the project. Moreover, the fact of dealing with spatial decisions determined by preferences, judgements and conflicting criteria, justifies the integration of a Multi-Criteria Evaluation (MCE) to the analysis.

On the one hand, fostering beekeeping helps the development of a sustainable economic activity that could help the locals to preserve the natural forest. As a non timber forest product (NTFP) honey production can be used as an alternative source of income, and a deterrent to extractive unsustainable practices.

On the other hand, the study aims to contribute with poverty alleviation, and therefore targets small poor rural communities where beekeeping could be a sustainable economic activity, and an important contributor to household income. Therefore, those variables are also relevant to the assessment of potential areas/candidates for honey production.

Hence this study provides a tool and a method to acquire a broad scale (National, Province level) understanding of which locations in rural Kenya fulfill the criteria for beekeeping. In order to identify these potential areas the study considers many relevant variables. This broad scale perspective serves as a preliminary overview of potential locations.

Moreover, this research aims to provide an alternative methodology for the location of beekeepers in rural Kenya at a primary stage. The objective of the method is to aid Honey Care Africa and simile organisations with a GIS-based MCE. The GIS-based MCE will enable these organizations to have a quick overview of the potential areas for beekeeping in rural Kenya considering specific variables. For the case of this research those factors are socio-economic and environmental.

Thus, the main goal of this research -and hopefully its contribution- is to help improving the decision making process of location suitability of beekeepers. Henceforward the analysis could serve as a conceptual model for the location of collection centres, organization and selection of target groups, and evaluation of their environmental context/constraints and socio-economic reality. These and other challenges demand a thorough knowledge of the local and regional context. This study in general and its conceptual model in particular will serve as a starting point to the systematization of this knowledge.

The text is organised in six chapters being chapter one its Introduction. Chapter two introduces the background of this research, its theoretical framework and institutional context, and describes the study area and its particularities. Chapter three presents the methodology. Therein the GIS and MCE procedures are described, discussed and analysed. The results of the research are presented in chapter four, and discussed in chapter five. Conclusions are presented in chapter six.

Chapter 2 - Background

2.1 - Context and theoretical framework

During the last decade of development work various stakeholders have been working under two assumptions. First, that participatory methods are a crucial element regarding any attempt to work with development and poverty alleviation (Osmani 2008, Cornwall & Brock 2005). Participatory methods will in this respect serve as a real communication channel, where the groups can express their needs, expectations, and concerns. At the same time the direct participation of the target group in the design of the development projects will help them to achieve consensual solutions for the common interest. Hence, participatory methods are a decision making instance where locals exert their right to express and decide over their own problems.

The second assumption, is the idea that there is room to make business at the Base of the pyramid (BoP) (Wheeler et al. 2005). Here the pyramid is used as a metaphor that illustrates the distribution of people's participation in the economic cycle of undeveloped countries, where the majority of the inhabitants normally share little or almost not benefit from it. Thus, this theoretical point of view argues that with good practices, and appropriate business management approaches, the forces inherent to the market will provide the drive to lift small rural populations out of poverty, making them, at the same time, sustainable. The latter is of course yet open for discussion, and in fact scholars like Arora and Romijn (2012) have questioned the functionalist side of BoP approaches.

Furthermore, the United Nations Environment Program (UNEP) and the Development Program (UNDP) advocate for the integration of an eco-system management approach into the development projects in Africa specifically, and the World in general (UNEP 2011, UNDP 2013): "*Ecosystem Management places particular emphasis on integrating our needs with conservation practice, and recognizes the inter-connectivity between ecological, social-cultural, economic and institutional structures when developing solutions.*" (UNEP 2011: 14). This quote hits the core of the present research project.

According to the UN reports on environment, 75% of the labor force in Kenya is related to agriculture while 80% of the country is arid or semi-arid (Omiti et. al. 2009). Moreover, the whole sub-saharan African region is especially vulnerable to climate change due to endemic poverty and high grade of dependence on rain-fed agriculture (Oluoko-Odingo 2009). On the other hand, a number of scholars agree nowadays that aid policies directed from the developed world had made little or no impact on the living conditions of the people they aim to help (Kulundo 2007; Oluoko-Odingo 2009). The last official census in Kenya from the year 2009 indicates that 46% of its population is poor (Kenya National Bureau of Statistics 2009). Accordingly in Sahn & Stifel's *Poverty Comparison Over Time and Across Countries in Africa* (2000), the scholars found little or no progress of the main poverty indicators in Kenya.

Thus, more permanent and sustainable solutions must be designed and implemented. Permanent in the sense of making possible for local populations to rely on solutions that are not dependent on foreign aid, but could come instead from their own initiatives, creativity, and independent generation of resources. Sustainable in the sense of seeking prosperity while securing their future, preserving their natural environment, economic resources and culture.

Moreover, from the above mentioned literature we can conclude that Kenya's high vulnerability to climate change calls for an immediate action that will attempt to secure the existing resources and their future management. Accordingly beekeeping has been a key player within development programs in several occasions during the past decades (Albers 2011). The important role bees and beekeepers play in the conservation of the environment, while providing a relatively constant and reliable income for the local groups, is well documented in the development literature. This study has taken as a reference examples from Ghana (Appiah et al. 2007), Malawi (FAO 2000, Mkanda 1994, Munthali 1992) and Tanzania (Albers 2011). A common line through these projects is the utilization of beekeeping as an economic alternative to forest extractive practices.

HCA is a Kenyan based non-governmental organization that has been working in this country since 1997. HCA has as its mission *"to partner small farmers across East Africa in order to strengthen income and growth through sustainable beekeeping"* (http://honeycareafrica.com/about-us/vision/ Nov. 2014). The organization has a considerable experience within social enterprise, targeting small farmers and providing them with technical and financial support. The picture below (*Photo 1*) shows one of HCA's finished products ready for delivering and further retailing.

Photo 1: Honey Care honey, Acacia type. Picture property of HCA.

HCA follows a so called tripartite model where local rural communities, the private sector, and organizations from the development sector work together. The goal of this model is to generate partnerships, synergies, that will contribute to find sustainable solutions to poverty (Wheeler et al. 2005). Furthermore, behind this model lies the believe that there is still room for business at the base of the pyramid (BoP). Thus, Honey Care Africa aims to converge elements within the system in order to lift rural populations out of poverty. However, HCA's management goal is to depend on its own capacity to generate resources and profit from its activities. In other words HCA follows a for-the-poor for-profit model.

HCA is concentrated in west Kenya and looking to expand to other regions. In the map presented below (*Figure 1*) it is possible to appreciate HCA's current distribution of beekeepers in Kenya. A pro-poor pro-profit venture, could play an important role developing sustainable agriculture across African countries, but it faces several challenges. Hence, like any other commercial enterprise HCA needs profit in order to survive. To secure business viability HCA needs to achieve a high level of efficiency in its decision making processes. Accordingly the location of potential beekeepers in rural Kenya is one decision of crucial significance.

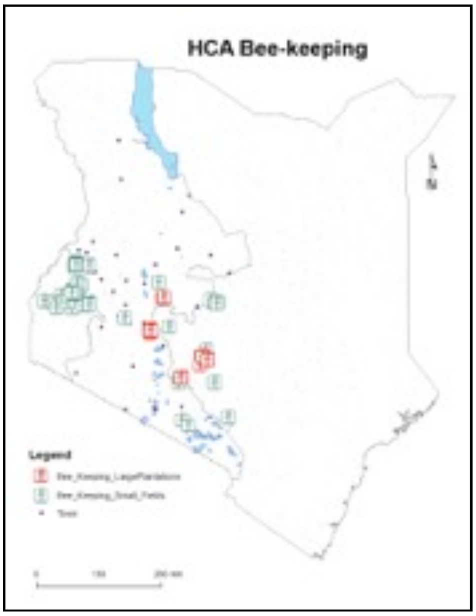


Figure 1: HCA's distribution of beekeepers in Kenya.

Photo 2: HCA bee-hive nearby Thika.
Source of picture: personal archive fieldwork.

2.2 - The study area

The study area covers the former province of Rift Valley, Kenya (see *Figure 2, 3 and 4* below). The study area was selected and limited due to practical reasons. The consideration of a larger area would demand considerably more efforts for gathering data, field visits and literature review. Therefore, the method applied for the selection of suitable areas in this area should, in its logic, work for the rest of the Kenyan territory. However, specific qualitative factors about different regions in Kenya might determine the reconsideration of weights, constraints, and/or inclusion or exclusion of certain variables.

Figure 2: Selected study area, Rift Valley, Kenya

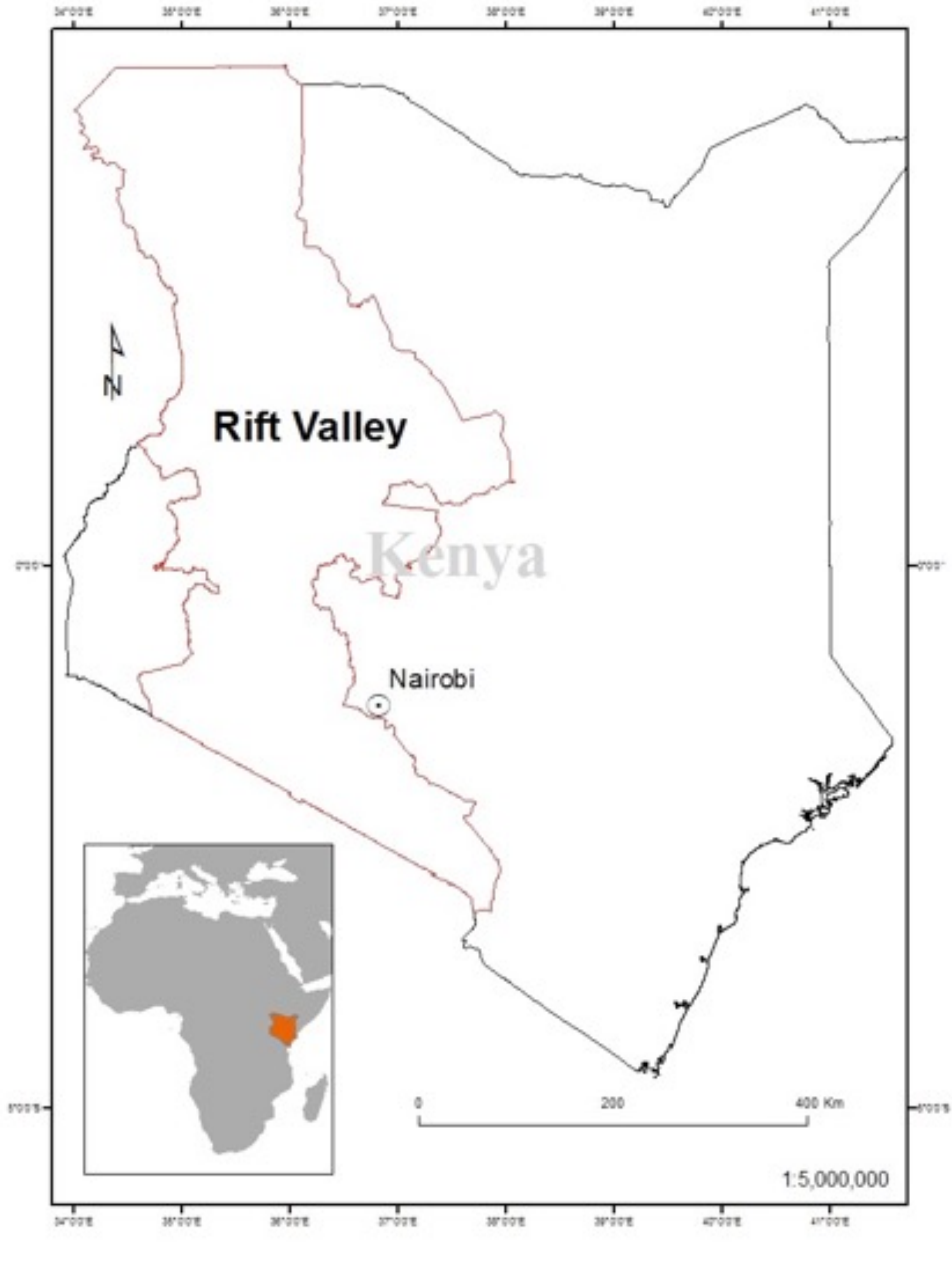


Figure 3: Study area districts Rift Valley

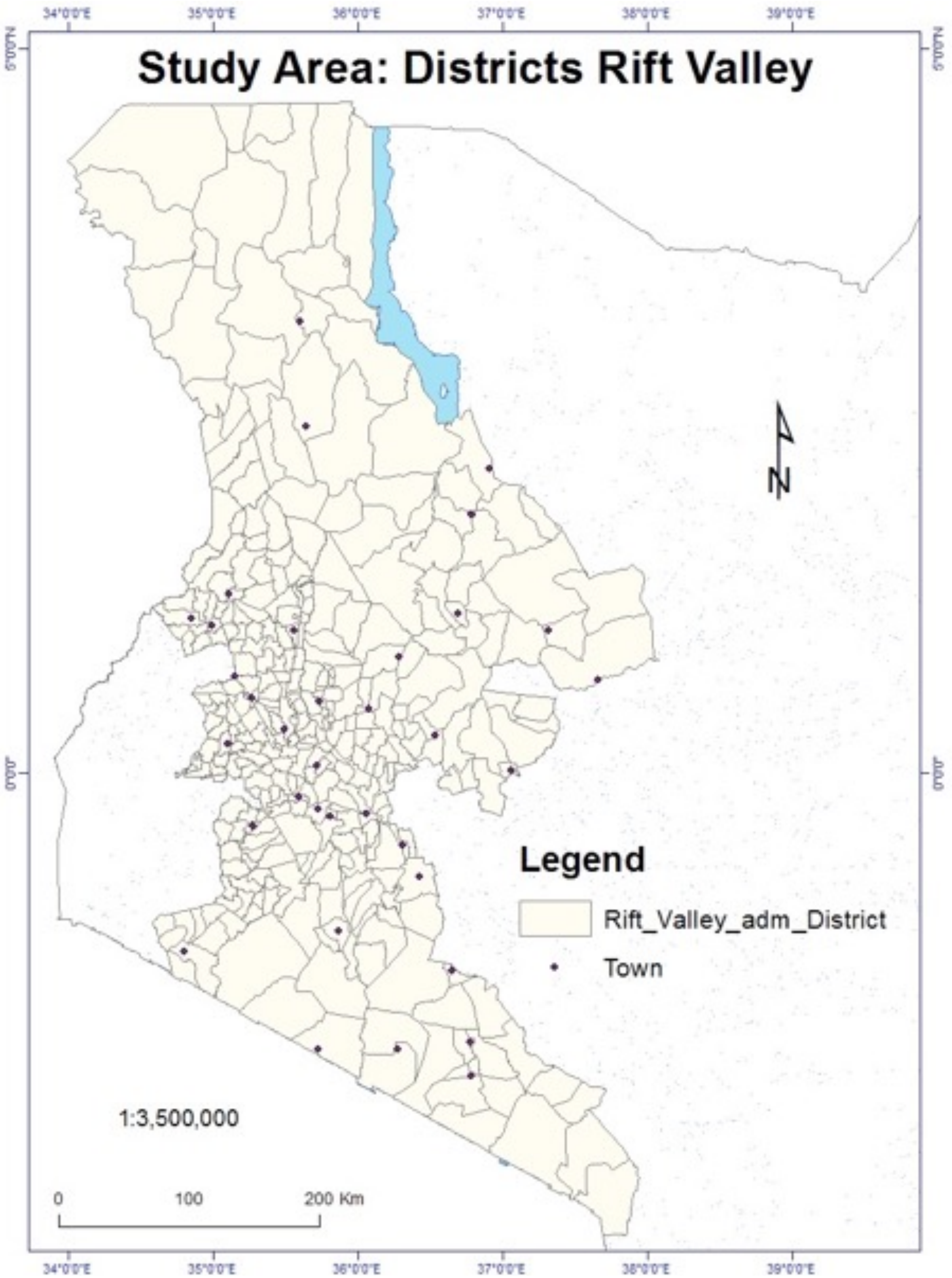
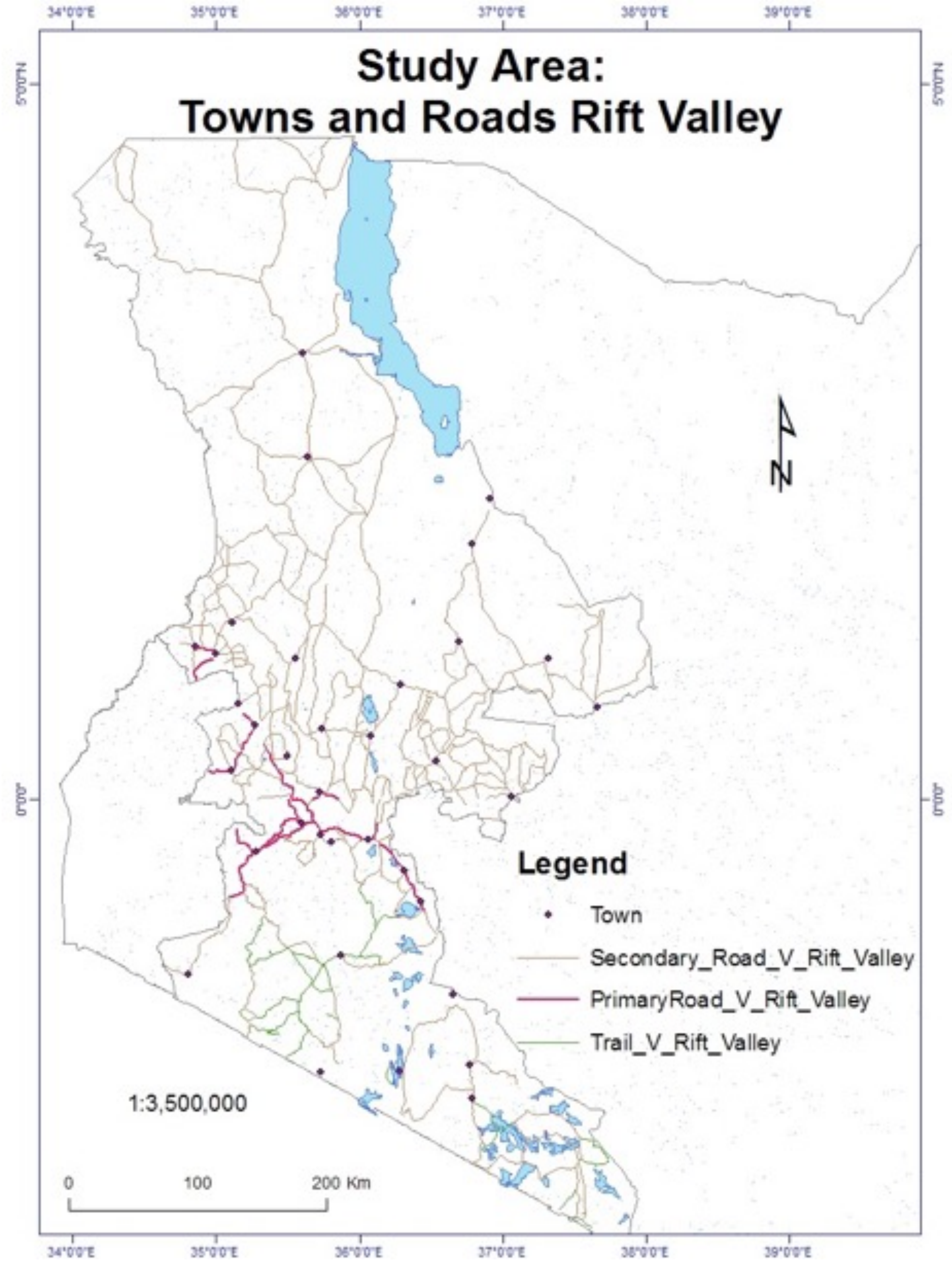


Figure 4: Study area Roads Rift Valley



As mentioned above, HCA has concentrated its activity in west Kenya, especially around the Kakamega forest. HCA is already active, although not in the same extent as in Kakamega, in the Rift Valley province too.

