Thesis submitted to the Department of Geomatics and Land Management, school of the Built Environment, College of Engineering Design Art and Technology, Makerere University as partial fulfilment for the award of Bachelor of Science in Land Surveying and Geomatics.

MAY 2018
DECLARATION:

I, Ojok Daniel Angulu declares to the best of my knowledge that the research presented in this report is my own brainchild and that where material is obtained from another source, due credit is given to the originator of the information.

Signature: Date: 10/12/2018

Ojok Daniel Angulu

Mr. Arthur Akanga (Supervisor)

Signature: Date: 10/12/2018
DEDICATION:

This report is dedicated to my parents, Mr. and Mrs. Angulu George, my siblings, Ajok Prossy and Surveyor Ndegeya Stephen and Surveyor Mawere Isaac for all their support during the course of the conception and subsequent preparation of this report.
ACKNOWLEDGEMENT:
I extend my appreciation to my supervisor, Mr. Akanga Arthur for due guidance and time sacrificed. I also acknowledge the Makerere Department of Geomatics and land Management for timely advice during the contacts hours, especially Mr. Mugumya Vincent, Mr. Makabayi Brian, I am forever grateful.
ABSTRACT:
Land use suitability analysis is a process of identifying the most appropriate location and distribution of future land uses (Collins, 2001; Malczewski, 2004). LUCIS is a goal driven model that attempts to derive probable future land-use patterns based on the three-broad land-use categories of agriculture, conservation and urban. LUCIS use analytical GIS models to determine where potential future conflicts may occur between competing land uses.

Wakiso District has been one of the fastest growing places in Uganda over the past two decades. Population expansions driven by sociodemographic, economic and settlement factors is the major cause of land cover change. These changes in land cover due to land use activities lead to a variety of changes in the preference/suitability of land parcels for the different land use categories.

In this study Landsat images (Landsat images) from 1990 to 2016 and LULC maps obtained from the ministry of Agriculture are used as the Primary sources of data. Image pre-processing, image classification (supervised) followed by prediction of future LULC and Future Space conflict diagram for the three major categories of Land uses identified. The results from the subsequent processes are analyzed and interpreted for meaning as regards what the future looks like if current growth and development trends are continued.
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LIST OF ABBREVIATIONS:

LULC : Land Use Land Cover
LUCIS : Land Use Conflict Identification Strategy
MCDA : Multi Criteria Decision Analysis
SUA : Single Utility Assignment
AHP : Analytical Hierarchy Process
MUA : Multiple Utility Assignment
CSD : Conflict Space Diagram
WDPDP: Wakiso District Physical Development Plan
NPHC : National Population and Housing Census
LCM : Land Change Modeler
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1 CHAPTER ONE: INTRODUCTION AND BACKGROUND

1.1 BACKGROUND:
Wakiso District, located in central Uganda has seen rapid growth rates over the last two decades, making it one of the fastest growing districts in the country. This growth is driven by sociodemographic, economic, and biophysical factors.

Table 1-1: Wakiso District Population growth (Adapted from WDPDP 2018-2040)

<table>
<thead>
<tr>
<th>Sex</th>
<th>1991</th>
<th>2002</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pop.</td>
<td>%</td>
<td>Pop.</td>
</tr>
<tr>
<td>MALE</td>
<td>279,866</td>
<td>49.7</td>
<td>440,534</td>
</tr>
<tr>
<td>FEMALE</td>
<td>283,021</td>
<td>50.3</td>
<td>467,454</td>
</tr>
<tr>
<td>BOTH</td>
<td>562,887</td>
<td>100.0</td>
<td>907,988</td>
</tr>
<tr>
<td>SEX RATIO</td>
<td>98.8</td>
<td>90.2</td>
<td>90.5</td>
</tr>
</tbody>
</table>

Wakiso is the most populous district in Uganda; housing 5.8% of Uganda’s population (NHPC2014). The district’s population has been increasing drastically, with a total population of 1,997,418 people (table 3.4) and a population density of 1,060 people per square kilometer. Comparatively, in 2002, the district had a total population of 907,988 people, population density of 560 people per square kilometer and a growth rate of 4.1% (NHPC 2002). The difference in population between 2002 and 2014 transcended into a population growth rate of 6.6% (NHPC2014). This means that in a period of about ten years the densities doubled.

Table 1-2: Wakiso District Urbanization trend 2002-2014(Source: NPHC)

<table>
<thead>
<tr>
<th>Local Govt</th>
<th>2002</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>F</td>
</tr>
<tr>
<td>Municipalities</td>
<td>28,900</td>
<td>28,618</td>
</tr>
<tr>
<td>Town Councils</td>
<td>8,160</td>
<td>8,542</td>
</tr>
<tr>
<td>Sub Counties</td>
<td>425,217</td>
<td>457,843</td>
</tr>
<tr>
<td>TOTAL</td>
<td>462,227</td>
<td>495,003</td>
</tr>
</tbody>
</table>

Wakiso ‘s population was 1,997,418 people in 2014 and is projected to reach 2,419,583 in 2017, 2,930,975 by 2020 and 10,523,404 in 2040 if it were to grow at the annual population growth rate established by the NPHC 2014 of 6.6% and if in- migration persists at the current pace.

1.2 Wakiso Population Projections by growth scenario:
The District Physical Development Plan identifies and analyses the long-term sustainable development of Wakiso District based on three development scenarios. These are:
• Business as usual with the ongoing population growth trend at 6.6% annual growth, accelerated in migration resulting into distinctive mismatch between service delivery and population explosion. This scenario also takes into consideration of the spillage of demand for services from the neighboring districts of Kampala, Mpigi, Mukono, Mityana and a host of others since this was the situation obtaining.

• The ideal scenario where it was assumed that population influx would begin to subside as surrounding districts of Mukono, Mityana, Mpigi and Luwero benefit from the integrated rural-urban development planning, with improved services and infrastructure extended to these districts and urbanization beginning to set therein. Annual population growth in this scenario was set at 3.3% which is the average urban population growth rate (Table 3.6).

• The third was the best-case scenario; whereby focused and deliberate interventions can result into a district that develops in a sustainable, orderly and balanced manner. This is determined at a mid-point annual population growth rate of 5%. Based on the above, alternative development are projected to be as follows:

Table 1-3: Wakiso District Population Projections (Adapted WDPDP)

<table>
<thead>
<tr>
<th>Growth Assumption</th>
<th>2017</th>
<th>2020</th>
<th>2040</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business as usual - (6.6%)</td>
<td>2,419,582</td>
<td>2,930,975</td>
<td>10,523,310</td>
</tr>
<tr>
<td>Ideal scenario - (3.3%)</td>
<td>2,201,760</td>
<td>2,427,007</td>
<td>4,645,937</td>
</tr>
<tr>
<td>Best case scenario - (5%)</td>
<td>2,312,261</td>
<td>2,676,732</td>
<td>7,014,612</td>
</tr>
</tbody>
</table>

Due to these trends it is crucial to project the magnitude and location of future expansion for the region to aid and support sustainable decision making. Visualizing how land-use change will be spatially distributed, and where competing land-use classifications will be in conflict, leads policy makers to examine alternative scenarios and actions for the future of a region.