The former Rift Valley province covers an area of 183.383 square km and has a population of about 10 million inhabitants (KNBS 2014: Census 2009). The selected area has international borders to the south with Tanzania, to the west with Uganda, and to the north with Ethiopia and South Sudan. The Great Rift Valley, a geological fault, crosses the area from the south of Lake Turkana in the north to the border with Tanzania in the south.

The last Census (from 2009) shows that around 46% of the population of Kenya lives below the poverty line. Here poverty is based on World Bank's definition where income per capita is below US$ 1,25 a day. In districts located in the north of the selected study area this rate comes up to 85% (KNBS 2010).

The landscape in Rift Valley varies from drylands in the north to closed forest in the west. In its central part, west from Nairobi and the Central province, Rift Valley concentrates most of the agriculture activity. There are significant extensions of savanna with isolated forests scattered through the province.

Chapter 3 - Methodology

The chapter is organized in five parts. The first part explains briefly the philosophical background of the study's methodology. A defence of the selection of GIS and MCE as working tools is given in the second subdivision of this chapter. Next, in the third, a flowchart of the methodology is displayed and commented. The fourth part delves into the origin and particularities of the gathered data. In the fifth and final section of this chapter the analytical procedures of the methodology are presented.

3.1 A philosophical background

The overlap of social and natural conditions necessary for the optimal selection of the locations in rural Kenya, demands a none pure philosophical approach to the study subject. Hence, in the necessity for consideration and interpretation of the local discourses, subjectivity, idiosyncrasy, and culture, this research must be based in hermeneutics, and at the same time contemplate postmodern philosophical positions.

However, the fact that the consideration of optimal locations also involves natural phenomena determines a more empiricist approach, something closer to naturalism. Hence, an interesting and promising perspective towards the study subject lays in *Scientific realism.*

> *"Scientific realism is a positive epistemic attitude towards the content of our best theoriesand models, recommending belief in both observable and unobservable aspects of the world described by the sciences."* (Chakravartty 2011).

In other words this study intends to combine the most positivist aspects of GIS with the subjective and qualitative side of decision making. Accordingly, the conceptual model of the analysis is an expression of a multi epistemological approach.

3.2 Geographic Information Systems and Multi-Criteria Evaluation

As it was mentioned above, the present project has as its main goal to help organisations like HCA find the optimal location for beekeeping in rural Kenya. In order to achieve this goal the project uses a GIS based Multi-Criteria Evaluation (MCE). Combining GIS and Multi-criteria Evaluation will provide the decision-makers with a proto-Spatial Decision Support System (SDSS). Thus this SDSS based on GIS-MCE analysis could be used to assist decision-makers at HCA in particular and development organisations in general.

Already back in the last decade of the previous century Stephen J. Carver highlighted the advantages and possibilities of customized GIS-MCE systems (Carver 1991). Moreover, Carver argues that GIS-MCE analysis provides a more rational approach to site location (Carver 1991). In this respect Malczewski refers to GIS and Multi-Criteria Decision Analysis as converging into complementing paradigms where GIS is currently characterized by a user-oriented technology with a strong focus in participatory approaches (Malczewski 2010: 380). The components of MCDA like value scaling, criterion weighting, and decision rule and criteria combination, enhance GIS analytic adeptness (Ibid: 380). At the same time, it moves GIS away from its most positivistic side by introducing opinions of experts and stakeholders for the definition of the criteria.

The type of integration of GIS and MCE in this study is called *loose-coupling*, where GIS and Multi-Criteria are exchanging data in order to perform the analysis, yet they remain independent of each other (Malczewski 2010: 383). In other words the conceptual model does not provide a *tight-coupling* approach where both systems could communicate through a common interface.
Furthermore the loose-coupling integration type in this study is regarded as unidirectional integration, with GIS being the principle software.

3.2.1 Geographic Information Systems definition

GIS could be defined as "...computer based systems specially designed and implemented for two subtle but interrelated purposes: managing geospatial data and using these data to solve spatial problems." (Lo & Yeung 2007:2).

GIS is nowadays used within a wide range of disciplines. At a first glance GIS is a formidable tool to store and access spatial data (Eastman 1995). However, GIS is much more than a spatial database.
GIS can be used as an analytical tool. As such it facilitates access to existing data, while providing the means to combine it with knowledge of relations and processes (Eastman 1995). Thus GIS can provide a firm ground to test our analytical models and spatial decisions, and act in consequence.

3.2.2 Multi-criteria Evaluation definition

MCE, the approach chosen for this study, is an approach within Multi Criteria Decision Analysis (MCDA). MCE is sometimes referred to as Multi Attribute Decision Analysis (MADA) or Multi-Attribute Evaluation (Malczewski 2010; Kahraman 2008). In this approach the problem or subject of the analysis has a *specific single objective,* the location of the most suitable areas for beekeeping in former Rift Valley province. Accordingly, decision-making based on a MCE system is a frequent choice when the analysis has a specific objective and it deals with different variables and/or criteria (Eastman 1995).

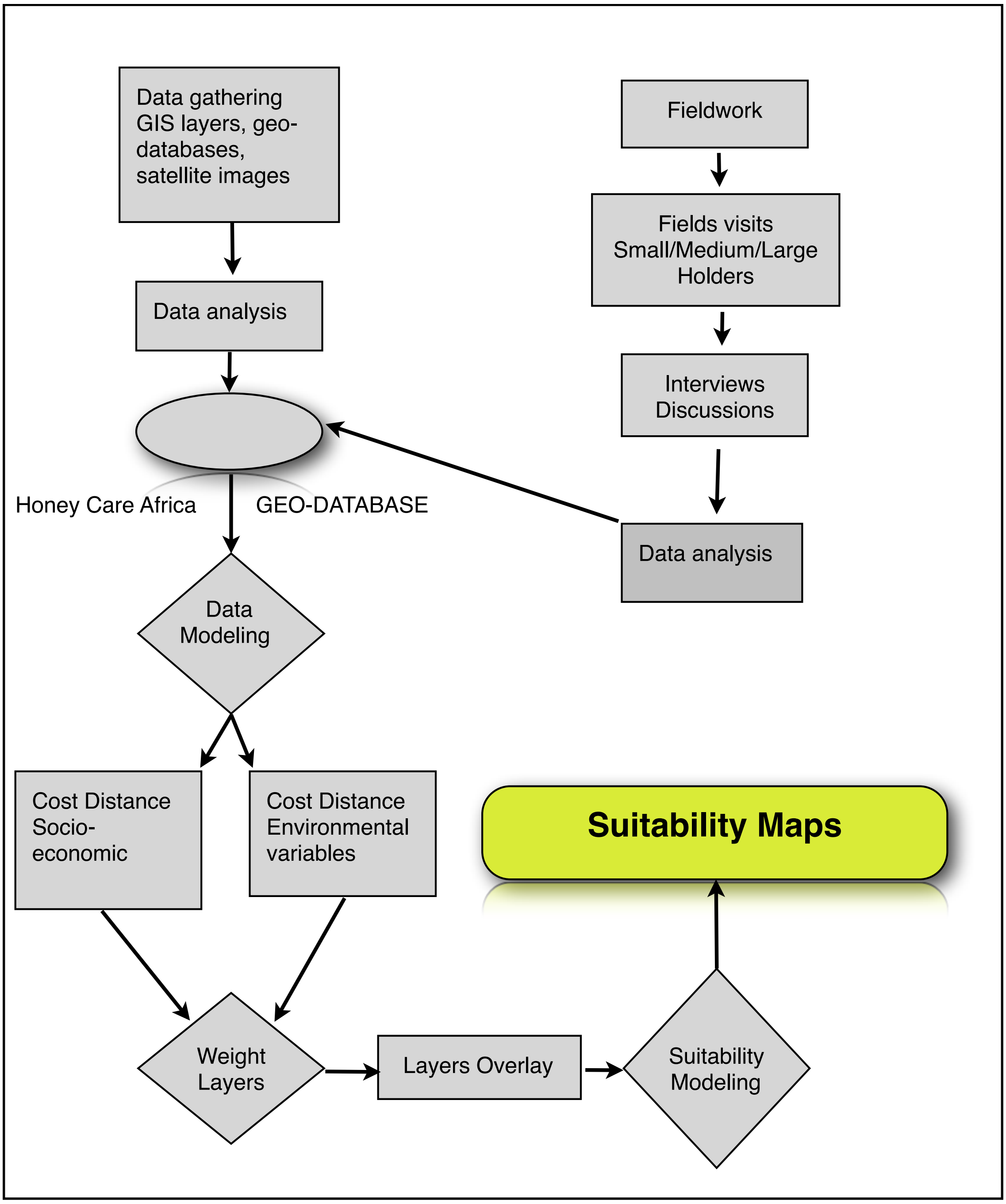
MCE facilitates decision making when we are confronted by an array of possible choices. When combined with GIS the criteria is often distributed in the space in an uneven manner and/or in eventual conflict to one another. A specific decision rule will determine the acceptable or optimal combinations of the criteria within a given area. In other words, to which extent a given location meets the requirements for suitability.

Abundant literature, scientific research and practical experience clearly expresses the virtues of combining GIS with Multi-Criteria Evaluation. The latter is a fact for urban and rural planning (Barredo 1999). In the last decades procedures utilizing GIS based MCE for decision making have been used for agricultural land use, residential locations and land suitability (Ibid), and the specific location of optimal areas for beekeeping as well (Estoque & Murayama 2010).

3.3 - Flowchart Research Methods

This section presents the flowchart of the research methods. The process of identifying potential locations for beekeepers in rural Kenya starts with the gathering of spatial data *(Data gathering)*. A more or less simultaneous search for optimal locations is conducted on the field. These *Fieldwork* visits will be used later as a control or validation tool. The visits to the field provide the research with a first hand impression of the variables chosen to run the analysis.

Furthermore, from this step on, all analysis, modelling and processing of spatial data, takes place within *Esri's ArcGIS* environment. The procedures and methodology of the analysis are explained in the following sections and this flowchart is meant to illustrate the logics and sequences of the study.



Box 1: Flowchart of the research methods.

3.4 - Data collection

This study uses mostly secondary data sources. However, important general observations, verifications and calibrations have taken place during fieldwork. Furthermore, HCA provided GPS coordinates of its current beekeepers. Those data were transformed from *cvs* files (comma separated values) into *shapefiles*. A *shapefile* is a non topological geometry file capable of storing attribute information relevant to the spatial feature (Esri 1998). Subsequently, two important features were generated: *Beekeepers big plantations* and *Beekeepers small farms*.

The datasets from which the analysis takes its input were mostly collected from the Food and Agriculture Organization of the United Nations (FAO) (http://www.fao.org/geonetwork/srv/en/

main.home). This site was a referent source where to collect spatial data and literature. Another important source of spatial data was the World Resources Institute (www.wri.org).

Most of the data gathered consists of aggregate data at a district level. Whether this factor is a limitation or not is difficult to affirm, yet the subject is topic of discussion in chapter 5. However, the design of this study has taken into consideration the type of data that were available in order to adapt its goals and procedures to it.

In the following segment of chapter 3 the reader will find a brief description of the spatial data utilized in the analysis of suitability. The main sources of spatial data for this study are FAO, WRI, and HCA.

3.4.1 Honey Care Africa Geo-database

Administrative borders (polygon): The administrative borders of Kenya were downloaded from the WRI spatial database (World Resource Institute, Kenya GIS data: http://www.wri.org/resources/data-sets/kenya-gis-data. Accessed July 1st 2013). Therein we can find all levels of national administrative limits, from country international to district border. All the maps in this study were made with the input of these attribute layers.

Agriculture (polygon): FAO's dataset (FAO's GEONetwork, The portal to spatial data and information: http://www.fao.org/geonetwork/srv/en/main.home. Accessed September 1st 2014). The data in this layer does not cover the whole Rift Valley province, but just the areas where concentration of agriculture is significant. We should bear in mind that the north and northeast areas of Rift Valley province are arid and semi-arid lands, where agriculture does not represent an important economic activity.

Forest (polygon): FAO's dataset (FAO's GEONetwork, The portal to spatial data and information: http://www.fao.org/geonetwork/srv/en/main.home. Accessed August 16th 2014). The most relevant and used attributes from this layer were: Closed trees on temporarily flooded land and Closed trees. Accordingly, this study follows FAO's *Closed forest* definition where trees must reach a minimum height of five meters, there is no presence of other land cover, and more than 40% of the area is covered by trees (FAO 2002).

HCA Beekeepers (point layer): This layer was generated from a cvs (comma-separated values) file delivered by HCA. The file was transformed into a *Shapefile* (.shp) for its further integration to the geo-database. The file contains essential information about current beekeepers working with HCA. Among this information we could highlight the presence of geographical coordinates, social and economic conditions of the household and the plot/area of habitat.

Roads Kenya (polyline): Source, WRI's dataset (World Resources Institute, Kenya GIS data: http://www.wri.org/resources/data-sets/kenya-gis-data. Accessed July 1st 2014). The most important attributes from this layer were *main road*, *secondary road*, and *trails*. The layer Road plays a substantial role in the identification of isolated locations within the study area, where distance/proximity to road was the main criteria. Furthermore, *Secondary roads* are specially significant to the analysis due to the prevalent extension of this attribute along the study area.

Towns (point layer): This dataset was downloaded from the WRI spatial database (World Resources Institute, Kenya GIS data: http://www.wri.org/resources/data-sets/kenya-gis-data. Accessed August 30th 2014). It was originally composed of two data-layers one with information about *Main towns* and another with information about *Other towns*. Registers for the study area were selected and later combined into one data-layer (Towns) for practical reasons. This is an important layer for the analysis, where distance to towns is deemed as an indicator of poverty derived from the lack of access to infrastructure and markets.

Land Cover (polygon): FAO's dataset for Kenya (FAO's GEONetwork, The portal to spatial data and information: http://www.fao.org/geonetwork/srv/en/main.home. Accessed September 1st 2014). This layer is very important as a source of data, but also for the control and calibration of general results. Furthermore, the layer is really valuable in the seek for a land cover/land use classification standard (LUCC). This layer has been generated by the *Africover* initiative, a FAO's led vast multi organization and inter disciplinary project which is part of Global Land Cover Network, (http://www.glcn.org/activities/africover_en.jsp. Accessed September 1st 2014).

Poverty indicators aggregate data district level (polygon): This layer was downloaded from the WRI, and is rather outdated (1999), (World Resources Institute, Kenya GIS data: http://www.wri.org/resources/data-sets/kenya-gis-data. Accessed September 1st 2014). However, it keeps its working-value due to the very little improvement in poverty conditions for Rift Valley in particular and Kenya in general during the past decade (See comments on Poverty based on Census data from 2009).

Protected areas (polygon): Dataset downloaded from FAO's database (FAO's GEONetwork, The portal to spatial data and information: http://www.fao.org/geonetwork/srv/en/main.home. Accessed July 2nd 2013). Relevant attributes for this study are Name Park/Reserve/area, and Area in square meters. This is a crucial datasource due to the fact that the definition of suitability for beekeeping in this study is dependent, among other variables, on proximity to *Protected Areas*. The definition and demarcation of a *Protected Area* is determined by the National Forest Act (2005), and the Kenyan constitution in general (Ministry of Environment, Water and Natural Resources 2014).

Slope (raster): Source layer downloaded from the WRI spatial database (World Resources Institute, Kenya GIS data: http://www.wri.org/resources/data-sets/kenya-gis-data. Accessed September 1st 2014). This is a raster layer generated from Kenya's digital elevation model at 90-meter resolution.

Villages (point layer): Layer indicating administrative unit the village belongs to, name of village, and geographic coordinates. This is an important layer regarding the expression of the results of the Multi-criteria Evaluation and the whole study. Our ultimate goal will be to generate a list with those villages which are suitable for beekeeping according HCA's development strategy. The villages located within the most suitable areas are listed in Appendix 1, (page 73).

Water bodies (polygon layer): Source WRI, (World Resources Institute, Kenya GIS data: http://www.wri.org/resources/data-sets/kenya-gis-data. Accessed July 1st 2013). Layer indicating location of water bodies within the study area. This layer was further rasterized and reclassified to 0 as valid value for all its surface. In this way water bodies will not be an expression of suitability when running the analysis. Moreover, this layer might be of more significance in the future when, for example, assessing site suitability at a larger scale.

3.5 - The MCE and the steps of the analysis

> "*Decision-making can be considered as the choice, on some basis criteria, of one alternative among a set of alternatives. A decision may need to be taken on the basis of multiple criteria rather than a single choice. This requires the assessment of various criteria and the evaluation of alternatives on the basis of each criterion and the aggregation of these evaluations to achieve the relative ranking of the alternatives with respect to the problem.*" (Bhushan et al. 2004: 12)

Some Multi Criteria Evaluations focus in selecting the suitable locations, while not paying attention to the areas that are not suitable or selected. An alternative to this are MCE which rank, order and evaluate the total area. The latter is the kind of analysis presented in this study.
As a preliminary approach to site suitability this study aims to inform about the situation of as much area as possible. The analysis evaluates the whole study area, where the value of each cell expresses a level of suitability. Furthermore, the study will use the generated suitability layer as a background or source for the identification of villages located within the most suitable areas (See a list of most suitable villages in Appendix 1).