All this growth if left unmanaged could result in inefficient land use designations. A solution to this problem is the Land-Use Conflict Identification Strategy Model (LUCIS) alongside the District Physical Development Plan, which provides planners, designers, developers, and other community stakeholders a framework to make thoughtful and informed decisions on how to best utilize or preserve land in the study area — now and in the future.

1.3 Land Use Conflict:

Land-use conflict can be defined as the comparison of the level of suitability for each of the differing land-use categories within a given land unit (Carr and Zwick 2007). A land unit is a raster cell that represents at a minimum, one acre. Where a land unit’s suitability metric is equal, land-use conflict is identified. If a specific land-use category has a higher suitability metric for a given land unit than the other categories, then no conflict has been identified. In
this case the land unit should retain its current land-use. Using this approach, the potential land-use conflict can be predicted for the entire region (Carr and Zwick 2007).

1.4 Land Use Conflict Identification Strategy:
LUCIS is a goal driven Geographic Information Systems (GIS) model that produces a spatial representation of where agriculture, conservation, and urban land-use suitabilities will be in future conflict and helps illustrate potential future alternative land-use scenarios (Carr and Zwick 2007).

Land use changes, driven by land use decisions, are the primary cause of natural resources loss and degradation (Beatley, 2000; Wilson, 1999). These impacts to environmental resources are the cumulative result of land use changes over time. Incremental accumulation of singular land use changes and decisions, which on their own may be minor in nature and impacts, can result in unanticipated major environmental impacts on the region (Carr & Zwick, 2007; Theobald, Miller, & Hobbs, 1997). Land use decision making and protection of natural resources must be considered together to sustainably plan for both urban and natural environments.

The power and decision-making authority behind land use changes comes primarily from local governmental legislation in the form of comprehensive plans, policies, and other regulations guiding development patterns (Norton, 2007; Ben- Zadock, 2003; Pierce et al., 2005). Requiring consistency with the comprehensive plan, the stated purpose is to promote development in specific areas to avoid adverse outcomes of unmanaged development such as urban sprawl and environmental impacts (Brody, Highfield, & Thornton, 2006). Visualizing potential growth patterns can lead to a better understanding of the power of independent decisions and their regional impacts as well as show whether policy supports or deviates from identified goals.

One tool to analyze potential growth patterns is the Land Use Conflict Identification Strategy (LUCIS), created by Margaret Carr and Paul Zwick (2007). LUCIS acts as a tool to predict spatial distribution of land use. When used to model future growth it provides a way to “reveal the spatial reality of incremental land-use change” (Carr & Zwick, 2007, p. 5). LUCIS uses GIS to spatially compare suitability for categories of land use – grouped as agriculture, conservation, and urban uses – and determines where spatial conflicts between the suitabilities exist. The concept builds on the idea that suitability reflects appropriateness of the location for that particular land use. Further, the tool assumes areas with low land use conflict but high land use suitability represents optimal location and likely spatial distribution. The LUCIS methodology can be utilized in the modeling of potential growth patterns based on goals identified in the suitability process (Carr & Zwick, 2007).
Land-Use Suitability Analysis is structured as a hierarchy of goals and objectives. The analysis follows the five steps of the LUCIS model:

Figure 1-1: Margarate Carr and Paul Zwick’s LUCIS model framework. (Carr and Zwick 2005)

1.5 Problem Statement:
Rapid growth in the last decade has seen Wakiso become the most populous District in Uganda (Wakiso District Physical Development Plan). More and more new growth is taking the form of Urban sprawl as people make individual land use decisions with short term goals. Despite the recognition of the downsides of sprawl, there is a disconnect between that understanding and the myriad individual land-use decisions made incrementally over time. In other words, there is an inability to see the connection between individual land-use decisions and the long-term spatial consequences of accumulation of those individual decisions.

The normal expectation for this and other areas is that growth will be uncontrolled, sporadic, representing short-term values, with little taste or skill. Slowly nature will recede, to be replaced by growing islands of development. These will in time coalesce into a mass of low-grade urban tissue, having eliminated all natural beauty.

This project embraces the premise that intelligent land-use analysis using a combination of GIS, model builder and LUCIS has the power to clearly and accurately represent the highly probable
consequences of those incremental decisions. Once the magnitude and distribution of the land-use conflict is understood, alternative future land-use and policies necessary to achieve them can be explored.

1.6 Justification:
LUCIS acts as a tool to predict spatial distribution of land-use. When used to model future growth it provides a way to “reveal the spatial reality of incremental land-use change” which provides planners, designers, developers, and other community stakeholders a framework to make thoughtful and informed decisions to examine alternative scenarios and actions now and in the future.

1.7 Research Questions:
- How has land cover changed from 1990-2016 and how will it look in the future?
- What trend has development taken over the years?
- What relationship exists between LC and the identified categories of land use?
- What trend is development likely to take in the future?
- What conflict exists between he different categories of land use in relation to suitability?

1.8 Objectives:
1.8.1 Main Objective:
To identify and analyze future land-use conflict between the identified land-use categories i.e. Agriculture, Conservation and Urbanization.

1.8.2: Specific Objectives:
To predict how land cover and land cover will look in the future.
To analyze suitability and preferences for the different categories of land use.

1.9 Description of the study area:
Wakiso District is located in the central region of Uganda. According to Uganda Bureau of Statistics (UBOS, 2014) census data, wakiso’s population was estimated to be 2,419,582 people and this population has increased by 6.6% between 2002 and 2014(NPHC). It is located at Latitude: 00°24'00"N and Longitude: 32° 28' 57" E and has an elevation of approximately 1200m (3200 ft.) above sea level. Wakiso covers a total area of 1906.7 sq.km and partly encircles Kampala District.
1.10 Organization of the report:
This research proposal report has been arranged into three chapters.

Chapter one entails the general background and introduction to the research, problem statement, objectives and description of the study area.

Chapter two has the literature review that basically contains a summary of the knowledge and methods in fields of studies that relate to the topic of study in this proposal report including drawing from those methods and studies as compared to the proposed method in this proposal report.

Finally, chapter three describes the flow of the methodology to be employed in carrying out the research in order to achieve the set objectives and answer the formulated research questions.
2  CHAPTER TWO: LITERATURE REVIEW

This chapter exposes requisite background information and an established literature review. Geodesign, alternative future analysis, scenario planning, the LUCIS Model, the Analytical Hierarchy Process (AHP), and pairwise comparison are all inspected in the following chapter sub-sections. At a high level geodesign is the theoretical framework that encompasses both alternative futures analysis and scenario planning. The LUCIS model is a tool that facilitates alternative futures analysis and scenario planning processes, and the AHP and pairwise comparison are components of the LUCIS model.

2.1  Geodesign:

Changing geography by design has been an ongoing practice for much of human history. The ancient Chinese built their settlements close to mountains and rivers to manifest their idea of a harmonious landscape (McElvaney 2012). The ancient Arabs built their cities to include narrow streets in order to capture the benefits of shading during the hot summer months (McElvaney 2012). Strategic choices, such as these, have been made consistently over time to ensure human safety and protection, sufficient access to resources, and a potential for future growth. The need to make more calculated, analytical decisions in planning fields has escalated over human history.

Throughout the twentieth century the systematic geographic design and planning methodology, now known as Geodesign, took theoretical shape by drawing from the work of Richard Neutra, Ian McHarg, Carl Steinitz, and others (McElvaney 2012). Inherently geography is concerned with place and processes, and design with the intent of creation, but only recently was the term Geodesign coined by Esri founder and President Jack Dangermond (McElvaney 2012). This key action has become a part of an ongoing initiative to join the theoretical knowledge of urban and regional planning with the systematic, computer-based science practice of GIS to assist designers, planners, and stakeholders in making more well-informed decisions for the future of their respective communities.

As mentioned, the ideologies that collectively form geodesign were forged over time. One of these instances was the groundbreaking work, Survival through Design, published by Richard Neutra in 1954. In the piece Neutra described his approach to design as the marriage of both biological and behavioral sciences. This practice, which he coined bio realism, highlighted the inseparable union of both man and nature, and draws attention to the values of incorporating scientific expertise in community planning and landscape architectural practices. Neutra’s contemporary Ian McHarg was forging similar ideas when he penned Design with Nature in 1969. It was here where McHarg promoted his framework for planning and design that essentially creates harmony between nature and its human inhabitants by considering both environmental and social factors during the decision making process.
2.1.1 Alternative Future Analysis and Scenario Planning:

An integral part of the well-informed decision making process is the ability to quickly evaluate design alternatives, scenarios, and their impacts. Alternative futures analysis and scenario planning have long been practices within the planning and design communities, but recently have become core components of the geodesign process. Alternative futures analysis and scenario planning methodologies have progressed significantly since 1990. In that time a number of studies have been conducted that encompass the current research paradigm, most notably Steinitz’s (et al. 2003) Alternative Futures for Changing Landscapes: The Upper San Pedro River Basin in Arizona and Sonora.

This study was performed by Steinitz and his colleagues from Harvard University’s Graduate School of Design in 2003. The work explored alternative futures of the Upper San Pedro River Basin. While the study produced ten alternative futures as well as a large amount of critical analyses, the overwhelming importance of the study was the illustration of Steinitz’s alternative futures methodology itself.

The overview of the approach is organized by the following; (1) the construction of a literature review, (2) an establishment of the research workflow, (3) a description of how the research is organized and in which manner data is obtained, (4) a brief natural and cultural history of the region, (5) the creation of an inventory of issues to be investigated, (6) identification of scenarios to be generated by the research, (7) assessment of the future impacts of each scenario in terms of land use development, hydrology, vegetation, landscape ecology, species and habitats, and visual preference, and (8) the summarization of the potential impacts and conclusions.

“Alternative Futures “for Monroe County, Pennsylvania study, which was conducted in 1993 by Harvard University Graduate School of Design researchers in collaboration with the Environmental Protection Agency (EPA) and local Monroe County government officials (Steinitz et al. 1994). Researchers concluded that due to natural beauty, recreational opportunities, and improved transportation Monroe County, PA would experience large scale growth over the next three decades (Steinitz et al. 1994). As a result, the county faced difficult decisions that pegged conservation efforts against new urban development. In an attempt to visualize the future, this scenario-based futures study researched growth trends and prepared six alternative futures for the year 2020. These included; (1) following the county’s comprehensive plan, (2) allowing development to be market-driven, (3) pursuing the strategic development interests of each township, (4) adopting a policy of land conservation with an emphasis on outdoor recreational opportunities, (5) concentration of new development in a corridor served by public transportation, and (6) conserving all existing undeveloped land (Steinitz et al. 1994). All models were mapped and used in public engagement efforts to allow citizens to visualize the consequences of each scenario.
“Alternative Futures for the Region of Camp Pendleton, California” was a study performed between 1994 and 1996 by the Harvard University Graduate School of design, Utah State University, the National Biological Service, the U.S Forest Service, the Nature Conservancy, and the Biodiversity Research Consortium (Steinitz et al. 1996). Researchers indicated that the study area was one of the most biologically diverse regions in the United States, and that major environmental stressors on the region were being caused by urbanization. In response, the study explored how rapid growth in the region of Camp Pendleton might influence the biodiversity of the area over time (Steinitz et al. 1996).

To frame the research, future change was modeled at the regional level using six different future scenarios, including; (1) a summarized local and regional plan projected over time, (2) spread pattern of low density growth, (3) spread pattern with conservation strategy, (4) private conservation strategy, (5) concentrating centers of development and new communities, and (6) concentrated growth in a single new city (Steinitz et al. 1996). Stakeholders used the differing models to assess their future development and conservation strategies.

While a small sample of the Geodesign paradigm, these studies exemplify the application and relevance of alternative futures analysis and scenario planning. Through this integrated approach, it is possible to extend traditional planning methods and how geography is viewed by providing innovative contexts and provocative visualization that are steeped in quantitative, science-based methodologies and results. Geodesign, alternative futures analysis, and scenario planning provide a framework for understanding the comprehensive impacts of decisions, allowing decision makers to logically reach conclusions, solve problems, and work towards a more sustainable future.

2.1.2 The LUCIS model:
In essence, LUCIS is a GIS suitability analysis that divides the landscape into three differing land-use classes based on potential future land-use conflict (Carr and Zwick 2005). The model exhibits many of the same theoretical characteristics as geodesign, producing an equivalent to each of Steinitz’s iterations (Table 4). The model was conceptually derived from the life’s work of Eugene P. Odum, a twentieth century ecologist, who defined a simple compartmental model that simulates human impact on the environment through land-use and ecosystem comparison (McElvaney 2012).
The LUCIS model was first introduced by Zwick and Carr in their 2005 paper Using GIS Suitability Analysis to Identify Potential Future Land Use Conflicts in North Central Florida. The paper introduced a six-step process for land-use modeling that included: (1) develop a hierarchical set of goals and objectives that become suitability criteria, (2) collect an inventory of available data, (3) determine suitability, (4) combine suitability to represent preference, (5) reclassify suitability into categories of high, medium, and low, high being the most suitable and (6) compare areas of conflict to determine the quantity and spatial distribution of potential land use conflict. Following their initial publication, Zwick and Carr published Smart Land-Use Analysis: The LUCIS Model through Esri Press in 2007. This full-length text provided breakdown of the LUCIS model from its theoretical framework to individual project implementation strategies. Included with the text was the model itself and sample data to test its functionality. Once the model was officially released, Zwick and Carr’s colleagues and students published a number of studies. These papers exhibited the malleability and cross-discipline relevance of LUCIS. Most notably, Abdulnaser Arafat displayed how LUCIS could be extended to include additional allocation and statistical tools to build a more complex, insightful model in successive papers published from 2010 to 2012 (Arafat 2010; Arafat 2011; Arafat 2012A; Arafat 2012B).