MCE, steps of the analysis:

a) Problem definition: Identification of optimal location for beekeepers in Rift Valley, Kenya.
b) Determination of criteria:

1) Socioeconomic:
- Distance to towns, Rift Valley.
- Distance to roads, Rift Valley.
- Percentage of poor people per district, Rift Valley.
- Agriculture small fields/holders

2) Environment:
- Proximity to Protected areas in Rift Valley
- Proximity to Closed Forest

c) Standardization of criteria scores
d) Determination of weights for each layer/criteria with the *AHP* (Analytical Hierarchy Process) method
e) Aggregation of the criteria - *Sum weighted overlay*
f) Validation

3.5.1 - Definitions

Criteria

Criteria expresses one or more determinants chosen to take a decision. These determinants or criteria can be measured and evaluated (Eastman et al. 1995: 539). Eastman identifies two types of criteria: Factors and constraints.

Factor

A factor expresses varying degrees of suitability, it can enhance or reduce suitability. It is a continuous expression of suitability (Eastman et al. 1995). Thus, its most apt expression within the GIS and this study is a RASTER file.

A raster is a matrix organized in rows and columns, where a cell or pixel is a unit (http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?TopicName=What_is_raster_data%3F, accessed February 17th 2015). These cells have normally a value expressing information about the surface. The raster can express thematic or discrete data (such as landcover, land-use), continuous (data representing temperature, altitude, etc), or pictures (Ibid). The units of a raster are located by coordinates, using normally a cartesian coordinate system (Ibid).

Constraints

Constraints: a constraint will limit the alternatives under consideration (Ibid). It is a restriction and expresses absolute non suitable conditions. Normally constraints will be expressed by Boolean variables (Eastman 1995). Thus, using boolean variables gives no room to trade off or gradual suitability. The AND operation, for example, will express as non suitable an area if any of the criteria fails to reach the threshold of suitability. The UNION operation, on the other hand, will express as suitable any areas that manage the threshold in at least one criteria.

For the case of this study no constraints were directly defined. However, water bodies were rasterized and reclassified to "0" value, in order to run the analysis without this cells forming part of the suitability output. In addition to this, the definition of constraints regarding the proximity to agro-industrial areas was initially taken into consideration and later dismissed. The appropriateness of this decision is discussed in chapter five.

Decision rule

Decision making in a Multi Criteria Evaluation follows a decision rule. "*The procedure by which criteria are combined to arrive at a particular evaluation, and by which evaluations are compared and acted upon, is known as decision rule."* (Eastman et al. 1995: 540). The decision rule in this study is of the kind Eastman et al. (1995) described as a *Choice Heuristic. "Choice heuristics specify a procedure to be followed rather than a function to be evaluated"* (Ibid). It determines a set of features and their combination, a statement or procedure to follow in order to make a selection.

3.5.2 - Data Modeling

3.5.2.1 - Establishing criteria and factors

One of the basic principles of determining criteria is that it has to be measurable. In this section a general justification of the criteria selected for this study is provided. However, a more in-depth discussion of the pertinency of these decisions is to be found in chapter 5.

Out of the available data, layers expressing socioeconomic conditions and landscape are selected and modelled to accord the analysis' goals.

The socioeconomic variables are reduced to Distance to towns, Distance to roads, Percentage of poor population, and Small crop fields/holders.

For these criteria the aim is to be able to distinguish those areas where poverty is higher. The selection of factors follows the assumption that distance to markets, towns and infrastructure are determinants for isolation, and the consequently lack of access to basic needs such as health, sanitation, education, and economic resources. Moreover, small farmers are specially considered into the variables due to their particular need for alternative income.

The so called environmental variables have as its main goal to find suitable areas which are proximal to forests and protected areas. The importance of beekeeping as an alternative economic resource and a disincentive for extractive practices was already mentioned in the introduction.

3.5.2.2 - Distance tools - Cost Distance and Euclidean Distance

In this step of the analysis distance layers for the different criteria are generated. The *Cost Distance* tool is an instrument that calculates the least accumulate cost for each cell to the nearest source cell over a cost surface (ArcGIS Desktop 10 Tutorial: 2015). When no cost raster is used, the procedure is similar to the *Euclidean Distance.* The euclidean distance gives the distance from each cell in the raster to the closest source. Both tools are to be found in the *Spatial Analyst Tools* section of the ArcGIS 10.2 Toolbox. The goal with this procedure is to generate raster layers expressing distance to a source, such as *Protected areas, Towns, Roads,* and *Closed forest*.

Hence, the distances to the reference criteria will be used later as factors indicating grades of suitability.

Figure 5: Rift Valley, Cost distance to towns.

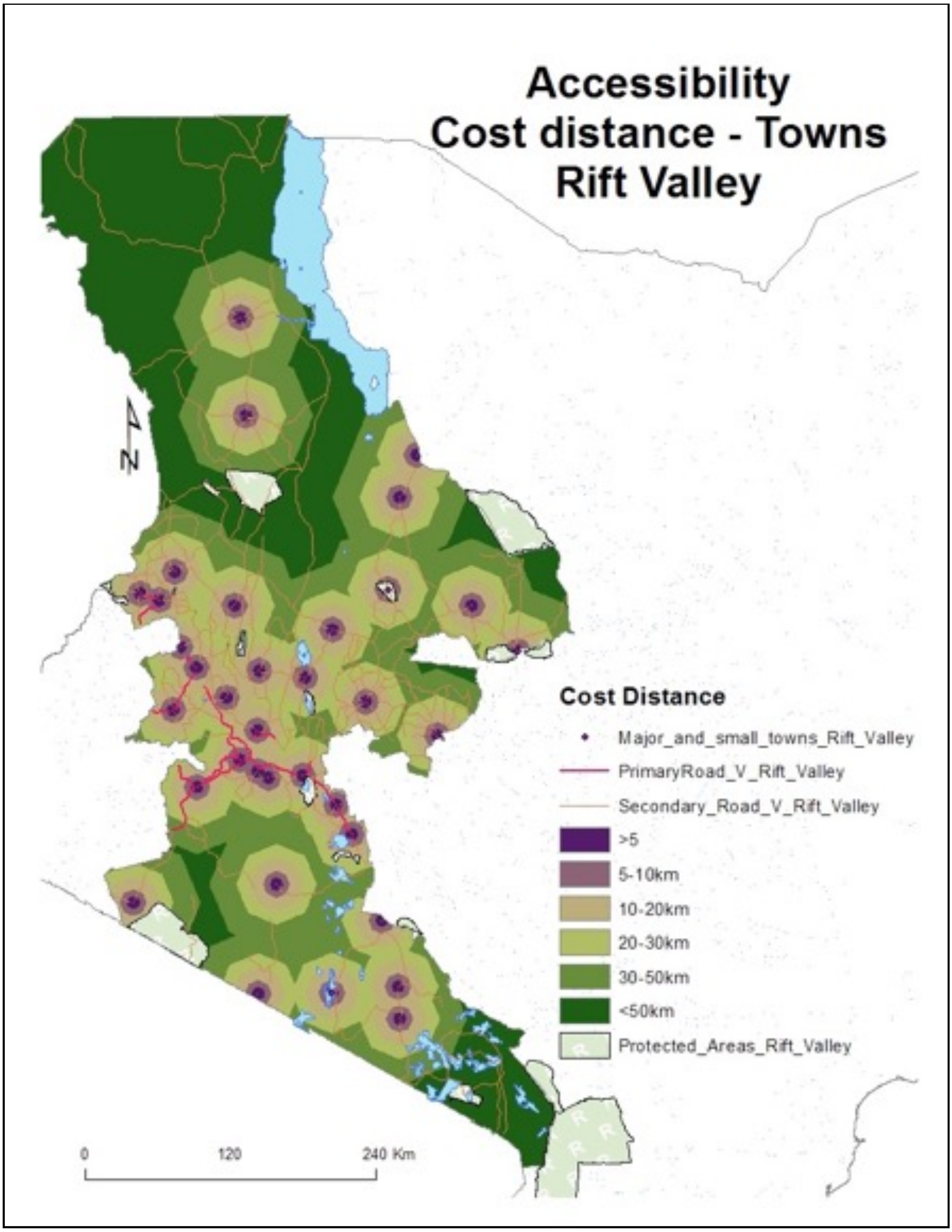
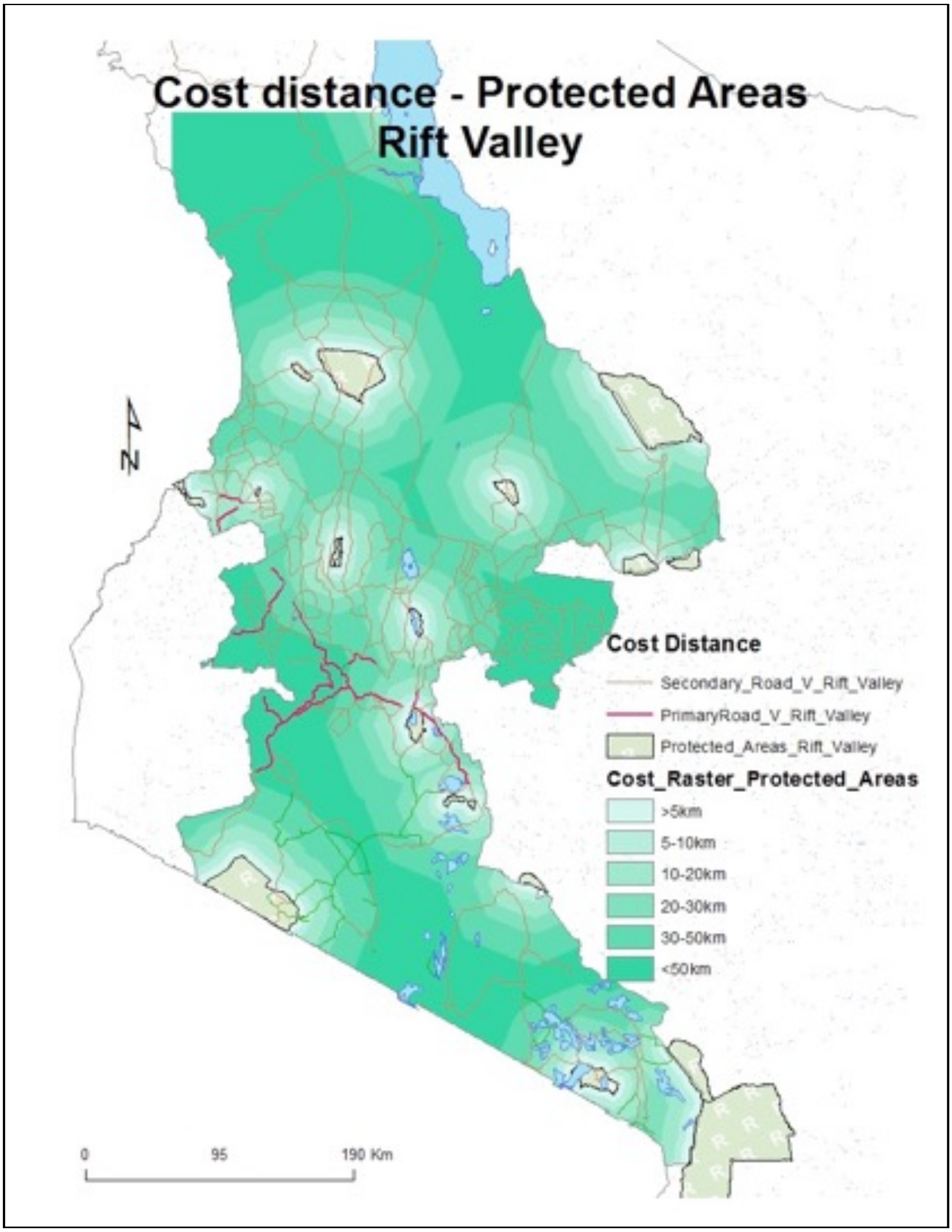


Figure 6: Rift Valley, Cost distance to protected areas.



3.5.2.3 - Standardizing

In order to be able to put together and consider different data layers and attributes the values have to be converted into a common scale. The process of converting different factors to a necessary common numeric scale is called *standardization* (Eastman citing Voogd 1983). The normal GIS procedure used to standardize the different layers is called Reclassification.

In ArcGIS 10.2, the software used in this study, *Reclassify* is a function available within the ArcToolbox, under the category of *Spatial Analyst Tools.* The tool allows you to reclassify or change the values in a raster layer.

This procedure will permit the further combination of factors expressed in the suitability equation explained in 3.5.3.

In this particular case standardization is not a very complex task due to the fact that four of the six factors are originally expressed in a common unit, kilometres. The consideration of the new values is based upon theoretical and empirical research in the fields of econometrics, geography and social development. Albers and Robinson (2011) analized villagers' spatial patterns of extraction in the adjacency of forests in Tanzania. The scholars show in their research the positive effect of beekeeping activities as a deterrent for unsustainable extractive practices (Ibid). Based on these patterns the classification of proximity to forests will consider more suitable those villages located within a 10 kilometres distance from it. Everything beyond ten kilometres will therefore score low in suitability.

The layer expressing aggregate values (percentages) of poverty by district in Rift Valley operates as a controller of the proximity to roads and towns layers, which are also suggesting poverty likelihood. A more detailed discussion of these decisions comes in chapter five.

Criterion	Importance (1 = least - 5 = most)				
Standardization	1	2	3	4	5
Layer proximity to towns	0-30 km	30-50km	50-70 km	70-100 km	>100 km
Layer proximity to secondary roads	0-20 km	20-30 km	30-40 km	40-50 km	>50 km
Layer distance to protected areas	>10 km	5-10 km	2-5 km	1-2 km	0-1 km
Layer % poverty per district	2-9%	10-29%	30-49%	50-69%	70-91%
Layer distance to Closed forest	>10 km	5-10 km	2-5 km	1-2 km	0-1 km
Small fields/holders					Small field

Table 1: Standardization of criteria

3.5.2.4 - Weighting and normalization

When utilizing a Multi Criteria Evaluation for decision making we are often confronted with a trade-off between a number of different criteria. The criteria in this study varies in aspects such as its quality and reliability, importance and preference. Therefore, in order to derive the importance of these differences among the criteria we assign weights to it. Assigning weights is a subjective action, and it could significantly influence the outcomes of the analysis (Zardari et al. 2014: 52-53). Hence it is important to assign weights following a rational, reproducible and reliable method.

This study uses Analytical Hierarchy Process' (AHP) pair-wise comparison and consistency ratio (CR) as a prioritization method. The AHP Pair-wise comparison is a commonly used technique for the assignation of weights in Weight Sum Overlay approaches (Eastman 1995). AHP has been used by decision-makers all around the world and across multiple disciplines (Bushan 2004: 15: Zardari et al. 2014: 103). It permits us to integrate the subjective level to the decision-making analysis in a rational and reliable way. Through this method the importance of the criteria will be assessed by pair-wise comparison, and thereby translated to weights (Zardari et al. 2014: 18).

Zardari asserts that Pairwise Comparison is *"the most user transparent and scientifically sound methodology for assigning weights representing the relative importance of criteria."* (Zardari et al. 2014: 58). However, the main disadvantage of the method arises when the decision maker must deal with numerous alternatives. Scholars using AHP affirm that pairwise comparison should not exceed seven criteria/alternatives due to *"validity and practicality"* (Aragon et al. 2012). In the case of this study the number of compared criteria is six.

Box *number 2* shows the *fundamental scale of absolute numbers* used for the pair-wise comparison of the criteria. Thus, the Pairwise comparison matrix displayed under in *Table 2*, feeds from values coming from *the fundamental scale of absolute numbers*. Once the table with the *pairwise comparison matrix* is completed with the *intensity of importance* that each criteria has regarding one another, the resulting values will be computed to generate the criterion weights (See *Table 3* and *4*).

The actual score of every comparison will be divided by the sum of a single factor comparison (that is to say the sum of the values of the column). Take a closer look to *Table 3*, where *Distance to closed forest* is significantly more important that *Proximity to towns*, and therefore scores "*6"*. In *Table 4* the value *"6"* has already been divided by the sum of values (*"22")* resulting from adding scores from the second column *Proximity to towns*. Thus each value deriving from the pairwise comparison matrix will be divided by the result of adding the scores of each comparison. For this example the result is expressed in *Table 4* and signalised by a cell with red border: *(6:22= 0.2727)*. Subsequently, weight calculation for each factor will result from the sum of the values expressed for each row of *Table 4* divided by the number of factors compared (in this case 6).

Box 2: The fundamental scale of absolute numbers (Saaty 2008: 86).

Intensity of importance	*Definition*	*Explanation*
1	Equal importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgement slightly favour one activity over another.
4	Moderate plus	
5	Strong importance	Experience and judgement strongly favour one activity over another.
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favoured very strongly over another; its dominance demonstrated in practice.
8	Very, very strong	
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation.