Arafat highlights one of his innovative approaches for extending LUCIS in a highly detailed and analytical piece entitled, Evaluating Accessibility and Travel Costs as Suitability Components in the Allocation of Land Use. Here he offers the ability to automate the allocation of land use process, and provides an alternative workflow for dealing with suitability that differ in criteria.
from typical land use classifications and analyses. For example, the allocation of land use in regards to affordable housing instead of residential housing was specific to this study. With this came a number of factors that augmented the overall LUCIS process, such as travel costs, and required a series of customizations to implement.

Elizabeth Thompson’s Envisioning Urban Growth Patterns that Support Long-Range Planning Goals - A Comparative Analysis of Two Methods of Forecasting Future Land Use Change (Thompson 2010) successfully evaluated the applicability and effectiveness of the LUCIS and FLUAM (Florida Land Use Allocation Method) models. Overall, it was determined that when compared to FLUAM, LUCIS provided a future land-use scenario where a higher population density could be achieved and those population centers would have greater access to future transit.

Emily Stallings’ Using GIS to Evaluate Land Use Conflict and Model Potential Environmental Impacts of Future Development Patterns: A Case Study of Central Florida (Stallings 2010) is a study that completely aligned itself with LUCIS, and stands as one of the main sources of inspiration and guidance for this study. Stallings provided an in-depth walk through of a baseline LUCIS implementation that effectively fills in gaps found in the workflow provided by Zwick and Carr in their 2007 publication. For instance, she offers a methodology for preparing land use data for initial representation mapping and subsequent analysis by using a systematic approach to classify current land use codes within a parcel fabric.

Each of these studies and texts provide extensive insight into varied LUCIS implementation strategies, and core principles such as the use of Single Utility Assignments (SUAs), Multiple Utility Assignments (MUAs), Complex Multi Utility Assignments (CMUAs), and the Analytical Hierarchy Process (AHP). The model as it is implemented in this study is an example of the geodesign framework at a county scale. Spatial decision-making models, such as LUCIS, are effective in managing complex decisions and determining compelling results that are regionally flexible and community based (McElvaney 2012).

2.2 Analytical Hierarchy Process:
The AHP is a multi-criteria decision-making approach introduced by Thomas Saaty in 1980 (Saaty 1980). By utilizing a series of pairwise comparisons, or the process of comparing two or more elements in regards to their general preference, the AHP helps digest subjective and objective information and systematically evaluate that information against specific criteria. The resulting metrics aid decision makers in selecting the best possible alternatives to their complex questions.
The AHP generates a weight for each evaluation criterion based on its creator’s pairwise comparisons. A higher generated weight for one criteria signifies greater importance when compared to its corresponding criterion. The AHP then assigns a score to each alternative in agreement with the pairwise comparisons of the scenarios depending on that specific criterion. Similar to the weighting procedure, a higher score represents superior performance in regards to a particular criterion with respect to a specific scenario. To conclude the process, the AHP calculates an ultimate value score by combining the criteria weights and scenario scores. From the resulting score a final ranking can be conceived from which a decision can be made. The benefit of leveraging the AHP is its ease of use and ability to support a large audience.
CHAPTER THREE: METHODOLOGY

3.1 Materials and Methods:

3.1.1 Materials

3.1.1.1 Data Acquisition
Landsat images will be obtained through the USGS website or Landsat look viewer website using the row and path (171 and 060 respectively) of the study area. These images will be used for obtaining the changes in land cover in the study area.

3.1.1.2 Ground trothing data
In order to assess the accuracy of the classification, a high-resolution satellite image will be used for the ground trothing exercise and GPS points will be collected and used for the trothing.
3.1.2 Methodology

3.1.2.1 Image Pre-processing and processing:
Preprocessing of satellite images is essential and aims at the unique goal of establishing a more direct linkage between data and the biophysical phenomena it represents (Parsa et al., 2016). Pre-processing is accomplished using ArcGIS version 10.0 for geo-referencing, mosaicking and sub setting of the image for the Area of Interest (AOI). Landsat 8 image will undergo spatial sharpening using the panchromatic bands, which will result in a 15m resolution. Meanwhile, Landsat 5 TM and Landsat 7 ETM+ images are in their original 30m resolution. Further image processing analysis is carried out using ENVI 4.0. The image is displayed in natural color composite using a band combination of 3, 2, 1 for Landsat 5 TM and 4, 3, 2 for Landsat 8. Maximum Likelihood supervised classification was performed using several selected regions, and Regions of Interest (ROI) is based on delineated classes of vegetation area, industrial and non-industrial area, water, open space area and farming area.
3.1.2.2  **Land Cover Classification:**
A supervised land cover classification will be performed and this method depends on the person’s prior knowledge about the study area. Therefore, the accuracy is also dependent on the classification skills of the person. Using the RO1 tool in ENVI software, training samples of the land cover classes will be created for each of the images by drawing polygons around the regions of interest. Spectral signatures will also be generated using the selecting training samples.
The maximum likelihood classifier will be used as the classification algorithm. This method is based on the probability that a pixel belongs to a particular class and takes the variability of classes into account by using the covariance matrix. It is a parametric classification algorithm and assumes normal distribution for each feature of interest (Guiying et al., 2012).

3.1.2.3  **Accuracy Assessment:**
Accuracy assessments for the 2001, 2008, and 2015 images were carried out to determine the quality of information provided from the data. If the data are to be used for change detection analysis, it is important to conduct accuracy assessment for individual classification (Behera et al., 2012). Kappa tests are used to measuring the accuracy of classification as the test is able to account all elements in confusion matrix including diagonal elements (Halmy et al., 2015). The Kappa test is a measure between predefined producer rating and user assigned rating, which can be expressed in the formula as:

\[
K = \frac{P(A) - P(E)}{1 - P(E)}
\]

where \(P(A)\) is the number of times the \(k\) raters agree, and \(P(E)\) is the number of times the \(k\) raters are expected to agree only by chance (El-Kawy et al., 2011; Pontius and Millones, 2011). Meanwhile, user accuracy can be defined as the probability of a pixel on the image actually representing a class on the ground. Producer’s accuracy indicates the probability a pixel being correctly classified and is mainly used to determine how well an area can be classified (Pontius and Millones, 2011).

3.1.2.4  **Change Detection:**
This is the process of identifying the differences in the state of a feature phenomenon by observing it at different times. In performing LULC change detection, the post-classification detection method is applied in the IDRISI Selva environment v.17, which involves two classified images to make a comparison to produce change information on a pixel basis. In other words, the interpretation between two images provide will provide changes “-from, -to” information. Classified images from two different data sets are compared using cross-tabulation in determining qualitative and quantitative aspects of changes for periods from 2001 to 2015.
The magnitude of change and percentage of changes can be expressed in a simple formula as follows:

\[ K = F - I \]
\[ A = \frac{(F - I)}{I} \times 100 \]

where K is magnitude of changes, A is percentage of changes, F is first data, and I is reference data (Mahmud and Achide, 2012). Additional, prediction or estimation of LULC changes for 2029 will also use IDRISI Selva environment v.17. This research study will use LULC techniques in remote sensing to determine differences and define the percentage of land use changes within that time, as well as estimation for the next 15 years.

3.1.2.5 Process Modelling:
The utility assignment analyses follow the steps that comprise representation modeling, collectively representing an equivalent to process modeling component of the geodesign framework. At a high level these steps transform the collected data from a series of attribute values contained in their original features, to utility values that will be ranked and assigned to a single land unit (or raster cell). The values created in this process will be plugged into land-use suitability models, which are then executed and analyzed to determine the relative suitability for each goal (CMUA), objective (MUA), and sub-objective (SUA) defined at the study’s onset.

3.1.2.6 SUA(Sub-objectives), MUA (Objectives and goals):
The model has a bottom-up hierarchical structure that begins by determining the suitability of each of the defined sub-objectives (SUAs), which in turn affected the determination of objectives (MUAs), and eventually goals (CMUAs).
Figure 3-1: Example for definition of goals, objectives and sub-objectives for Urban Land-use:

<table>
<thead>
<tr>
<th>Overall statement of intent:</th>
<th>Determine the lands preferred for agriculture, conservation and urban use in Christian County, Missouri. Compare the resulting preferences to derive the most likely locations for future conflict and provide decision support for preferred future land-use pattern.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Urban Land Use</strong></td>
<td></td>
</tr>
<tr>
<td>Statement of intent:</td>
<td>Identify lands most suitable for urban development</td>
</tr>
<tr>
<td>Goal 1</td>
<td>Identify land most suitable for residential use</td>
</tr>
<tr>
<td><strong>Objective 1.1</strong></td>
<td>Determine land suitably located for residential use</td>
</tr>
<tr>
<td><strong>Subobjective 1.1.1</strong></td>
<td>Identify land with high accessibility to employment opportunities</td>
</tr>
<tr>
<td><strong>Subobjective 1.1.2</strong></td>
<td>Identify land with high accessibility to healthcare facilities</td>
</tr>
<tr>
<td><strong>Subobjective 1.1.3</strong></td>
<td>Identify land with high accessibility to parks and recreation</td>
</tr>
<tr>
<td><strong>Subobjective 1.1.4</strong></td>
<td>Identify land with high accessibility to schools and daycare</td>
</tr>
<tr>
<td><strong>Subobjective 1.1.5</strong></td>
<td>Identify land with high accessibility to shopping</td>
</tr>
<tr>
<td><strong>Subobjective 1.1.6</strong></td>
<td>Identify land proximal to emergency services</td>
</tr>
<tr>
<td><strong>Subobjective 1.1.7</strong></td>
<td>Identify land proximal to existing public water and sewer services</td>
</tr>
<tr>
<td><strong>Objective 1.2</strong></td>
<td>Determine land physically suitable for residential use</td>
</tr>
<tr>
<td><strong>Subobjective 1.2.1</strong></td>
<td>Identify soils suitable for septic systems</td>
</tr>
<tr>
<td><strong>Subobjective 1.2.2</strong></td>
<td>Identify soils suitable for roads and streets</td>
</tr>
<tr>
<td><strong>Subobjective 1.2.3</strong></td>
<td>Identify soils suitable for structures with basements</td>
</tr>
<tr>
<td><strong>Objective 1.3</strong></td>
<td>Determine land with property values suitable for residential development</td>
</tr>
</tbody>
</table>

**Single Utility Assignment:**

In order for suitability analysis to be meaningful, all of the layers must be reclassified into similar standard intervals to satisfy Chrisman’s interaction rule for combining spatial data. Carr and Zwick used intervals from one to nine to assign a “range of utility” to each layer, where one is the lowest suitability and nine is the highest. The method proposed in the LUCIS model requires the translation of criterion maps to this common scale whereupon they become single utility assignments (SUA). The level of complexity in determining the range of utility for SUAs
varies depending on the level of measurement of the attribute used to define suitability. It is much easier to assign utility values to interval and ratio data that already have known intervals. With this type of data, it is quite common for the modeler to assign the values (Carr and Zwick, 2007).

Multiple Utility assignment (Objectives):

Once each SUA suitability surface is created for all of the sub-objectives, they are combined to create MUAs. Each MUA is created using the same process, the only difference between them being: the number of SUAs used to derive each MUA, and the weights given to the set of SUAs used in that sub-model. An example of this process is the urban objective that determined lands physically suitable for residential land. The Raster Calculator tool multiplies each input dataset by a weight, derived from the modeler’s intuition, and added them together.

Multiple Utility assignment (Goals):

The relative suitability MUAs (Objectives) are then combined to get the set goal. Each MUA(Goal) will fulfill the goals established during the study’s goal and objective definition phase. The MUAs (Objectives) are multiplied by equal weights and then added together using the Raster Calculator tool.

3.1.2.7 *Ca* Markov simulation of future LULC:

The Markov chain model was presented by a Russian mathematician named Andrei A. Markov in 1970. This model was first used by Burnham for land use modeling (Mishra and Rai, 2016; Parsa et al., 2016). Markov chains are stochastic processes (Halmy et al., 2015; Subedi et al., 2013) and the matrices to show changes between land use categories (based on the basic core principle of continuation of historical development) (Koomen and Borsboom-van Beurden, 2011) and are often used in modeling and simulation changes and trends of LULC (Halmy et al., 2015; Mishra and Rai, 2016; Parsa et al., 2016). The homogeneous Markov model for prediction of land use changes can be mathematically presented as follows (Subedi et al., 2013):

\[ L_{(t+1)} = P_{ij} \times L_{(t)} \]
where $L(t)$ and $L(t+1)$ represent land use status at time $t$ and $t + 1$ respectively. Including $\sum_{m=1}^{m} P_{ij} = 1 (i, j = 1, 2, \ldots, m)$ is the transition probability matrix in a given state.

Practically in IDRISI Selva v.17, this study uses 2001 and 2015 map into Markov chain model to produce the transition matrix changes between the current 14 years, and the process is repeated onto map 2015 and 2029 for future land use to derive the transition matrix changes.

CA-Markov Model will use the 1990, 2000 and 2010 maps to produce a simulated 2017 map, which is important to validate with actual LULC of 2017 map through KIA (Kappa Agreement of Index) approach (Mishra and Rai, 2016; Parsa et al., 2016). Afterwards, the techniques are repeated using the 2000, 2010 and 2017 map to produce a simulated 2030 map.

3.2 Expected Deliverables:

- Future LULC projection maps.
- Space conflict Diagram.
- Visualization of Future land use conflicts.
4 GIS MODEL:
The development of the GIS model was the major part in this work. The presented model aimed at integrating land-use suitability and stakeholder wishes, which can be used as a tool for the decision-making process. As explained in the materials and methods chapter, three major land-use categories were developed: urban, agriculture and conservation. Each of them has been visualized in a scheme in such a way that relationships between goals, objectives and sub objectives can be clearly seen. In addition, the goals, objectives and sub objectives will be described and argued.

The model was developed with the notion to be as complete, accurate and relevant as possible. Furthermore, the model should be operational in the context of Wakiso District conditions. This means that the model should not require huge computer resources, and it should be relatively easy to work with. The current situation of data availability made it difficult to develop the models. Of some desired datasets, it was almost certain that they would not be available in the near future, such as land values. Normally, land value would have been included in the model due to its importance. However, when a dataset will not be available during the timeframe of the project, there was no reason to include it.