Table 2: Pair Wise Comparison Matrix

Factors	proximity to secondary roads	proximity to towns	% Poverty per district	Small field	distance to closed forest	distance to protected area
proximity to secondary roads	1	1	1/3	0.2	1/6	1/6
proximity to towns	1	1	1/3	1/5	1/6	1/6
% Poverty per district	3	3	1	1	1/3	1/3
Small field	5	5	1	1	1/3	1/3
distance to closed forest	6	6	3	3	1	1
distance to protected area	6	6	3	3	1	1

Table 3: Pairwise comparison Matrix Sum Calculation

Factors	proximity to secondary roads	proximity to towns	% Poverty per district	Small field	distance to closed forest	distance to protected area
proximity to secondary roads	1	1	0.33	0.2	0.1666	0.1666
proximity to towns	1	1	0.33	0.2	0.1666	0.1666
% Poverty per district	3	3	1	1	0.3333	0.3333
Small field	5	5	1	1	0.3333	0.3333
distance to closed forest	6	6	3	3	1	1
distance to protected area	6	6	3	3	1	1
Sum	**22**	**22**	**8,66**	**8,4**	**3**	**3**

Table 4: Weight calculation after Pairwise comparison Matrix

Factors	proximity to secondary roads	proximity to towns	% Poverty per district	Small field	distance to closed forest	distance to protected area	Weight
proximity to secondary roads	0.0454	0.0454	0.0381	0.0238	0.0555	0.0555	**0.05**
proximity to towns	0.0454	0.0454	0.0381	0.0238	0.0555	0.0555	**0.05**
% Poverty per district	0.1363	0.1363	0.1154	0.1190	0.1111	0.1111	**0.12**
Small field	0.2272	0.2272	0.1154	0.1190	0.1111	0.1111	**0.14**
distance to closed forest	0.2727	0.2727	0.3464	0.3571	0.3333	0.3333	**0.32**
distance to protected area	0.2727	0.2727	0.3464	0.3571	0.3333	0.3333	**0.32**
Sum	1	1	1	1	1	1	1

Once the weights for each factor are generated an evaluation of its results is conducted through the calculation of the *Consistency Ratio* (CR). The (CR) informs about the coherence or level of consistency of the pairwise comparisons. When the CR is larger than *0.10* the judgements need to be revised (Saaty 2008). Hereunder, in *Box 3*, it is possible to appreciate the steps followed for the calculation of the CR while in *Table 5* Saaty's *Random Consistency Index* (RI) is displayed. The RI value to be used in this case is 1.24 which corresponds with the number of factors in the analysis.

Box 3: Calculation of the *Consistency Ratio*

CR = Consistency index (CI)/Random Consistency Index (RI)

• CI = $(\lambda_{max} - n)/(n - 1)$

• λ_{max} is the Principal Eigen Value; ***n*** is the number of factors

• λ_{max} = Σ of the products between each element of the priority vector and column totals.

• λ_{max} = (22*0.05) + (22*0.05) + (8.66*0.12) + (8.4*0.14) + (3*0.32) + (3*0.32) = 6.3392

• CI = (6.3392 – 6)/6-1 CI = 0.3392/5 CI = 0.0678

• CR = CI/RI = 0.07/1.24 **CR = 0.056 < 0.10 (Acceptable)**

Table 5: Values for the Random Consistency Index (RI) (Saaty, 1987: 171).

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

3.5.2.5 - Weight Sum Overlay

The operation where all weighted layers are aggregated is called *Weighted Sum Overlay* or *Weight Linear Combination*.

The *sum weight* method is considered optimal for generating information of quantitative kind, and the method's results are normally expressed as a ranking or performing scores (Zardari et al.2014: 11-12). Moreover, the MCE method *sum weight* offers high levels of transparency (Ibid).

As mentioned above the different layers are standardized to fit the *Weighted Sum Overlay.*

Weighted Sum Overlay combination offers an alternative where the expression of suitability is reached through a *trade off* between the different criteria. Thus, the presence of a low score in one criteria, will not necessarily rule out suitability for the given area.

The weights will thus have a substantial effect on the outcome. In this case they represent the subjective opinion of the researcher and not HCA's policy decision or strategy. In order to check the accuracy of the outcome, suitability expressions are compared with already existing optimal locations. In this way the weighting process achieves a higher level of consistency and overt validity.

3.5.3 - Suitability

The *weighted sum overlay* is an analytical tool available in the *spatial analyst* extension of ArcGIS. In this study standardized factors are combined by means of weighted sum overlay. Thus each factor is multiplied by a weight, and then the results are summed to arrive to a solution where suitability is:

$$Suitability = \sum w_i X_i$$

Where w_i = weight assigned to factor i

X_i = criterion score of factor i

In other words, each cell of each layer has a value varying from 1 to 5 (*Standardized values*) which will be multiply by its weight and later summed up with the results of other layers. Hence, for the layer expressing *Proximity to towns* a cell with value '3' will be multiplied by the weight value (0.05) of the same layer. This will result in a weighted value for that cell of '0.15'. The same cell but in the *Closed Forest* layer will express a result value coming from the multiplication of its value and the specific weight of the layer (for Closed Forest weight is 0.32). Subsequently the resulting weighted values of those two cells will be summed up.

Box 4 hereunder illustrates the way ArcGIS's *weight sum overlay* calculates suitability by adding the results of all weighted layers in the analysis.

Box 4: Illustration of Weight Sum Overlay

								+						
3	4	5		0.15	0.2	0.25			3	3	4	0.96	0.96	1.28
3	3	1		0.15	0.15	0.05		+	3	3	2	0.96	0.96	0.64
3	2	5		0.15	0.1	0.25			3	1	5	0.96	0.32	1.6

Raster with values of *Proximity to towns* are multiplied by the assigned weight (0.05)

Values of *Distance to closed forest* * (0.32)

=

1.11	1.16	1.53
1.11	1.11	0.69
1.11	0.42	1.85

Weighted Sum Overlay taking as example two layers or factors.

Suitability =
Proximity to towns (3*0.05)= 0.15 + *Distance to closed forest* (3*0.32)= 0.96

Suitability of the top left cell = 0.15 + 0.96 = 1.11

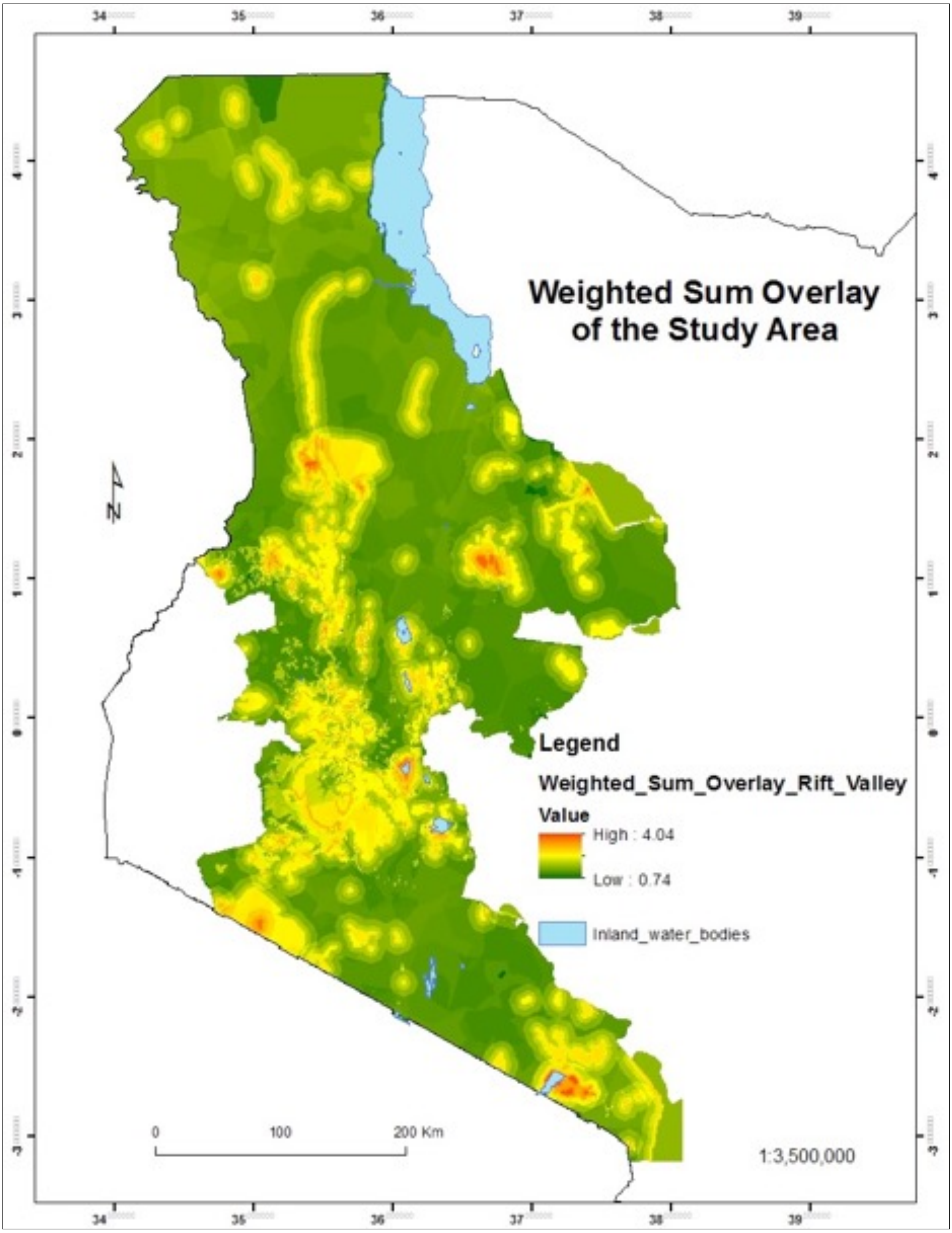


Figure 8: Map resulting from the Weighted Sum Overlay Rift Valley

The resulting Weighted Sum Overlay is reclassified in order to present the results. This reclassification of the suitability layer is performed within the ArcGIS environment. Four classes are defined and the reclassification of data is performed by the *equal interval*, a standard procedure in the spatial analyst tool box of the software.

3.5.4 - Accuracy of the analysis

This step has as its main goal to assess the results of the analysis and its different main components (Malczewski 2010: 382). In this study the assessment of the analysis will consist in contrasting the suitability maps and its suggested locations with the field visits, the information of HCA, and Kenya's population and economic indicators (KNBS 2014).

The pictures under were taken during fieldwork and they show traditional methods for beekeeping, living conditions, and honey collected around Lake Baringo.

Photo 4: House at a village near Lake Baringo
Source: photo by author

Photo 5: Honey collection at a village center near Lake Baringo
Source: photo by author

Photo 6: Traditional log-hive hanging at HCA's office in Nairobi
Source: photo by author

Photo 7: Traditional log-hive hanging from a tree nearby Lake Baringo.
Source: photo by author

Chapter 4: Results

As a result of the analysis six high suitable areas are highlighted, Turkana in the north, Samburu, Trans Nzoia, and Nakuru in the centre, and the surroundings of Masai Mara and Amboseli National Park in the south. In this chapter we take a closer look to these resulting high suitable areas for beekeeping. In general we could assert that high suitable villages are located within or nearby protected areas and closed forests. Nevertheless factors such as isolation, Poverty rate by district, and small fields/farm proved to be a significant determinant as well.

The most suitable areas resulting from the analysis cover approximately 1.853 square kilometres. That is roughly 1% of the total study area. Within these areas there is a significant number of rural villages where the first prospections should take place.

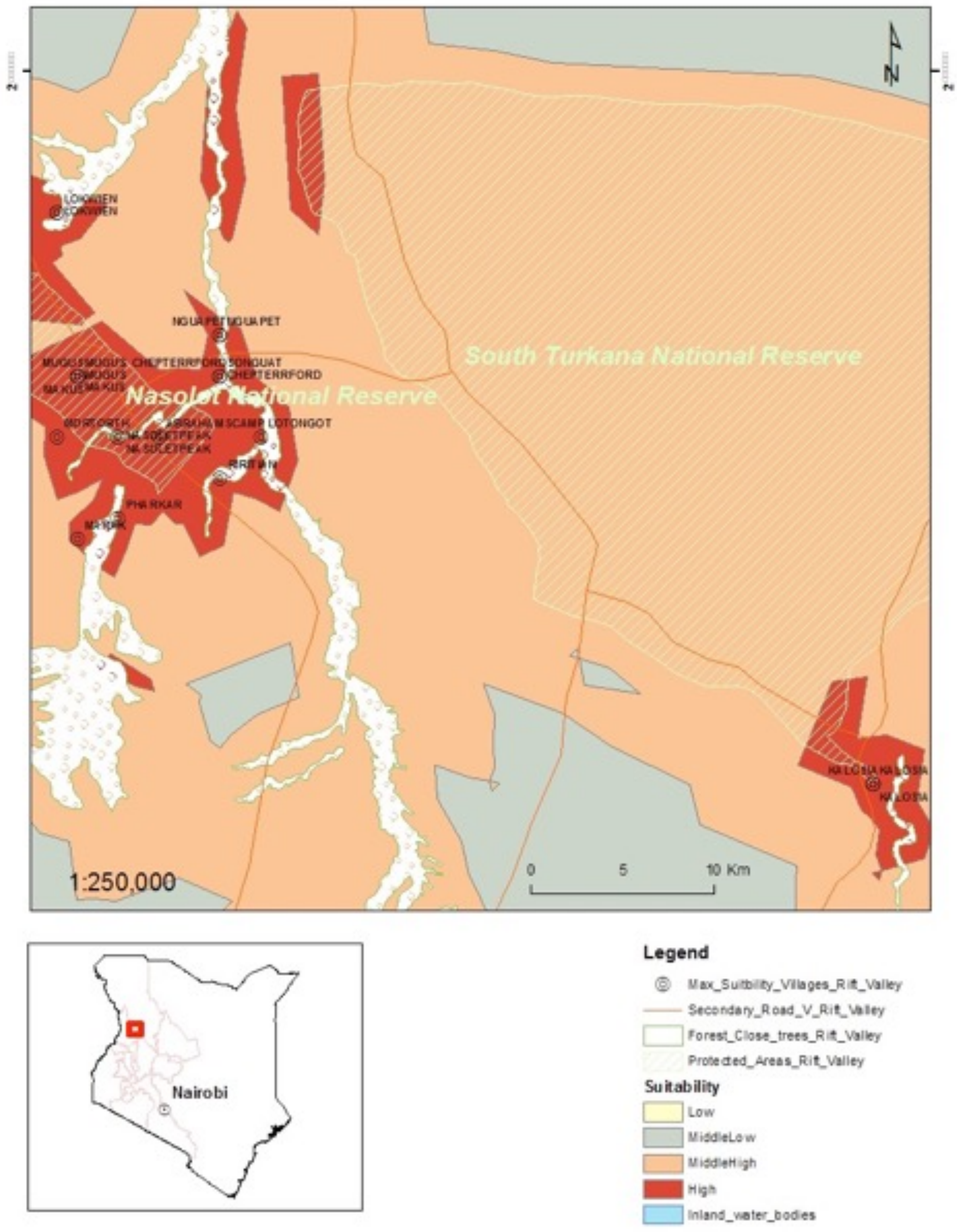
4.1 - Turkana

The Turkana county, located in the northern part of the study area and illustrated in *Figure 9*, although presenting one the highest percentages in poverty rates it scores relatively low in suitability. Some patches of mid-high suitability can be observed around national parks and closed forests.

The southern tip of the *South Turkana National Reserve* area and the surroundings of *Nasolet National Reserve* score particularly high in suitability due to the concentration of suitable factors such as closed forest, high poverty rates, and protected areas. In this area vegetation and forest is to be found mostly to the sides of the Turkawel river. These are definitely potential areas for the location of beekeepers within the poorest district of the study area.

Hereunder is possible to see a detailed map of the areas and the most suitable villages to target for beekeeping in Turkana districts.

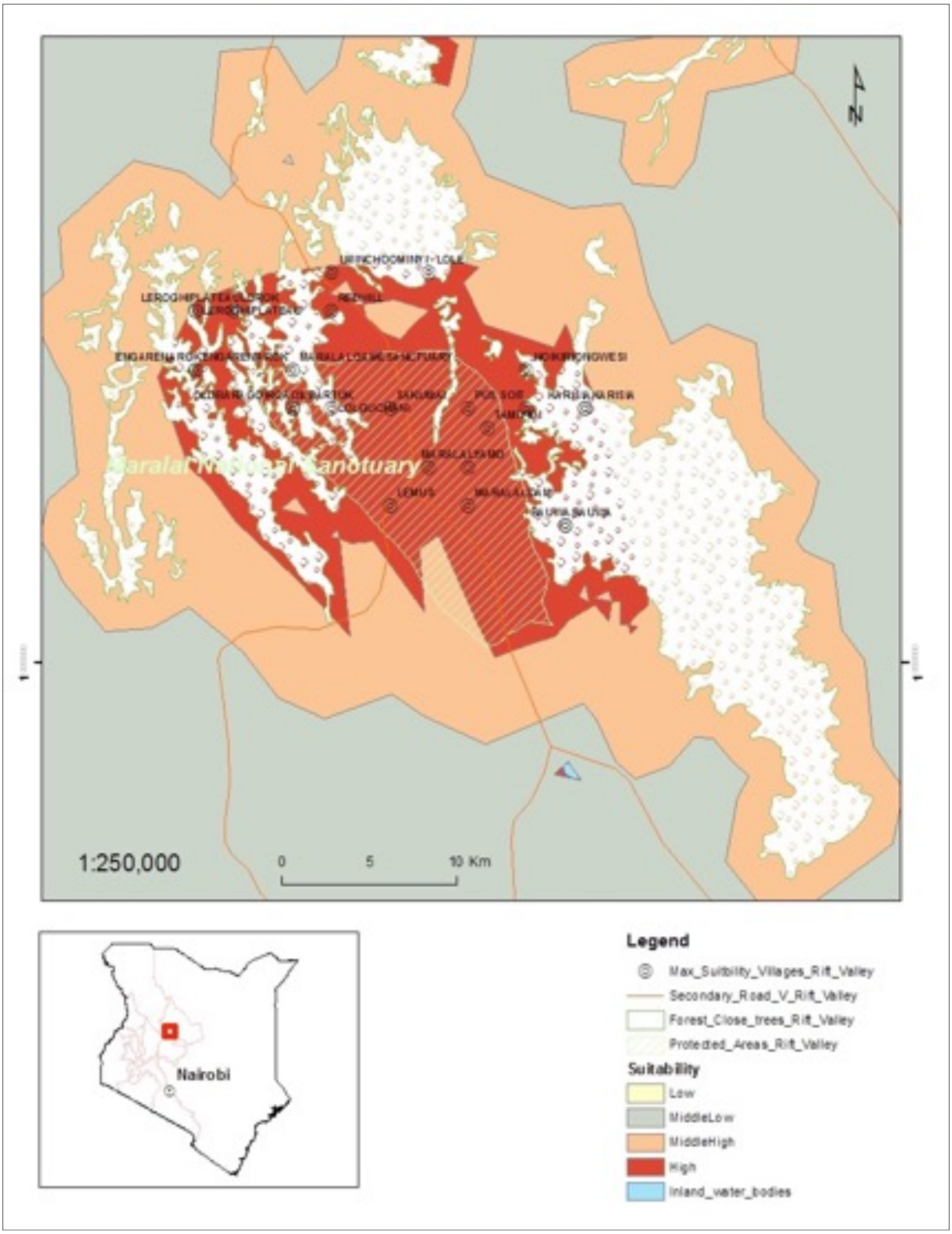
Figure 9: Suitability map of southern Turkana with high suitable Villages.