4.1 URBAN MODEL:
The first part of the Wakiso District Model that will be presented is the urban model. The aim was to include everything that is important when it comes to urban development. Carr and Zwick (2007) defined it as followed: “This category includes all land-uses commonly found within the umbrella of urban use.

This include residential, office and commercial, retail, wholesale and warehouses, and industrial and institutional uses. Urban parks and recreational areas like golf courses are also included in this category”. All goals and objectives in the Wakiso Model are clearly shown in the URBAN MODEL.

Four goals are particularly stressed in the urban model: Lands most suitable for residential land-use, office/commercial land-use, retail land-use and industrial land-use. All goals were subdivided in two objectives; lands most suitable from both physically and economically point of view. These were then further subdivided in themes that were of relevance for the concerning objectives.

4.1.1 Lands suitable for residential land-use:
The first goal, which aimed at finding lands most suitable for residential land-uses, consisted of two objectives and fourteen sub objectives, as can be seen below. Firstly, it is important to live close to facilities like schools and health care for the vast majority of the population. In general, people prefer to live near one another, and therefore lands proximal to existing residential areas were included.
Furthermore, it is convenient to live close to roads; most activity in Wakiso District is centered along the roads. Recreational areas, such as parks and cultural or historical sites, were also found preferable to live close to. It is cost-effective to have residential areas close to existing public water and sewer services.

Finally, lands proximal to existing office/commercial and retail land-uses were identified as suitable.

Apart from sub objectives dealing with economical suitability, there were also a number of sub objectives describing the physical suitability for residential land-use. Six sub objectives were included to model this type of suitability. First of all, the soil should be suitable to build on. Secondly, the land must be free of potential floods, in order to be a safe place to live. Good air quality, land free from hazardous waste, and an environment free of noise also ensured a safe and convenient domicile.

4.1.2 Lands suitable for office and commercial land-use:
The second goal aimed at finding lands suitable for office and commercial land-use. The sub objectives describing the physical suitability for office and commercial land-use were identical to the ones for residential land-use. For offices, it is important to be located along roads to be easily reachable for customers. To amplify this, a sub objective was included that searches for crossings of major roads, which are even more attractive for offices to be located. Furthermore, it is preferable to develop offices within urbanized areas to increase the chance of success. Finally, areas close to utility services, such as water and sewer services, were identified as preferable concerning cost effectiveness.

4.1.3 Lands suitable for retail land-use:
The third goal was developed to locate suitable places for retail land-use. From physical point of view, there were four considered themes. Firstly, soils should be suitable. Furthermore, lands free of both hazardous waste and flood potentials were defined as suitable. The sub objectives describing the economical suitability were identical to the ones for office and commercial land-use.

4.1.4 Lands suitable for industrial land-use:
The fourth and final goal aimed at finding suitable lands for industrial land-uses. When looking at physical suitability, lands should be free of flood potential. Concerning economic suitability, there were more elements to take in consideration. In contrast with the other urban development types, it was not favorable to mix industrial land-use with other urban land-uses. It is preferable to develop industry far from residential land-uses. However, lands proximal to roads and existing industrial areas were defined as preferable.
4.2 Agricultural model:
Carr and Zwick (2007) defined agriculture as followed: "This category includes the full range of Agricultural uses and can be customized depending upon one’s region and character of agriculture to be found there " . Agriculture is subdivided in four goals, and will be described in this paragraph. A visualization of the agricultural model can be seen in figure below. All the goals and objectives that were used in the Wakiso District model were adopted from the Florida case study.

4.2.1 Lands suitable for croplands:
The first goal identified lands that were suitable for croplands; the goal was subdivided in two objectives: physical and economical suitability. Physical suitability was further subdivided in three sub objectives. The first sub objective identified lands with suitable soils for cropland. This is important to ensure good growth of crops. Firstly, existing croplands were located. If lands were currently used for crop production, it should be physically suitable (Carr and Zwick, 2007). Secondly, the topography was also considered for its suitability for croplands. Steep slopes, which makes it vulnerable
to erosion. Finally, lands close to water were identified as suitable. Crops need water to grow, which makes lands close to water more interesting than lands far away from water.

Economical suitability was described by a single sub objective, which is proximity to markets. The reasoning behind this is that lands close to markets make it easier to sell produced crops.

4.2.2 Lands suitable for livestock:
The second goal aimed at identifying lands suitable for livestock. Like before, a distinction was made between physical and economical suitability. Two sub objectives were used to describe the physical suitability. As in the first goal, topographical suitability and existing lands of that type of land-use were included.

Economical suitability was subdivided in two sub objectives. The first identified lands close to markets, and the second dealt with lands close to troublesome adjacent land-uses. The smell generated by livestock is undesirable for residential areas and should therefore be positioned away from residential areas.

4.2.3 Lands suitable for timberland:
The third and final goal of the agricultural model aimed at the identification of lands suitable for timberland. Forestry is the recommended land-use for areas with slopes ranging between 22 and 55% (Verdoordt and Van Ranst, 2003). The objectives and sub objectives were again similar to those of croplands. Existing timberland should be identified as well. On the economic side, lands close to markets were identified as suitable.
4.3 Conservation model:
Carr and Zwick (2007) defined conservation as follows: “This category includes lands with some degree of permanent protection with at least a partial conservation mission. These may be publicly owned like national and state parks or forests, wildlife refuges and management areas. They may also be privately owned like agricultural lands protected through conservation easements.” The model is shown in figure below. All the goals and objectives that were used in the Wakiso District model were adopted from the Florida case study. In addition, all sub objectives in the Wakiso District model were adopted.

4.3.1 Lands suitable for protecting native biodiversity:
The first goal aimed at identifying lands suitable for protecting native biodiversity. This was subdivided in three objectives. Existing conservation lands and areas proximate were assigned as suitable for protecting native biodiversity; otherwise they would not have been protected. Areas proximal to existing conservation areas often have the same characteristics, and are therefore also interesting to protect (Carr and Zwick, 2007). However, they are often transformed into agricultural land-uses. These lands should be considered for protection, or to serve as buffer areas around existing protected areas (Farrington, 2008). The second objective identified lands with a relatively low road density. A low road density means fewer disturbances for flora and fauna, and makes it therefore suitable for conservation (Carr and Zwick, 2007). The last objective, which identified lands with high native biodiversity, consisted of three sub objectives. Wetlands and water bodies with high native biodiversity was the first sub objective. Wetlands and other water bodies are of general importance to the Wakiso District biodiversity, and are home to many species, of which some are endemic. Moreover, water bodies should also be protected against overfishing and dominance of exotic fish. The second sub objective identified forests with a high native biodiversity. Large parts of Wakiso District used to be
covered by forest, but when population increased, more and more forest was converted into agricultural lands, or was used for fuel. The forests that are left are of enormous importance to the biodiversity. Conservation, and if possible, expanding these forests, is therefore of great importance.