4.2 - Samburu

Situated in the west of the Samburu district (see *Figure 10*), the *Marala National Sanctuary* area of influence presents similar suitability conditions as southern Turkana.

Figure 10: Detailed map with villages and high suitability areas at Samburu district.



4.3 - Trans Nzoia

The map (see *Figure 11*) under illustrates the suitability situation in this area, which has much potential for beekeeping.

Not so far from the area described above, some kilometres south from Kitale, HCA has an important presence with a cluster of beekeepers near to Kamukuywa. However, the focus on protected areas and closed forest of this analysis determined that HCA's cluster in the region was displayed in an area with *MiddleLow* suitability.

Figure 11: Detailed Suitability map Trans Nzoia.

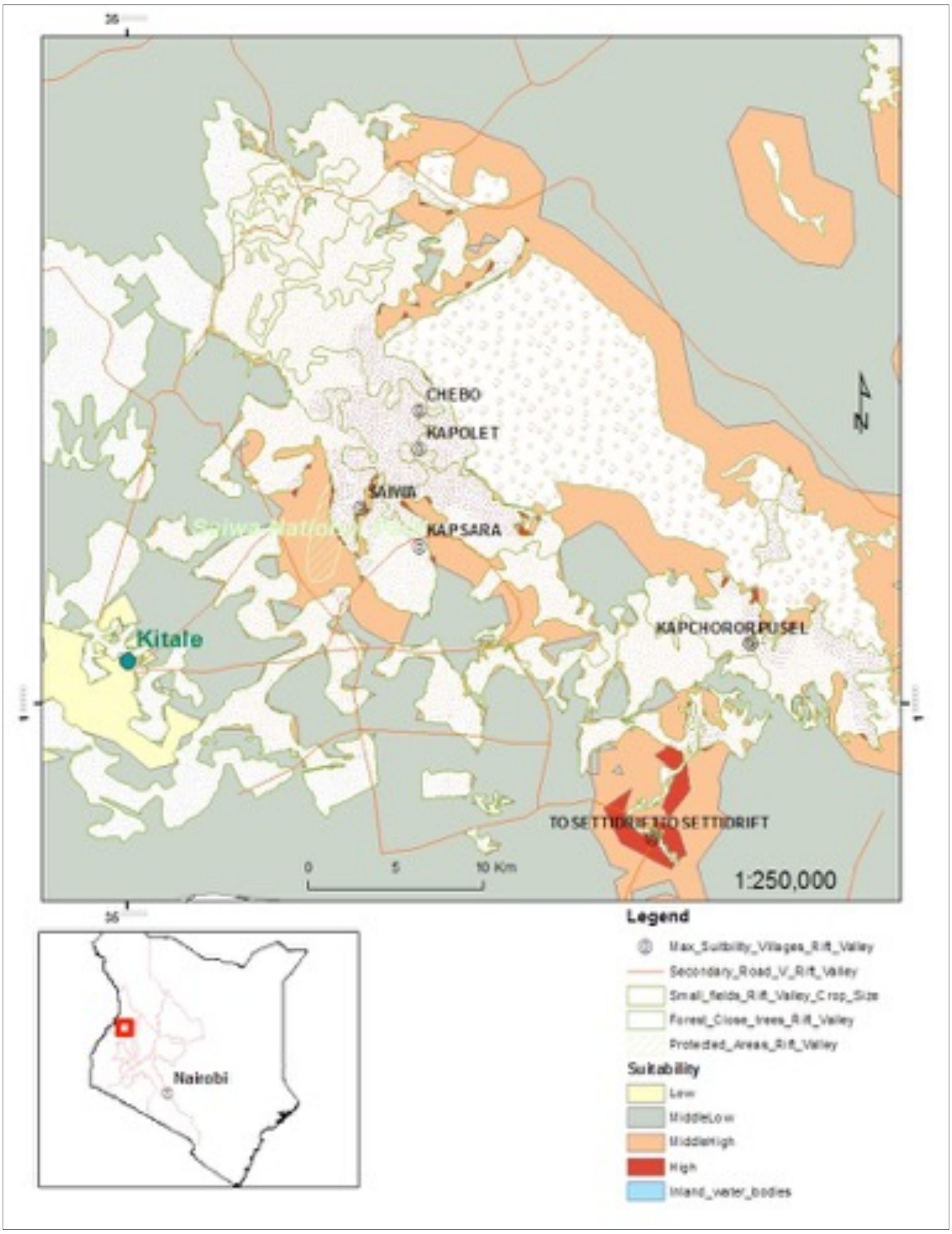
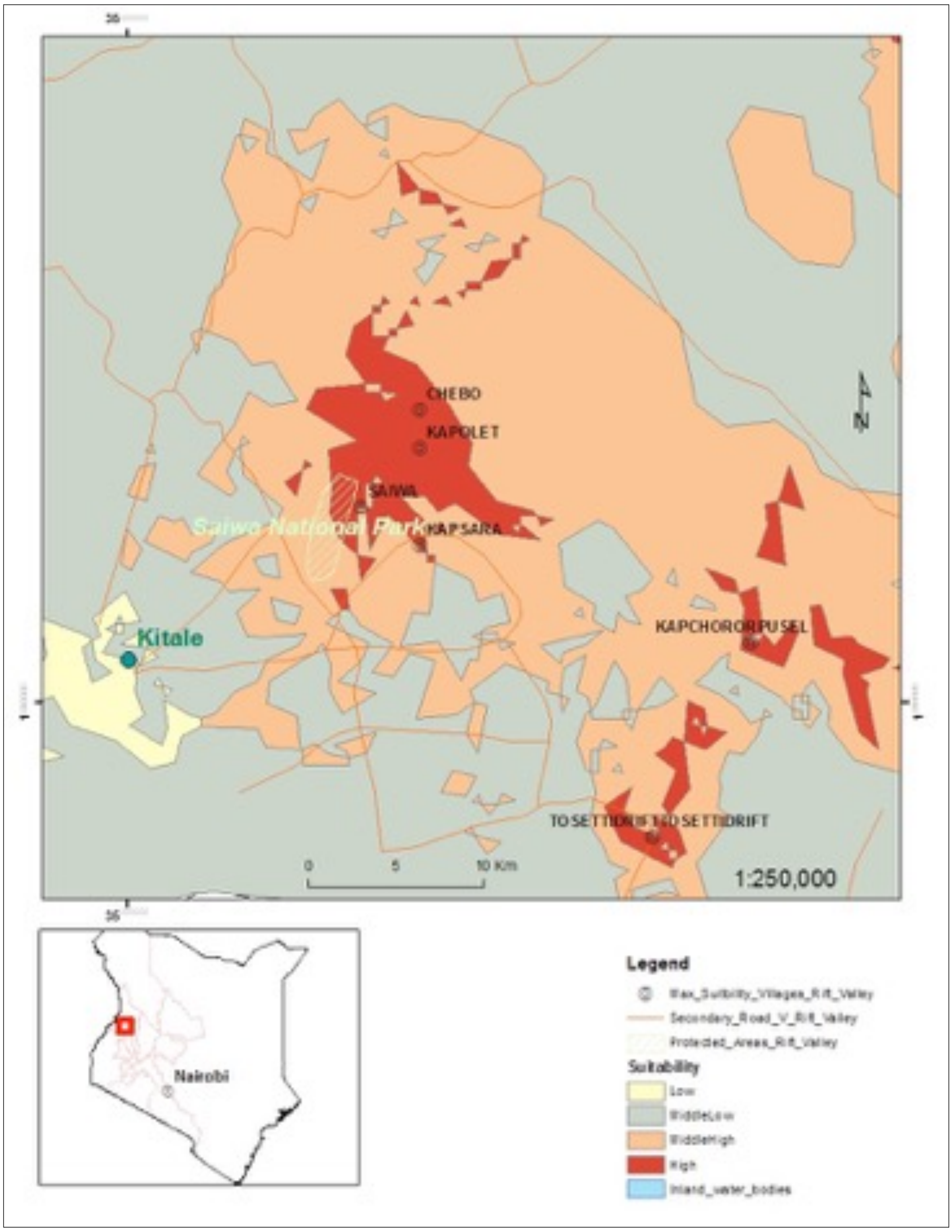


Figure 12: Suitability map Trans Nzoia without details.



4.4 - Nakuru

The area surrounding the Lake Nakuru National Park (see *Figure 13*) presents high suitability due to the proximity of closed forest, and the protected area. Furthermore this is an area of numerous small holders and agriculture production. Poverty percentage varies from 10 to 50 % in the counties surrounding the National Park. West from Nakuru city, the high suitability of the outskirts of cities like Molo and Londiani (see *Figure 14*) is due to the important presence of small farmers and closed forests.

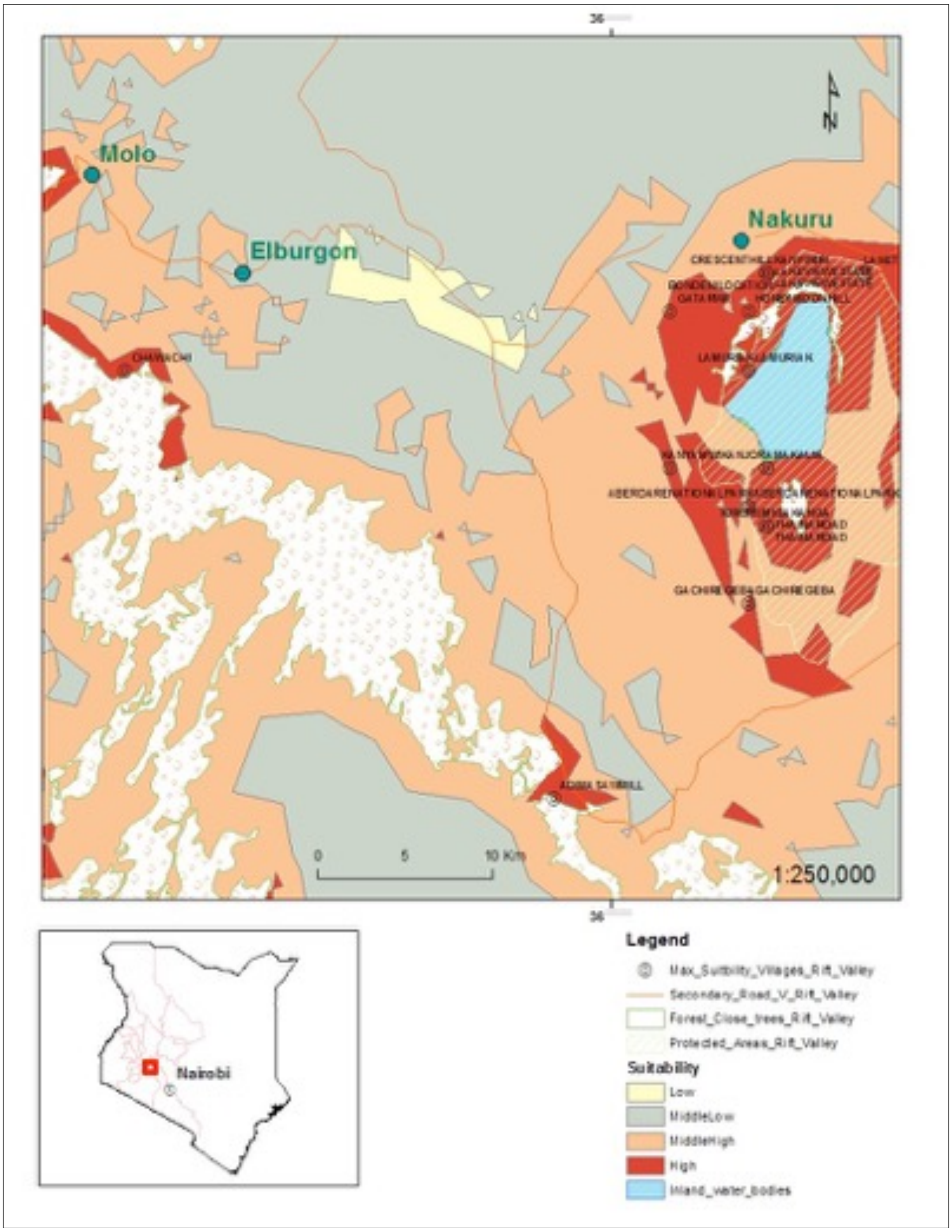
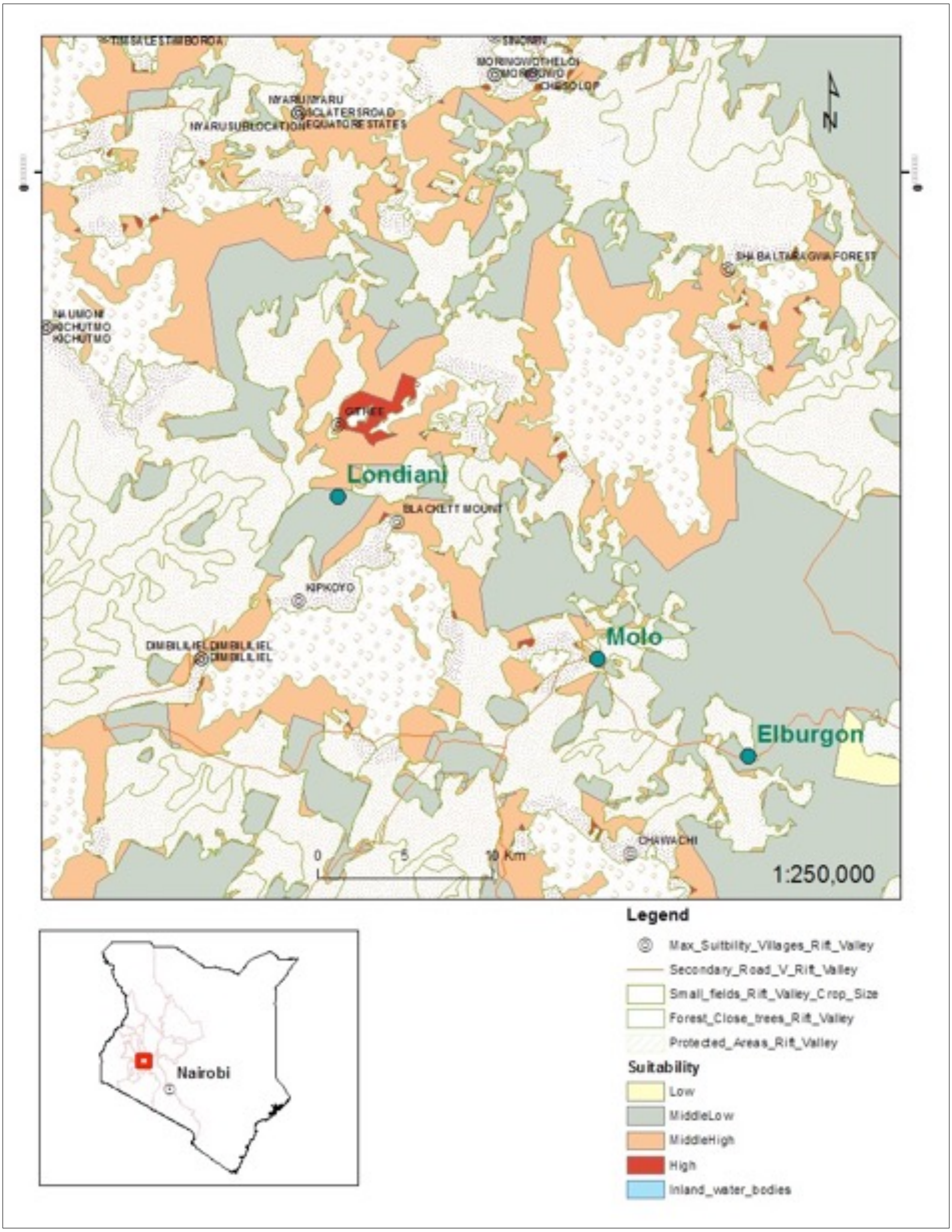


Figure 13: Detailed map of suitability around the Lake Nakuru National Reserve where high suitable villages are located and labeled.

Figure 14: Map showing suitable villages in the Londiani area. The map shows the concentration of small crop fields and closed forest.



4.5 - The Masai Mara and the Amboseli National Park

South in the study area we can observe two areas with high suitability, the Masai Mara National Reserve area of influence, and the Amboseli National Park. These areas are illustrated in *Figure 15 and 16* right under.

The Masai Mara area scores high in suitability due to isolation, poverty rates, the protected area, and closed forest.

Also in the south, the surroundings of the Amboseli National Park are high suitable for beekeeping. High suitability in this area is the result of isolation, proximity to some patches of forest, high poverty rates, and the presence of the protected area of Amboseli National Park.

Figure 15: High suitability in the south of the study area.