4.3.2 Lands suitable for protecting water quality:
Water is of great importance; all life on earth depends on it. Two objectives were devised for the identification of lands suitable for water quality protection. The first objective identified lakes, wetlands, rivers and streams with buffers of sufficient size to filter runoff. Native vegetation plays an important role in filtering contaminants and particulates. A buffer of native vegetation around the mentioned features ensures better water quality (Carr and Zwick, 2007; Farrington, 2008).
In addition, the same applied to springs. Native vegetation around springs ensures a better water quality. The motive to separate springs from other surface water features was that springs are usually the primary or significant source, and should therefore get greater protection than other surface water features (Carr and Zwick, 2007).

4.3.3 Lands suitable for protecting important ecological processes:
The first objective for the third goal aimed at identifying lands that are important for flood storage. Three sub objectives were used here; wetlands, rivers and open water, they were all identified as suitable for flood storage functions.
As stated earlier, native vegetation plays an important role in protecting water quality, but it is not limited to that. Especially (native) forests are of key value for the protection of ecological processes. According to Farrington (2008), forest is a key element in the regulation of the climate and river systems, in preventing erosion, and in the carbon cycle. What is left should be protected, and if possible expanded. Therefore, lands that need permanent vegetation cover were included in the second objective describing the protection of important ecological processes.
5 RESULTS AND DISCUSSIONS:

5.1 Creating suitability maps:
As described in chapter three, the first thing that was done was a data inventory. The available datasets were inspected on their content to determine the usability for the various objectives and sub objectives. When the data pre-processing was completed, the models were built in Model Builder. A significant part of the models designed for the Florida case study were adopted and modified to fit in the Wakiso District model. Therefore, the shapefile of Wakiso District was created and then used as reference for extent, cell size and mask. These three environmental settings made sure that the outputs were consistent. Depending on the aim of the suitability analysis, different geo-processing tools were used. Sometimes, a sub objective existed only out of suitable or not suitable, which in case of the model resulted in a map with values of 1 or 9. However, most of the time there was some sort of distance involved, like distance from schools. In that case, the Euclidian distance tool was used.

5.2 Evaluation Modeling:
In this adaptation of the LUCIS model, pairwise comparison and goal weighting analyses were equivalent to evaluation modeling in the geodesign framework. This process weighed and combined the CMUAs for each land-use category to establish final collapsed suitability rasters. Typically, CMUAs are weighted by the AHP using stakeholder rationale. This study differed in its approach due to a lack of resources and access to stakeholder involvement. Instead, CMUAs were weighted equally (with the exception of urban goal 1, identify lands suitable for residential land-use) to accommodate this change. Urban Goal 1 was given a heavier weight to accommodate the growing need to house existing and projected citizens under the assumption that the desire for urban residential land logically outweighs the desire for alternative urban land, such as urban industrial. Because weights were used to determine which goals were valued more than others within a specific land-use type, the preference of urban residential land over other forms of urban land only affected the urban land-use classification.

CMUAs and their derived weights were combined using the Raster Calculator tool to create three final land-use suitability surfaces, one for each classification. This sub-model multiplied each CMUAs (or goals) by their respective pairwise comparison weight and added the results together to produce a single suitability surface for each land-use class.
<table>
<thead>
<tr>
<th>Goal</th>
<th>Description</th>
<th>Suitability Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Agriculture</td>
</tr>
<tr>
<td>Goal 1</td>
<td>Identify lands suitable for croplands</td>
<td>.34</td>
</tr>
<tr>
<td>Goal 2</td>
<td>Identify lands suitable for livestock</td>
<td>.33</td>
</tr>
<tr>
<td>Goal 3</td>
<td>Identify lands suitable for timber</td>
<td>.33</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Conservation</td>
</tr>
<tr>
<td>Goal 1</td>
<td>Identify lands suitable for protecting native biodiversity</td>
<td>.25</td>
</tr>
<tr>
<td>Goal 2</td>
<td>Identify lands suitable for protecting water quality</td>
<td>.25</td>
</tr>
<tr>
<td>Goal 3</td>
<td>Identify lands suitable for protecting important ecological processes</td>
<td>.25</td>
</tr>
<tr>
<td>Goal 4</td>
<td>Identify lands suitable for resource-based recreation</td>
<td>.25</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Urban</td>
</tr>
<tr>
<td>Goal 1</td>
<td>Identify lands suitable for residential land-use</td>
<td>.40</td>
</tr>
<tr>
<td>Goal 2</td>
<td>Identify lands suitable for office/commercial land-use</td>
<td>.20</td>
</tr>
<tr>
<td>Goal 3</td>
<td>Identify lands suitable for retail land-use</td>
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</tr>
<tr>
<td>Goal 4</td>
<td>Identify lands suitable for industrial land-use</td>
<td>.20</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1.0</td>
</tr>
</tbody>
</table>
5.3 Change Modeling:
There were three main tasks that were required to isolate and quantify potential land-use conflict:
(1) remove land within the study area whose use will not change, (2) normalize and collapse suitability results, and (3) combine the normalized and collapsed suitability results to identify and measure areas of conflict.

5.4 Developable Land:
When calculated within a GIS, land-use suitability is an indication of the degree to which any given unit of land (i.e. raster cell) is suitable for a land-use category (Carr and Zwick 2007). But regardless of the degree of suitability found from the application of LUCIS, in reality the uses of certain land units are highly unlikely to change. For instance, there is very little likelihood that a unit of land currently classed urban industrial will be converted to conservation over time. To accommodate this phenomenon a raster mask consisting of existing urban land, open water, and major roads was created. First, urban parcels were converted into raster cells using the Feature to Raster tool and then reclassified using the Reclassify tool. Land units that contained current urban land were reclassified to NoData, and all other land was reclassified to 1. Similarly, a hydrology feature class containing all open bodies of water was converted to raster using the Feature to Raster tool. All lands that were considered open water were reclassified to NoData, and all other land was reclassified to 1. Finally, a major road feature class was converted to raster using the Feature to Raster tool and then reclassified using the Reclassify tool. All land units that contained major roads were reclassified to NoData and all other land units were reclassified to 1. Each mask was multiplied together using the Raster Calculator tool and the resulting surface exposed only developable land within the study area.
5.5 Preference, normalize and collapse maps:
In the next step, suitability was transformed into preference. All goals of the land-use categories were combined into one final map, representing the preference for each land-use category. In reality, this should be done by using weights derived from stakeholders’ wishes, but in this case, all goals were given the same importance. In addition, a development mask was created that contained all current urban, conservation and water areas. The preference maps of the land-use categories are shown below.