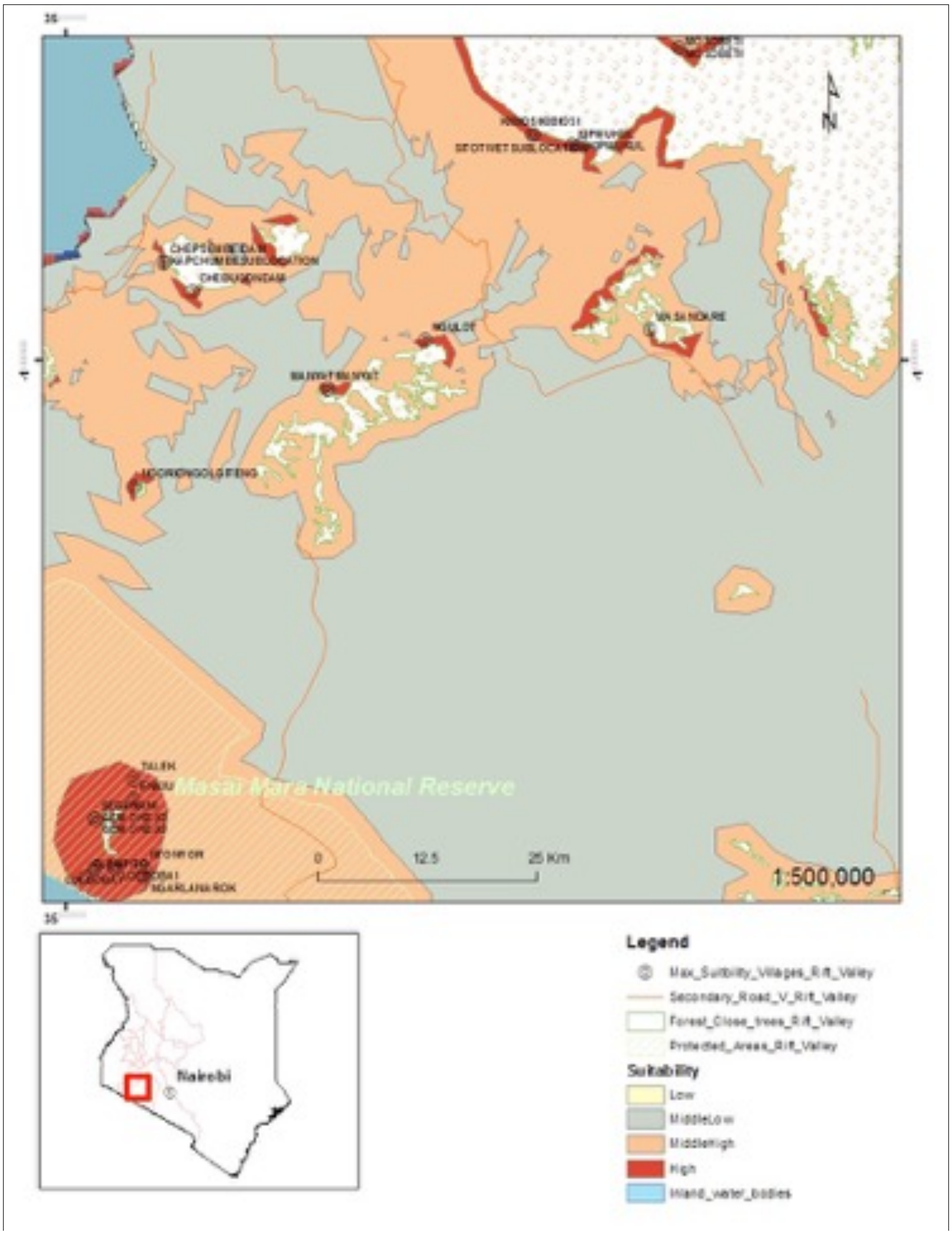
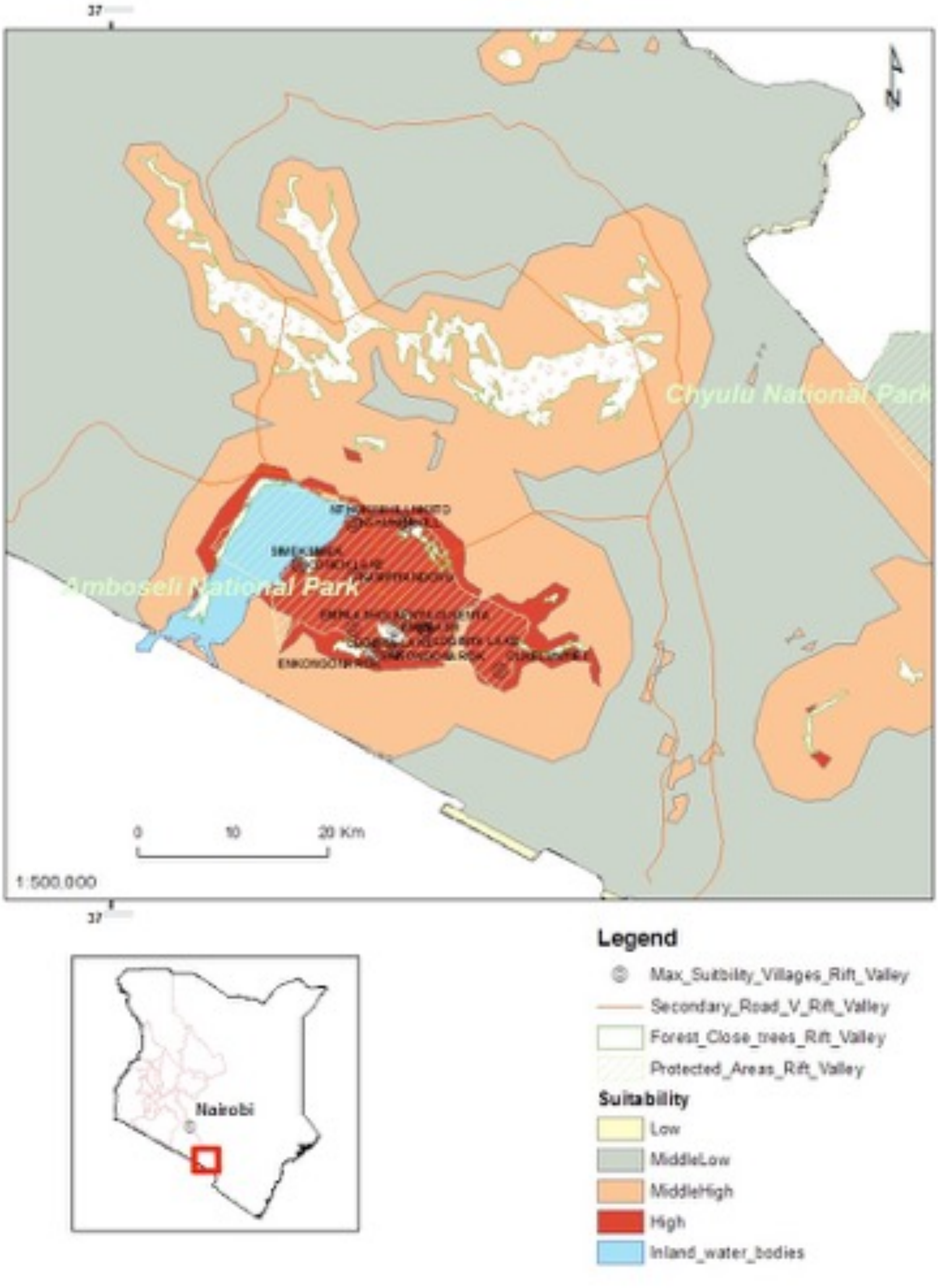


Fig. 16: Detailed maps of high suitable areas and villages.



In the next chapter a discussion of the results, and the convenience of the selected methods and techniques is presented.

Chapter 5 - Discussion

The results of the analysis show a close concordance with the experiences on the field. The resulting *suitability* layer can be used as an expeditious and reliable resource for the location of potential new beekeepers in Rift Valley.

This chapter discusses four main aspects of the study. The first one is the reliability of the expressions of suitability resulting from the analysis. These are discussed and contrasted under the light of information coming from the literature research and HCA's current localisation of beekeepers.

The second aspect to be discussed is the pertinency and ability of the conceptual model -the GIS based MCE and its methodology- to achieve the objectives proposed.

The third considers the selection of factors for the definition of environmental variables. The fourth point in this chapter discusses the socioeconomic aspects included in the model. To finalize the discussion chapter some comments on limitations and shortcomings of this study are presented.

5.1 - The reliability of the analysis - Discussion of suitable areas

5.1.1 - Turkana

The predominant economic activity in the district of Turkana is nomadic pastoralism, and the weather is dry with an annual average precipitation around 250mm. This remains a limitation for even traditional methods for beekeeping, where the minimum annual rainfall for reliable beekeeping cannot be below 750mm (Gupta et al. 2014: 559). The KNBS statistical abstract from 2014 indicates that only 120 square kilometres in this district get enough annual precipitations for beekeeping (KNBS 2014). This is consistent with the results for the area where some few patches with mid-high suitability were located near closed forest and national parks.

Worth to mention is that in 2013 a UNESCO based research group funded by Japan found significant underground water reservoirs in Turkana. Further research and assessments of the quality of the aquifers is currently taken place (UNESCO 2013). This element could change the economic matrix of one of the poorest regions in Kenya.

A region that has historically based its economy in pastoralism could face the dawn of an agriculture revolution with all its implications. It is difficult to foresee which type of agriculture production would the region develop. Nevertheless, due to its low population density an intensive and smallholder agriculture pattern in the region would not be easy to conceive. However, regardless of the productive structure, beekeeping could become a more significant economic activity in a relative near future.

5.1.2 - Samburu

Less than 10% of Samburu's area is considered highly apt for agriculture (KNBS 2014), and accordingly the main economic activity is pastoralism. These conditions, as for the case of Turkana, restricts suitability areas mostly to national parks. Both examples, Turkana and Samburu show that the study presents a satisfactory relation between weighting of social (Poverty rate), economic (small holders) and natural variables (protected areas and closed forest).

Although poverty rates are significantly high in the northern region of Rift Valley, the natural and economic conditions are not present, and this determines that the resulting suitable areas are rather few.

5.1.3 - Trans Nzoia

In Trans Nzoia county, where Kitale is the main city, the totality of the productive land is considered to have high potential for agriculture (KNBS 2014: 107). Accordingly the high suitability rendered by the analysis in this area is originated in the significant amount of small fields/holders, the high incidence of poverty (varying between 50-70%), and the proximity to closed forest and protected areas.

5.1.4 - Nakuru

According to KNBS statistical abstract from 2009, approximately 50% of Nakuru's county offers high potential for agriculture (KNBS 2009: 107). The area has already been targeted by HCA as a potential area for beekeeping, and therefore it confirms the reliability of the current results. However, the result of the present analysis provides a more informed decision due to the consideration and comparison of the different variables, and the identification of villages/spots with better suitability within this very apt area for beekeeping.

5.1.5 - The south and the Amboseli National Park

The Masai Mara National Reserve is located in Narok county next to the border with Tanzania. The protected area of Masai Mara National Reserve is home to arguably one of the most spectacular wild animal migration on earth. The area borders with the Serengeti reserve in Tanzania. The local population of the region bases its economy on livestock, managed in a semi-nomadic pastoralist manner. However, in the past decades crop cultivation and subsistence agriculture has developed to be an economic activity practiced by up to 46% of local Masai's households (Homewood et al. 2001). Furthermore, over 50% of Narok's county available land is rated to have high potential for agriculture (KNBS 2009: 107).

The Amboseli National Park suitability appears to be special. The areas surrounding the park are suitable due to isolation, proximity to some patches of forest, high poverty rates, and the proximity of the park as a protected area. A closer evaluation has to be taken regarding the swamp system of the park and the results of its intensive agriculture practices.
However, also in the south, less than 2% of the land in Kaijiado's county has high potential for agriculture (Ibid). Annual rainfall is around the 600mm or less (Ibid). This are elements that definitely compromise the suitability of the area, and therefore the pertinency of the results for this neighbour county.

The results of the analysis show consistency with the information gathered during field visits, the reviewed literature, and the knowledge that HCA has of the selected areas. The fact of being able to identify specific locations within relative large areas represents the biggest asset of this results.

5.2 - The conceptual model

The conceptual model is based on the use of GIS software to generate a Spatial Database, which is the source of data of a MCE. For the integration of the database the spatial information was modelled and adapted to the needs of the study.
Hence the study develops a specific methodology for decision support. A methodology where development organzations can integrate new data/updates to the existing data, and thereby use it for further analysis. In this section different decisions taken for the modelling of data and its utilization in the analysis are discussed.

When describing a MC-SDSS (Multi Criteria Spatial Decision Support System) we frequently pay heed to the way and degree of integration between GIS and the MCDA techniques (Malczewski 2010: 382).
This study has design a *single user strategy* where the main subject or focus of the analysis has been optimal location for beekeeping regarding proximity to protected areas and forest; smallholders; and access to infrastructure such as towns and roads. It is therefore a *multi attribute decision model*.

This study has utilized a single-user approach and philosophy regarding the integration of GIS and MCE, and the conformation HCA's spatial decision support system (SDSS). The consideration of a more tight coupling approach between GIS and MCE was ruled out due to the scope of this study.

However, a bidirectional communication between the software and the multi-criteria, will represent an asset to an organization's working methodology. The reason for choosing this strategy was mainly its practical convenience in order to achieve the objective of the analysis. However, GIS's versatility maintains open the possibility to provide the analysis a more participatory approach.

From a closer integration between GIS and MCDA and the further generation of a SDSS we could develop a more group oriented and collaborative decision making processes (Malczewski 2010: 384). Furthermore, the integration of local groups to the decision-making process might improve performance and loyalty of beekeepers and other stakeholders. The former are in fact very sensitive aspects of the relation between HCA and beekeepers, which have become a significant challenge in the last years. Side-selling being one of the main problems. Hence, logistics strategies, practices, and further development of the local beekeeping production could be some of the potential areas where to introduce a more participatory approach.

Again, the relation of GIS and MCE is a more uni-directional one, having GIS as a main provider of information, and output. However, the permanent evaluation and discussion over the criteria used in the analysis gives a more bi-directional profile to the articulation of GIS and MCE. Considerations taken in order to define small field/small holder, and the search for new elements to integrate to the analysis such as proximity to Community Based Forest Management groups, or Agro-industrial complexes to avoid, are examples of reciprocity between GIS and MCE. This reciprocity has several advantages and great potentiality which makes it worth of further exploration.

Subsequently, which MCDA method and technique to choose was not a simple issue. In their analysis of MCDA methods Guitoni & Martel (1998) saw the large number of alternatives as a weakness rather than a strength. Moreover, no single MCDA method can be used in all decision problems (Ibid: 512). To put it bluntly, one could go into the circle of designing a MCDA to decide which MCDA is going to use. However, the mentioned scholars presented in their work several aspects to consider when deciding which MCDA to use.

Regarding the distance tools and the cost distance and euclidian distance. The procedures are based on a straight line, and this could be deemed as a limitation. We all know that in certain terrain straight line mobility is not an option. However for the specific criteria this study considers, the fact of using straight line distances does not represent a significant limitation.

The Weighted sum method combined with AHP's pairwise comparison to define the weights of the different criteria fits these to-consider aspects or guidelines. The chosen method is characterized as a discrete MCDA method. Within the discrete MCDA the method falls into the category of single synthesizing criterion approach. This method assumes that there is a function or value to represent the decision maker preferences (Ibid: 506). Basically, the method allows us to arrive to a preference situation.
Furthermore, the method is used for *Cardinal* type of data/information of a deterministic nature (Ibid: 515), all aspects that fit the kind of problem we aim to solve in this study.

With regard to the elicitation process, the subjective character of thresholds of preference and weights is often target of critiques towards MCDA methods. These subjective side of the method is very likely to affect the outcomes. However, the use of the Analytical Hierarchy Process for the assignation of weights is an attempt to relativize and control the subjective side of weights definition. The AHP method for weight definition is widely used within MCDA (Zardari et al. 2014). Furthermore, Farajzadeh et al. (2007) results' of comparing weighting methods for suitability analysis in a GIS environment suggests that AHP pairwise comparison is one of the most accurate methods.

However, both Zardari et al. (2014) and Farajzadeh et al. (2007) agree in that AHP's weakness resides in its poor performance when dealing with high number of comparisons. Accordingly, in this study we carefully limited the number of alternatives to a minimum, whereas the consistency rate shows an acceptable expression for validation.

Moreover, Guitouni & Marte (1998) consider the AHP a method difficult to assess. Here is worth to note again the importance of the visits to the field, and HCA's own previous experience on the field. Correlation between primary data and the results of the analysis at the present scale are satisfactory and were already commented in the previous section (5.1).

Another aspect worth of discussion is AHP's method for weight definition and is its potential to incorporate opinions and judgements of different stakeholders to a single decision matrix. The latter is source of debate. Zardari argues that AHP is not a recommendable eliciting method in those situations where many stakeholders are involved due to its lack of transparency when processing the information (Zardari et al. 2014). However, Estoque and Murayama (2010) apply the AHP method with participation of stakeholders without any special regard, in their suitability analysis for beekeeping sites in La Union, Philippines.

Different stakeholders could easily work with the decision matrix to express their preferences between the different alternatives. Accordingly, Saaty (2008) suggests that group decision has been effectively made with AHP, and recommends some techniques for the aggregation and synthesis of judgements. Hence the opinion of numerous stakeholders could be evaluated and incorporated to the decision process in a rather transparent and objective way. However, this issue merits further research and some testing in order to prove its validity for the case of HCA.

Another technical issue worth to discuss is resolution. The raster analysis worked with a cell resolution of 440x440 meters. This cell size can be considered as too coarse to deal with variables such as small fields, let alone specific site suitability at household level. However, the cell size is appropriate to deal with the broad scale of Rift Valley. Similar GIS studies considering a broad scale like Bocchi's et al. (2006) *Environmental Security in Kenya* used a much smaller scale, with input data of 1km x1km cell size, yet manage to draw important conclusions.
Thus, the analytic resolution of the analysis has to be adapted to its aims. Single site assessment at household or small farm level will therefore demand a much less coarse resolution.

The consideration of *Fuzzy overlay tools*. Fuzzy logic provides tools to cope with inaccuracies in the geometry and attributes of spatial data (Esri 2012). The Weighted Sum Overlay is based on what Esri calls crisp sets (Esri 2012). Therefore weighted sum overlay will always present cells that either they are in or out of a given criteria or class. However, fuzzy overlay could be used to deal with uncertainty and potential inexactitudes in the procedure of assigning a class (Ibid). In order to assess location of beekeepers at a greater scale, household for example, the incorporation of this method could represent a significant asset. For example when suitability of a household is assessed by annual rainfall, specific honey bee related flora, habitat, etc.
However, for the case of the present analysis, as long as the criteria continue to be based in distances, and proximity to specific features, the fuzzy logic does not represent a substantial improvement to this study.

To conclude with this section, the conceptual model was designed to achieve the goals of the study, whereas intending to integrate and address the most techno-positivist side of GIS, its socio-political participatory potential, and the MCDA methodology.

5.3 - The environment and the selection of relevant variables

As mentioned in chapter one, one of the main criteria for this location suitability analysis is proximity to forest and protected areas within the study area. The selection of this criterion was briefly discussed above. Basically, beekeeping is used by locals as a sustainable forest resource. Furthermore, management needs and environmental awareness coming with beekeeping could work as a deterrent for non sustainable extractive practices. Hence the goal in this matter is to change the behavior of forest degrading actors. The literature justifying this choice is vast. In this section we will discuss some practical examples in rural Africa which account for the pertinency of this decision.

In order to define the environmental criteria two points were taken into consideration: first, that the dynamics of forest management and beekeeping can work together in somewhat optimal fashion. Second, that efforts to protect the environment and alleviate poverty should be considered together, never apart, let alone confronted.

As commented in chapters one and two of this research project, the UN and its specific annexed bodies are specially concern with providing an environmental approach to every development project. Currently, although acknowledging the importance of beekeeping for the environment, HCA lacks an environmental approach to its spatial decisions.

Albers & Robinson's work with forest management in Tanzania accounts for some relevant points that we follow here in order to define the environmental variables.

The scholars concluded that the placement of alternative income projects like beekeeping can augment enforcement in controlling the pattern and amount of forest degradation. Projects that offer a high enough return can pull labor out of resource extraction activities, therefore helping to reduce forest degradation (Albers 2011). Furthermore transition and alternative income strategies are particularly important for small holders (Razack & Robinson 2008).

Thus, the importance of beekeeping as an alternative economic activity that will help preserve the forests, whereas providing extra income to the local groups and/or families, determined the inclusion of forests, national parks, environmental reserves and surrounding areas in the multi-criteria evaluation.

One step further would be to target Community Based Forest Management, a form of participatory management, which several scholars (Albers 2011; Himberg et al. 2009;) associate with a significant improvement in the awareness of locals about the consequences of not preserving the forest. While on fieldwork we contacted Kenyan scholars working with several CBFM groups in the west of Kenya. Their study concludes that CBFM significantly contributes to a change in attitudes and practices when interacting with environment in general and the forest in particular.

Forests are important for the regulation of water cycles, prevention of soil erosion, carbon cycle and mitigation of climate change (Muller & Mburu 2009: 968).

Kenyan forest cover has decreased by 0.3% annually in the period of time 1990-2005 (Ibid: 970). Furthermore, households situated in the vicinity of forests depend heavily on its resources (Ibid).

"Beekeeping replaces cutting trees" affirms the International Union for Conservation of Nature (IUCN 2011).

Appiah et al. 2007 indicate that dependence on forest resources and tropical deforestation in Ghana is mainly caused by poverty driven agriculture, lack of alternative rural wage employment other than farming, household poverty level, and traditional land practices (Appiah et al. 2007). The answer to these problems, argues Appiah, is community-based forest management (CBFM) (Ibid: 482).

In this sense beekeeping, as a non-timber forest product, is important in order to rebuild and start rural economic activity (Ibid). Moreover, it helps diversifying agriculture and it can be integrated to pastoral agriculture and agroforestry in a relative easy way (Ibid).

In a research on public attitudes and needs around the Kasungu National Park in Malawi, Mkanda and Munthali (1994) found out that about 90% of respondents wanted to use the area for beekeeping (Mkanda & Munthali 1994: 29). Mkanda and Munthali also noted a change in the approach of policies directed towards wildlife resources (Ibid). As mentioned before, in the past decades the focus has turned into a more integrative pro-participatory approach, where rural communities make use of the resources in a negotiated and sustainable manner.

Accordingly, distance to areas delimited by CBMF programs or the REDD (Reduced Emissions from Deforestation and Degradation) initiative could be relevant environmental variables to include in a future expansion of this study.

5.4 - The socioeconomic variables

The socioeconomic variables direct our attention towards Poverty and the role beekeeping can play in poverty alleviation efforts. However the pressure over the available resources, the subsequent environment degradation, and the consequences of an -more than ever- imminent climate change, remind us of the inextricability of environmental and socioeconomic factors. In other words, poverty and environmental degradation are two sides of the same coin. Helping to prevent one of them should always take into account the other.

Furthermore, the existing economic driven pressure on natural resources in Kenya has already originated environmental conflicts (Bocchi et al. 2006).

The suitability of socioeconomic criteria was based on:

1) *Isolation based on distance from main and secondary roads*
2) *Isolation based on distance to towns*
3) *Small and medium farmers without irrigated land (crops varying from fruits, avocados, macadamia, coffee, tea, corn).*
4) *Poverty percentage per district*

Poverty is a relative concept. Accordingly, its definition and measure is always charged with important cultural, philosophical and political values. In this study the definition of poverty was based on the findings of relevant scientific research (Okwi et al. 2007, Oluoko-Odingo 2009, Sahn & Stifel 2000) for the study area specifically, and the whole country in general. Moreover, these researches evaluate poverty from a geographical point of view. The additional consideration of *Poverty percentage by district* is used as a method of control, and a way of illustrating the possibilities of the conceptual model.

The type of data contained in the layer *Poverty percentage by district* was already commented in chapter three. The definition of poverty used in this layer is not a spatial determined one. Nevertheless some types of spatial relations have been taken into consideration as well. This is the case of access to health care, education (schools), and sanitation (sources of drinking water, sewage disposal).

Hence, two main factors are considered regarding the socioeconomic variables to be included in the Multi-Criteria Evaluation. On the one hand the analysis considers isolation as a relevant determinant of poverty. The economic geography literature in general and specific Kenyan research studies, show a significant correlation between distance or access to town and/or main roads and poverty levels (Okwi et al. 2007, Oluoko-Odingo 2009). The more isolated the population the more likely to be poor/poorer. Conversely, and this is also shown by Okwi's research *Spatial determinants of poverty in rural Kenya*, the closer the population is to built-up areas and infrastructure the lower the poverty levels are (Okwi et al. 2007). However, proximity to forests, regardless of isolation, could determine a better welfare (Ibid), this is rather intuitive due to the amount and variety of resources the forest provides (nuts, fruits, firewood, herbs, etc). Worth to mention is that spatial determinants of poverty can vary from region to region, and it is therefore always important to consider the conditions on the ground (Okwi et al. 2007).
On the other hand, the analysis estimates the socioeconomic conditions of the households taking into consideration the size of landholding/fields use for agriculture.

A great deal of consensus exists around the idea that GDP (Gross Domestic Product) growth originated from agriculture is more effective reducing poverty than GDP growth of the other sectors (World Bank 2008). Accordingly, the OECD makes reference to several researches showing the importance of agriculture in poverty alleviation. Following this literature the increment in agriculture production has a much bigger impact in poverty alleviation than the growth in any other economic sector. (OECD 2006).
Small-scale farmers play a central role in securing food supplies (Oluoko-Odingo 2009: 315). Hence, several scholars agree on the importance of empowerment and development of small farmers in order to maximize effects on poverty alleviation (Livingston et al 2011, Irz et al 2001, Oluoko-Odingo 2009).

However, the definition of small farmers and/or smallholders is rather elusive. In her presentation "Small farms: current status and key trends", Nagayet (2005) analyses different conceptual approaches to the term. The fact is that what we call a small farmer depends on its context, and thus varies from one continent to another, and even within the same continent or region its consideration and definition might present particularities. For Eastern Africa the average landholdings is *2.5* hectare, and although low compare worldwide, this is higher than in the rest of Africa (ETI small holders guide 2005). The state of Kenya however considers a small holder any farmer holding less than 20 hectares (ETI small holders guide 2005).

Nevertheless, most sources define a small farm as holders with less than 2 hectares (Hazel et al. 2007).

However, context matters regarding the small farmer definition, and therefore many scholars and organizations tend to complement the definition with various qualitative indicators of small farming. Among the most used indicators we find the level of technology involved in the different productive processes, degree of dependence on household members, and production for subsistence and/or commercial oriented production (Hazel et al. 2007).

Consequently with the lack of a standard definition for the small farmer, there are several definitions in use which have a more or less qualitative or quantitative approach. Here under we see some criteria extracted from the *Framework Report* of the *African Smallholder Farmer Group* (ASFG 2013: 12-13) that were useful regarding the objectives of this project:

- *Farmers who own other assets in addition to their land, such as livestock or machinery; and who have sufficient access to inputs, services and knowledge to enable them to be active in markets to a greater or lesser extent. They are typically better connected, both physically and socially/commercially, and are often involved in producing for export, niche/high value added markets or integrated rural value chains.*

- *Farmers with only a little land to farm (one hectare or less) and few other assets; who lack access to high-quality inputs, credit, services and equipment; who may be cut off from markets due to geographic isolation, poor infrastructure, lack of information or a combination of these; whose rights to land and other resources may be weak; and who have not, as yet, managed to access markets in a way which can increase their productivity and lift them out of poverty.*

- *Finally, those subsistence farmers who are unable to survive on farm income alone, but who rely substantially, or even entirely, on off-farm work, remittances and/or social subsidies. This group includes the poorest and most vulnerable farmers, including a high number of women-headed households; and a growing number of farmers who no longer own any land at all. (ASFG 2013: 12-13)* http://www.asfg.org.uk/framework-report/introduction-1

The OECD uses a five-level classification of 'rural worlds' (ASFG 2013: Ibid): *Large commercial farms, smallholders who produce commercially, smaller farms mainly devoted to subsistence, landless laborers, and the poorest households that need social assistance* (OECD 2006). The former three categories described would correspond to OECD's "smaller farms mainly devoted to subsistence" (ASFG 2013: ibid).

Due to the fact that most of the geographic data gathered for this project was produced by UN's agency FAO, it was most logical to use as a reference FAO's small/medium/big farms definition. However, these definitions were made taking as a reference Mozambique's rural context. It was therefore very important for us to verify during the visits to the field the suitability of these definitions for rural Kenya. In the *Table 6* we can see the FAO's classification for Mozambique.

Factors	Small farms	Medium farms	Large farms
1. cultivated area	without irrigated land, fruit trees or plantation	<10 ha	≥50 ha
	with irrigated land, fruit trees or plantation	<5 ha	≥10 ha
2. Number of cattle	<10 head	10-50 head	≥50 head
3. Number of head of sheep, goat and pigs	<50 head	50-500 head	≥500 head
4. Number of fowls	<5.000 head	5.000-20.000 head	≥20.000 head

Table 6: FAO's farm classification for Mozambique (FAO 2010: 9)

Photo 8: Small farm (15 hectare) tea plantation
Source: photo by the author

Photo 9: Langstroth hive hanging from an avocado tree at small field (5-10 hectares)
Source: photo by the author

Hence, the present project has as a goal to target small/medium holders who produce commercially (<50 ha without irrigation like the one showed in the pictures above), and smaller farms mainly devoted to subsistence (Photos 8 and 9 were shot in a small farm of 5-10 hectares). In order to identify these holdings within the available spatial datasets the project used FAO's landuse classification for Kenya. In addition to this, the visits to the field have provided this research project with significant elements for the consideration of the criteria. From the visits to the field we have corroborated that medium large and large irrigated fields have normally a corporate commercial oriented production.

Furthermore, the large fields run by agro-industrial multinationals we visited (see photo 10 and 11), although they were very keen on establishing alliances with HCA to incorporate beekeeping to their management programs, they were reluctant or not willing to make public the list of chemicals used in their plots. These were sufficient arguments either to exclude large fields from the suitability criteria or assign them as a constraint to it. Moreover, in interviews with HCA's technicians on the field we were informed that beehives in agro-industrial plantations were not producing as expected.

However, this was a fact that they could not assure it had a relation to the use of chemicals. The pictures below show examples of industrial scale plantations visited during fieldwork.

Photo 10: Agro-industrial enterprise - Avocado plantation, nearby Thika, Kenya.
Source: photo by the author

Photo 11: Agroindustrial enterprise - Macademia plantation, nearby Thika
Source: photo by the author

5.5 Shortcomings and solutions

One important limitation of the analysis is data. As in most of the developing world access to updated and reliable data in Kenya presents numerous challenges.

Geographic databases and geo-referenced datasets which were relevant and updated for this study were not easy to find. This has in many ways determine much of the scope of the present study. The fact of counting with fragmentary data, and/or data which was never gathered and systematized taking into consideration its potential inclusion to a spatial database is a clear limitation that will be later subject of discussion.

Furthermore, the analysis and its results do not inform us much about the dynamics of poverty. It utilizes aggregate data (in some cases rather outdated), and bases its decisions in secondary data, previous empirical studies, and theoretical research. This is a weak point that was to a certain extent addressed through the work in the field. However, although the poverty data considered is more than a decade old, studies like *Understanding poverty dynamics in Kenya* (Kristjanson et al. 2009) suggest that not much change has occur to the poverty patterns in the country in the last fifteen years. According to the mentioned study just 12 per cent of poor households in Kenya managed to escape from poverty in the last fifteen years, while 20 per cent had fallen into it (Kristjanson et al 2009: 986).

Another shortcoming regarding the data for the analysis is the lack of information about beekeepers in Kenya. No national georeferenced database of beekeepers is to be found or easy accessed. This kind of information could add a substantial value to the geodatabase and the potential analysis to be drawn from it.

The visits to the field provided the research with a first hand perception of the conditions on the ground. Through the field dimension it was possible to understand the relevance of the proximity to infrastructure and how determinant this could be to come out of poverty. The same could be said about the elusive concept of small farmer/holder, a category that varies greatly with the context.

Another field that has much potential to contribute with this type of analysis is econometrics of poverty in rural Africa. Econometric analysis are already being applied for understanding the use of forest resources, its relation to environmental degradation, welfare, and poverty.

Finally, the inclusion in this study of the type of crops grown by small and medium holders appeared to be pivotal. Honey bees have preference for specific crops and farmers have their interest in bees pollinating their plantations. In this regard the limitation was again the available data. The generation of a georeferenced data layer with registration of crops per area or plot is a realistic and achievable goal, that could strengthen the suitability analysis in a significant manner.

Some information regarding the crops produced in small plots is already available (FAO's data layers already detailed above) and it was taken into consideration in this study. Moreover, HCA's database has kept detailed records of crop variation for its beekeepers. However, for the consideration of a comprehensive extensive area like former Rift Valley province the information available was too little. Therefore crop variation, although being a very relevant element for this analysis, it was not taken into the model as a stand-alone variable.

Chapter 6 - Conclusions

The GIS based MCE of the study area fits into the realm of development practitioners. For the case of HCA specifically, the analysis provides a broad scale suitability map that could be used as a preliminary selection of villages where to find potential beekeepers. Moreover the incorporation of GIS supplies HCA with a Geographical database, where more data can be added, increasing therefore its potential as an analytical tool.

Relation between the data gathered and impressions of fieldwork, current location of HCA's entrepreneurs, and the results of the analysis, permit us to state that the conceptual model and subsequent analysis arrives to reliable conclusions.

The most suitable areas cover approximately 1% of the former Rift Valley province. Villages within the selected areas were identified and targeted as sites where HCA could look for potential beekeepers. However, taking into consideration the recent finding of underground water reservoirs in the northern region of Turkana, this part of the study area merits a closer inspection. This is open to future prospections.

Moreover, the incorporation of complementary datasets and a consideration of the conceptual model for the assessment of suitability at a greater scale are necessary. These models should in addition take into consideration strengths and limitations of the current model.

Hence, this study and its conceptual model could be the starting point of other analysis which HCA could benefit from. A possible area of expansion might be logistics and commercial viability. A logistic approach based on the present conceptual model could, with some minor adaptations, evaluate the commercial costs of collecting and producing honey in remote and isolated areas of rural Kenya, whereas donors and investors will have the certainty of dealing with an organization that takes the spatial dimension seriously into their risks analysis.

This study aimed to make GIS and MCE methods more accessible to development practitioners. Normally avoided due to the need of special and often costly expertise, the utilization of GIS tools and MCE methods for decision-making is not as much practiced as it could be.

The GIS based MCE and the consequently produced SDSS could contribute to future research in the field of development as the means of an accessible database where datasets can easily been retrieved and used for other purposes.

Furthermore, the study reviewed important references within the subjects of poverty alleviation, development, econometrics, MCDA, and GIS applications. Scholars interested in these subjects should find here references to many classic and up to date publications dealing with these themes.

Last, the use of participatory methods within development programs in general, and GIS in particular has been a recurrent element to be considered. The presented methodology and its conceptual model can be easily modelled to incorporate such elements. More specifically, the hereby applied AHP method has been successfully used for decision making involving several stakeholders before. Its virtues and limitations were already discussed. Thus, the further systematization, standardization and accessibility of the data could facilitate a more open participation and integration of the local groups in future endeavours.

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Appendix 1: List of villages with max suitability in Rift Valley

Max_Suitability_Villages_Rift_Valley							
LATDD	LONGDD	ADMINCO	THEME	COUNTRY	KENYAVI	OBJECTID	NAME
-0,42	36,07	1	PRK	KE	37	8	ABERDARENA TIONALPARK
-0,42	36,07	1	PRK	KE	38	9	ABERDARENA TIONALPARK
1,82	35,42	8	CMP	KE	60	15	ABRAHAMSCA MP
-0,57	35,97	8	MFG	KE	110	22	ADIMASAWMI LL
-1,38	34,78	8	MKT	KE	464	170	ANGATABARA GOI
-1,38	34,78	8	AREA	KE	467	173	ANGATALOITA
0,82	35,42	8	STM	KE	606	212	AROBOBUCH
0,82	35,42	8	STM	KE	607	213	AROBOBUCH
1,07	36,77	8	HLL	KE	1046	346	BAUWA
1,07	36,77	8	HLL	KE	1047	347	BAUWA
-0,18	35,63	8	HLL	KE	1199	385	BLACKETT MOUNT
-0,3	36,08	8	ADMD	KE	1307	406	BONDENILOC ATION
-0,35	35,75	8	STM	KE	1949	514	CHAWACHI
0,53	35,75	8	FRST	KE	1967	522	CHEBARTIGO NFOREST
0,53	35,75	8	FRST	KE	1968	523	CHEBARTIGO NFOREST
1,15	35,15	8	STM	KE	2000	552	CHEBO
-0,93	35,13	8	PND	KE	2028	574	CHEBUGONDA M
-0,9	35,1	8	PND	KE	2284	758	CHEPSEMBEI DAM
1,85	35,45	8	FORD	KE	2313	782	CHEPTERRFO RD
1,85	35,45	8	FORD	KE	2314	783	CHEPTERRFO RD
0,05	35,7	8	AREA	KE	2404	858	CHESOLOP
-2,62	37,18	8	LK	KE	2617	909	CONCH LAKE
-0,3	36,08	8	HLL	KE	2627	914	CRESCENTHIL L
-2,68	37,23	8	AREA	KE	3640	1178	EMPAASH
-2,68	37,27	8	AREA	KE	3641	1179	EMPAASH
1,15	36,58	8	PND	KE	3826	1305	ENGARENARO K
1,15	36,58	8	PND	KE	3827	1306	ENGARENARO

LATDD	LONGDD	ADMINCO	THEME	COUNTRY	KENYAVI	OBJECTID	NAME
							K
-1,45	35,07	8	AREA	KE	3892	1356	ENKIU
-2,7	37,25	8	SWMP	KE	3897	1361	ENKONGONAR OK
-2,7	37,25	8	SWMP	KE	3898	1362	ENKONGONAR OK
-2,7	37,27	8	HTL	KE	3899	1363	AMBOSELISER ENALODGE
-2,7	37,27	8	HTL	KE	3900	1364	AMBOSELISER ENALODGE
0,03	35,58	8	EST	KE	3976	1420	EQUATOREST ATES
-0,47	36,07	1	HLL	KE	4304	1527	GACHIREGEB A
-0,47	36,07	1	HLL	KE	4305	1528	GACHIREGEB A
-0,43	36,08	1	PPL	KE	4376	1537	GAKANGA
-0,32	36,03	1	SCH	KE	4625	1555	GATARWA
-0,13	35,6	8	STM	KE	5158	1626	GITHEE
-0,32	36,07	8	HLL	KE	5830	1717	HONEYMOON HILL
1,13	36,63	8	AREA	KE	6109	1773	ILBARTUK
0,72	35,82	8	PPL	KE	6502	1968	ISSA
0,72	35,82	8	PPL	KE	6503	1969	ISSA
0,72	35,82	8	ADMD	KE	6973	2042	KABARKEBOS UBLOCATION
1,65	35,77	8	BLDG	KE	8029	2422	KALOSIA
1,65	35,77	8	BLDG	KE	8030	2423	KALOSIA
1,65	35,77	8	BLDG	KE	8031	2424	KALOSIA
-2,63	37,23	8	AREA	KE	8361	2529	KAMPIYANDO VU
-0,4	36,08	1	AREA	KE	8745	2638	KANJORA
-0,4	36,03	8	EST	KE	8817	2651	KANYAMWI
-0,3	36,08	1	STM	KE	8858	2661	KANYIRIRI
-0,03	35,37	8	STM	KE	8941	2680	KAPARUSO
-0,03	35,37	8	STM	KE	8942	2681	KAPARUSO
0,57	35,78	8	STM	KE	8950	2687	KAPCHEBU
0,62	35,8	8	PPL	KE	8963	2697	KAPCHEPKOR
1,03	35,32	8	MKT	KE	8975	2709	KAPCHOROR
-0,9	35,1	8	ADMD	KE	8983	2717	KAPCHUMBES UBLOCATION
1,13	35,15	8	STM	KE	9148	2853	KAPOLET
1,08	35,15	8	STM	KE	9187	2883	KAPSARA
0,62	35,8	8	ADMD	KE	9288	2963	KAPTERESUB LOCATION
0,6	35,52	8	AREA	KE	9289	2964	KAPTERIK
1,13	36,78	8	HLL	KE	9563	3063	KARISIA

1,13	36,78	8	HLL	KE	9564	3064	KARISIA
0,63	35,52	8	CTRF	KE	10631	3360	KESOP
0,63	35,52	8	CTRF	KE	10632	3361	KESOP
0,63	35,52	8	CTRF	KE	10633	3362	KESOP
0,73	35,82	8	FRST	KE	10645	3371	KETNWANFOREST
0,73	35,82	8	FRST	KE	10646	3372	KETNWANFOREST
0,62	35,8	8	STM	KE	11064	3431	KIBEREGET
-0,77	35,48	8	HLL	KE	11101	3443	KIBIOSI

LATDD	LONGDD	ADMINCO	THEME	COUNTRY	KENYAVI	OBJECTID	NAME
-0,77	35,48	8	SCH	KE	11102	3444	KIBIOSI
-0,08	35,45	8	AREA	KE	11224	3482	KICHUTMO
-0,08	35,45	8	AREA	KE	11225	3483	KICHUTMO
-0,57	35,35	8	FLLS	KE	12056	3643	KIPINIKWEFALLS
-0,55	35,38	8	SCH	KE	12090	3661	KIPKIYEN
-0,22	35,58	8	STM	KE	12097	3667	KIPKOYO
-0,78	35,53	8	AREA	KE	12122	3691	KIPMUKUL
-0,78	35,52	8	MKT	KE	12123	3692	KIPMUKUL
0,73	35,82	8	MKT	KE	12183	3740	KIPSORAMON
-0,03	35,37	8	STM	KE	12193	3750	KIPTARIET
-0,43	36,08	1	AREA	KE	12441	3825	KIRURUMI
0,07	35,7	8	ADMD	KE	13431	4085	KONASUBLOCATION
1,05	35,47	8	ADMD	KE	13530	4125	KORELACHSUBLOCATION
1,05	35,47	8	ADMD	KE	13531	4126	KORELACHSUBLOCATION
-0,63	35,6	8	PPL	KE	13545	4131	KORIKABEMITIK
-0,3	36,08	8	PPLX	KE	14420	4338	LAKEVIEWESTATE
-0,3	36,08	8	PPLX	KE	14421	4339	LAKEVIEWESTATE
-0,35	36,07	8	STM	KE	14473	4367	LAMURIAK
-0,35	36,07	8	STM	KE	14474	4368	LAMURIAK
-0,3	36,13	8	RSTN	KE	14476	4370	LANET
0,32	36,32	8	AREA	KE	14522	4399	LARIAKSETTLEMENT
0,6	35,77	8	SCH	KE	14619	4459	LELEAN
1,08	36,68	8	STMI	KE	14689	4520	LEMUS
0,05	36,28	8	SPNG	KE	14928	4665	LILIBETO
1,2	36,65	8	AREA	KE	14999	4686	LMINCHOOMINYI
-2,68	37,3	8	SWMP	KE	15083	4747	LOGINYA LAKE

LATDD	LONGDD	ADMINCO	THEME	COUNTRY	KENYAVI	OBJECTID	NAME
-2,68	37,3	8	SWMP	KE	15084	4748	LOGINYA LAKE
-2,68	37,3	8	SWMP	KE	15085	4749	LOGINYA LAKE
1,93	35,37	8	AREA	KE	15276	4916	LOKWIEN
1,93	35,37	8	AREA	KE	15277	4917	LOKWIEN
-1,52	35,03	8	AREA	KE	15300	4936	LOLDOBAI
-1,52	35,03	8	AREA	KE	15301	4937	LOLDOBAI
-1,52	35,03	8	AREA	KE	15302	4938	LOLDOBAI
-1,52	35,05	8	HLL	KE	15303	4939	LOLDOBAI
-1,52	35,05	8	HLL	KE	15304	4940	LOLDOBAI
-1,52	35,05	8	HLL	KE	15305	4941	LOLDOBAI
1,2	36,7	8	RKS	KE	15309	4945	LOLE
1,13	36,65	8	AREA	KE	15318	4954	LOLGUCHANI
1,18	36,58	8	PLAT	KE	15649	5214	LEROGHIPLATEAU
1,18	36,58	8	PLAT	KE	15650	5215	LEROGHIPLATEAU
1,18	36,6	8	AREA	KE	15652	5217	LOROK
1,82	35,47	8	STM	KE	15764	5306	LOTONGOT
-0,4	36,08	8	STM	KE	16521	5437	MAKALIA
-1,03	35,27	8	HLL	KE	16994	5488	MANYAT
-1,03	35,27	8	HLL	KE	16995	5489	MANYAT
1,77	35,38	8	AREA	KE	17096	5512	MARAK
1,1	36,7	8	PPL	KE	17100	5515	MARALAL
1,08	36,72	8	PND	KE	17101	5516	MARALALDAM
1,15	36,63	8	RESW	KE	17102	5517	MARALALGAMESANCTUARY
-0,97	35,6	8	PPL	KE	17348	5590	MASANDARE
0,05	35,68	8	AREA	KE	18992	5878	MORINGWO
0,05	35,68	8	AREA	KE	18993	5879	MORINGWO
1,82	35,37	8	STMI	KE	19009	5889	MORTORTH
0,57	35,8	8	FRST	KE	19018	5894	MOSEGEMFOREST
0,57	35,8	8	FRST	KE	19019	5895	MOSEGEMFOREST
-0,68	35,63	7	MKT	KE	19025	5899	MOSOBETI
-0,68	35,63	7	MKT	KE	19026	5900	MOSOBETI
1,85	35,38	8	AREA	KE	19563	6005	MAKUS
1,85	35,38	8	AREA	KE	19564	6006	MAKUS
1,85	35,38	8	AREA	KE	19565	6007	MAKUS
1,85	35,38	8	AREA	KE	19566	6008	MAKUS
1,85	35,38	8	PPL	KE	19567	6009	MUGUS
1,85	35,38	8	PPL	KE	19568	6010	MUGUS
1,85	35,38	8	PPL	KE	19569	6011	MUGUS
1,82	35,4	8	PK	KE	21459	6581	NASOLETPEA

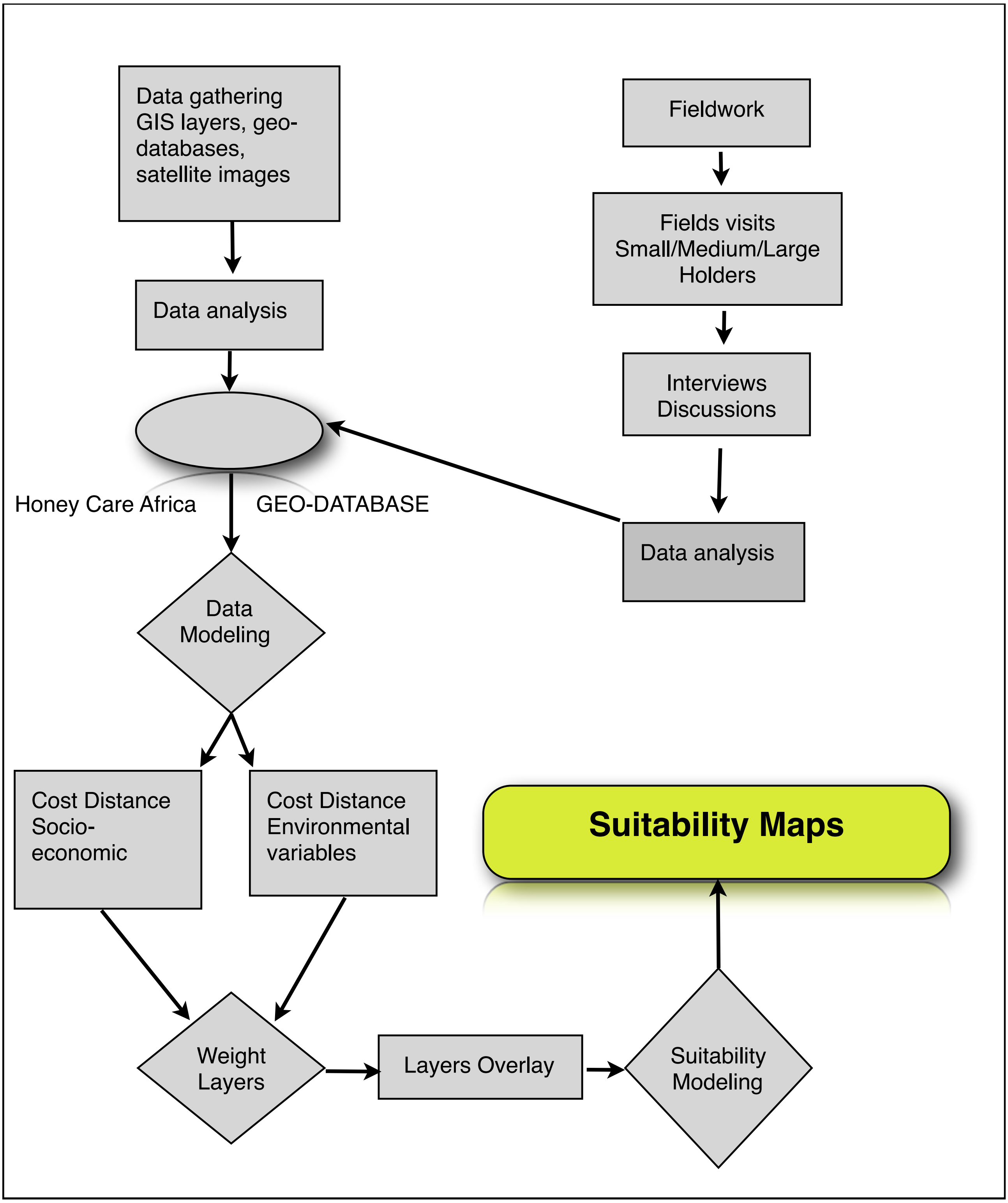
							K
1,82	35,4	8	PK	KE	21460	6582	NASOLETPEAK
-0,08	35,45	7	HLL	KE	21512	6621	NAUMONI
-0,57	35,35	8	STM	KE	21674	6666	NDERBOIWET
-1,53	35,08	8	STM	KE	22113	6806	NGARLANAROK
-1,13	35,07	8	AREA	KE	22462	6953	NGORIONGOLGITENG
1,87	35,45	8	STM	KE	22511	6974	NGUAPET
1,87	35,45	8	STM	KE	22512	6975	NGUAPET
-0,98	35,37	8	HLL	KE	22544	6982	NGULOT
1,13	36,75	8	PND	KE	22628	7002	NGUSORANI
-2,58	37,28	8	AREA	KE	22790	7050	NKIITO
1,15	36,75	8	AREA	KE	22827	7076	NOIKIRIONGWESI
-0,25	35,53	8	STM	KE	23388	7188	DIMBILILIEL

LATDD	LONGDD	ADMINCO	THEME	COUNTRY	KENYAVI	OBJECTID	NAME
-0,25	35,53	8	STM	KE	23389	7189	DIMBILILIEL
-0,25	35,53	8	STM	KE	23390	7190	DIMBILILIEL
0,03	35,58	8	PPL	KE	23509	7205	NYARU
0,03	35,58	8	PPL	KE	23510	7206	NYARU
0,03	35,58	8	ADMD	KE	23511	7207	NYARUSUBLOCATION
0,72	35,82	8	STM	KE	23569	7209	NYIKIM
-1,52	35,08	8	STM	KE	23594	7221	NYONYOR
1,13	36,63	8	RD	KE	24013	7336	OLDBARAGOIROAD
-1,53	35,02	8	HLL	KE	24078	7387	OLEMPITO
-2,72	37,37	8	AREA	KE	24197	7486	OLKELUNYIET
-2,68	37,3	8	SWMP	KE	24199	7488	OLKENYA
-2,68	37,3	8	SWMP	KE	24200	7489	OLKENYA
-0,63	36,23	8	MT	KE	24781	7922	EBURRU OLDOINYO
-0,63	36,23	8	MT	KE	24782	7923	EBURRU OLDOINYO
-0,63	36,23	8	MT	KE	24783	7924	EBURRU OLDOINYO
-0,63	36,23	8	MT	KE	24784	7925	EBURRU OLDOINYO
-2,58	37,23	8	HLL	KE	24826	7939	NTHUKINIHILL
-2,58	37,23	8	HLL	KE	24827	7940	NTHUKINIHILL
1,07	35,45	8	AREA	KE	24849	7954	ORWA
0,57	35,77	8	PPL	KE	25070	8047	PEMWAI
0,57	35,77	8	FRST	KE	25071	8048	PEMWAIFORE

							ST
0,57	35,77	8	FRST	KE	25072	8049	PEMWAIFOREST
1,78	35,4	8	AREA	KE	25111	8076	PHARKAR
1,13	36,72	8	RKS	KE	25251	8160	PUS SOIT
1,03	35,32	8	RDGE	KE	25255	8163	PUSEL
1,18	36,65	8	HLL	KE	25480	8194	REDHILL
1,85	35,35	8	AREA	KE	25498	8197	EREMAI
1,85	35,35	8	AREA	KE	25499	8198	EREMAI
1,8	35,45	8	AREA	KE	25603	8217	RIRITIAN
-3,05	37,7	8	PPL	KE	25672	8238	ROMBO
-1,47	35,03	8	STM	KE	25688	8247	GEM OKEJO
-1,47	35,03	8	STM	KE	25689	8248	GEM OKEJO
1,1	35,12	8	STM	KE	26064	8346	SAIWA
1,13	36,68	8	AREA	KE	26083	8357	SAKUMAI
0,03	35,58	8	RD	KE	26300	8440	SCLATERSROAD
-1,47	35,03	8	STM	KE	26310	8448	SEGANANI
0,6	35,77	8	PPL	KE	26445	8511	SERKONGHUN
0,6	35,77	8	PPL	KE	26446	8512	SERKONGHUN
LATDD	LONGDD	ADMINCO	THEME	COUNTRY	KENYAVI	OBJECTID	NAME
-0,05	35,8	8	FRST	KE	26477	8533	SHABALTARAGWAFOREST
0,05	36,28	8	PPL	KE	26512	8534	SHAMENEI
-2,62	37,18	8	STM	KE	26904	8625	SIMEK
-2,62	37,18	8	STM	KE	26905	8626	SIMEK
0,07	35,68	8	SCH	KE	26935	8643	SINONIN
-0,77	35,48	8	ADMD	KE	27039	8698	SITOTWETSUBLOCATION
1,03	34,75	8	STM	KE	27069	8711	RONGAI
1,03	34,75	8	STM	KE	27070	8712	RONGAI
1,85	35,45	8	AREA	KE	27211	8791	SONGUAT
1,02	34,73	8	MFG	KE	27399	8875	SUAMSAWMILLS
0,58	35,8	8	PPL	KE	27628	8952	TALAI
-1,43	35,07	8	STM	KE	27634	8957	TALEK
0,6	35,52	8	PPL	KE	27644	8963	TAMBACH
1,12	36,73	8	AREA	KE	27655	8965	TAMIYIOI
-3,05	37,7	2	AREA	KE	27747	9007	TAVETA
-0,43	36,08	1	RD	KE	27914	9074	THAINAROAD
-0,43	36,08	1	RD	KE	27915	9075	THAINAROAD
0,05	35,7	8	AREA	KE	27983	9080	THELOI
0,42	35,8	8	PPL	KE	28176	9114	TIMBOIWO
0,42	35,8	8	PPL	KE	28177	9115	TIMBOIWO
0,07	35,48	8	MFG	KE	28182	9120	TIMSALESTIMBOROA
0,93	35,27	8	BDG	KE	28334	9194	TOSETTIDRIFT
0,93	35,27	8	BDG	KE	28335	9195	TOSETTIDRIFT

1,9	35,35	8	HLL	KE	28385	9201	TSONGURU
0,72	35,82	8	FRST	KE	28566	9259	TUTWOINFOR EST
0,72	35,82	8	FRST	KE	28567	9260	TUTWOINFOR EST
1,05	35,42	8	ADMD	KE	29127	9325	WAKORSUBLO CATION
-0,62	35,6	8	SCH	KE	29177	9327	WAMGONG
1,1	36,72	8	STM	KE	29638	9398	YAMO

Appendix 2: Flowchart of the research methods



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