To compare the three land-use categories in a fair way, the preference maps were normalized. The maximum value of each of the preference maps was determined, and a raster with that maximum value was created for each of them. Then the preference maps were divided by the corresponding raster with the maximum values. This resulted in three new maps with values between 0 and 1. Collapsing the maps was the next step. Standard deviation was used to create three preference classes: low, medium and high preference. A development mask (shown above) was used to exclude areas that were already permanently designated, such as open water, conservation areas, and urban areas. At this point, it became possible to compare the different land-use categories. The collapsed preference maps are shown below. Finally, two more maps were developed, showing intensity of conflicts, conflicts between land-use categories, and areas that have one preferred land-use type.
The strength of mapping “collapsed suitability” is that suitable values may be easily combined to show different relationships among the three categories (Carr and Zwick 2007). Collapsed suitability surfaces did not differ greatly from before they were normalized, collapsed, and limited in size, but a more refined picture of where land-use classes were suitable and at what magnitude was clearer.
Combination of rasters to form 27 unique conflict categories

Reclassification of rasters to collapse normalized preferences into three categories: (1) low, (2) medium, and (3) high preference

Normalized preference rasters
CONFLICT SPACE DIAGRAM
Showing conflict classes

Legend
Areas_of_LandUse_Conflict
Value
- Urban/Conservation conflict
- No Conflict
- Major conflict
- Urban/Agricultural conflict
- Agriculture/Conservation conflict
- Area excluded by development mask
5.6 TIME SERIES ANALYSIS:
5.6.1 LULCC Maps:
The accuracy assessment resulted in an overall accuracy of 90.1%, 87.5%, and 92.4%, and 93.3% for 1990, 2000, 2010 and 2017 LULC maps (Figure) below, respectively. The most significant changes in both periods (1990–2000 and 2000–2017) is the transitions from vegetation to urban areas. Over 20 years, from 1990 to 20010, vegetation lost 16% to urban. This indicates the increased conversion of vegetated land for urbanization purposes, especially during the last decade in Wakiso District.
5.6.2 Transition Potential Modeling:
The LULCC results indicated two significant changes to urban areas: from vegetation and from water, consequently, both were the model’s major transitions. Both transitions to urban areas had the same driving forces, depending on the visual examination of the urban spatial trend, which indicated that the selected predictor variables affect both of them.

![Potential Transition 2000 to 2010](image)

5.6.3 Model Validation:
The validation process aims to determine the quality of 2017’s predicted map in relation to 2017’s LULC map (the map of what exists in reality). There are two endorsed approaches to validate a model: the visual and the statistical approaches. In the visual validation, a three-way cross tabulation between 2010’s LULC map, 2017’s predicted map, and the map in reality was run to illustrate the accuracy of the model results.

The visual validation of the simulated change in 2017 resulted in a map of correctness and error. The map consists of 1.4% hits, 54.5% false alarms, and 44.1% misses. The simulated change is 6.61% of the landscape, less than the observed change, which is 7.71% of the landscape.
(1) Hits: Model predicted change and it occurred in reality.
(2) False alarms: Model predicted change to urban areas while it persisted in reality.
(3) Misses: Model predicted persistence and it became urban in reality.
(4) Null success: Model did not predict change and it did not occur in reality.

On the other hand, Kappa variations that compared the projected LULC in 2017 with the actual LULC map in 2017 resulted in Kno and Klocalion of 0.4444 and 0.7489 respectively. The interpretation of these low values is that the majority of the study area experienced change, as, even with the new urban communities that were constructed in Wakiso District areas during the last 25 years (from 1990 to 2017), formerly vegetated area forms the major land cover that was subjected to high urbanization during this period. Because of this, it was essential to perform the visual validation throughout the FOM test, as, although Kappa coefficients obtained in this study are above 0.7489, comparing both results reveal the fact that the correct localization of the projected LULCC in areas of change is more pronounced than that in areas of no change. However, Kappa statistic results are more promising than visual validation.

5.6.4 LULC Map Prediction for 2030:
The changes between 1990 and 2017 were modeled using the real LULC maps in order to predict the LULC map of 2030 with a different prediction period (13 years). Fourteen percent of the vegetation and 0.8% percent of the water in 2017 are expected to transition to urban areas in 2030. Urban expansion has boomed over 25 years, from 1990 to 2017, and the modeling results confirm that it will be increasing to 2030. The urban areas were 27728,92087,137794 and 256,937 hectares in 1990, 2000, 2010 and 2017, representing 6.18%, 20.53%, 30.72% and 57.282% of the total area of Wakiso District, respectively. In 2030, according to the model estimations, the urban areas in Wakiso District will expand to 68.26% hectares. This vast planned and unplanned growth is a serious driving force towards the conflicts between the land use categories (Urbanization, Agriculture and Conservation).
5.7 VISUALIZATION OF FUTURE AND USE CONFLICTS:
In order to visualize where exactly the land use conflicts between Agriculture, Urbanization and Conservation is most likely to be situated/located, the projected LULCC map of 2030 was overlaid with the Space Conflict Diagram. with the Space Conflict Diagram. the Space Conflict Diagram. with the Space Conflict Diagram.
After a more detailed view of the location of future land-use conflict, it became more evident that urban suitability dominates the landscape when compared to the other aggregated conflict categories. This can be observed in the next largest category in acres being agriculture/urban conflict, exposing that not only was the majority of land suitable for potential urban development, but that the majority of land that may be suitable for agriculture also possess high urban suitability. This also has an effect on the amount of land that was agriculture preference dominant. If most of the suitable agriculture land was in conflict with urban land, then agriculture preference dominant land would be expected to be limited. The smallest portions of acreage in conflict belonged to agriculture/conservation, major conflict, and agriculture preference.

It can be observed that the majority of the study area holds urban preference. This was especially true along major highways and the limits of lands close to Kampala city where the largest concentration of existing urban land is located. But around the outer ring of this space some intermittent conservation and agriculture land was preferred. This may be because of the location of wetlands, Central forest reserves, streams and existing open or wooded land.

6 CONCLUSIONS:
This study was performed to detect and analyze the potential future land use conflicts Wakiso District using the various factors that determine land use trends in the study area. Time series Analysis in the study area over a period of 27 years, from 1990 to 2017 was used to model the changes to estimate the LULC in 2030. Four Landsat scenes obtained in 1990, 2000,2010 and 2017 were classified using Maximum Likelihood classifier. LULCC detection was performed and the results show that, from 1990 to 2000, 8% of the vegetation was lost to urban areas, and 13% was lost between 2000 and 2017.

The transitions from vegetation and water to urban were modeled using LCM, with the driving forces: distance to road network and distance to existing urban areas. These factors were considered in similar studies and proved to dominate the urbanization for future scenarios. Areas with a high road density clearly represent high tendency to become urban, and areas of low road density are most unlikely to become urban. From the visual inspection of the LULC maps, it was clear that new built-ups tend to be near the existing urban areas and road networks, to make use of the available infrastructures, services, and facilities.

To validate the model, the simulated 2017 map was examined against 2017’s real LULC map, applying both visual and statistical approaches Kappa statistics, respectively. Kappa coefficients (Kno and Klocalion) were below 90% because the majority of the study area experienced change. The results highlighted the problem of insufficient predicting variables and modeling both transitions (from vegetation and water to urban) using the same driving forces (distance from road networks and distance from urban areas), as the majority of the misses occurred in the new built-ups in the formerly vegetated areas that turned to urban areas. The projected 2030 LULC map estimates an urban transition of 11% from vegetation and 2.6% from water, between 2017 and 2030 respectively.
REFERENCES:


