UNIVERSITY OF NAIROBI

COLLEGE OF BIOLOGICAL AND PHYSICAL SCIENCES

SCHOOL OF COMPUTING AND INFORMATICS

DIGITAL MAPPING OF FOOD BANKS IN KENYA

CAROLYN WANGARI KAREGA: P54/6317/2017

Supervisor

CHRISTOPHER MOTURI

A research project report submitted in partial fulfillment of the requirement for the award of Master of Science in Information Technology Management of the University of Nairobi

May 2019

DECLARATION

This project is my original work and to the best of my knowledge this research work has not been submitted for any other award in any University.

Signature ________________________________ Date ______________

Carolyne Wangari Karega
P54/6317/2017

This project report has been submitted in partial fulfillment of the requirement of Master of Science in Information Technology Management of the University of Nairobi with my approval as the University supervisor

Signature: ________________________________ Date: ______________

Christopher A Moturi
Director ICT Center
University of Nairobi

DEDICATION

This project is dedicated to my Family, my daughter Brilliant, my dear parents and siblings.

Your love, motivation and patience have kept me going.

ACKNOWLEDGEMENT

I am indebted to all those who helped, inspired and supported me to complete my studies.

Firstly I thank the almighty God for the good health during my study, financial blessings to pay my fees among others and strength to keep on going against all odds.

My sincere gratitude goes to my supervisor Mr. Christopher Moturi and Dr. Daniel Orwa for his advice. The dedication and commitment to ensure that I stay on the right path of research was highly noted and appreciated.

I am thankful of my family for being there for me even when I had less time for them. I also give thanks to the School of Computing and Informatics lecturers who gave their knowledge to educate and advise me on various aspects of my study.

Finally, I thank the School of Computing and Informatics community, for giving me a favorable environment to successfully carry out this study

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

AHP: Analytical Hierarchical Process

API: Application Programming Interface

FRAmework for Sensor Application Development

GDP: Gross Domestic Product

GIS: Geographical Information Systems

GPS: Global Positioning System

ICT: Information Communication Technology

IoT: Internet of Things

IP: Internet Protocols

KACE: The Kenya Agricultural Commodity exchange

MCA: Multi Criteria Analysis

MDA: Model Driven Architecture

MDG: Millennium Development Goals

NCPB: National Cereals and Produce Board

NFC: Near Field Communication

NFP: National Food Policy

NGOs: None Governmental Organizations

OWA: Ordered Weighted Average

PCs: Personal Computers

QGIS: Quantum Geographic Information System

RFID: Radio Frequency Identification

SGR: Strategic Grain Reserve

SOA: Service Oriented Architecture

UWB: Ultra-Wide Band

WSN: Wireless Sensor Network

DEFINITION OF TERMS

Analytical Hierarchical Process - is one of Multi Criteria decision making method used to derive ratio scales from paired comparisons.

Geo- Analytics - Location-based data, combined with powerful analytics, puts a wealth of information at your fingertips which is a foundation of smart decision making.

Geo-coding - providing geographical coordinates corresponding to a location
Geocoding -This is the process of attaching location coordinates to an address. (Michael, et al., 2004)

Multi Criteria Analysis – it is applied to many complex decisions in solving problems characterized as a choice among alternatives.

Spatial Data- Is the geographic location representation data of a component (Goodchild, et al., 2005)

Spatial Interpolation- Spatial interpolation is a GIS mathematical method of estimating values at geographic locations where no values have been provided by using values known at a certain location (Azpurua & Ramos, 2010)

ABSTRACT

This research presents a case study of food banks for local level use to help identify suitable geographic location areas with inadequate distribution of food aid. Kenya is affected by periodic drought seasons, which have a profound effect on seasonal food crises. Inefficiency in the food distribution system may be hindering the realization of the full benefits of food bank programs. This study was rooted in food aid distribution problem arising in Kenya, and the solutions provided can be applied to other developing countries. The aim of the study was to investigate and demonstrate food bank distribution by using GIS technology. The methodology employed included determination of various criterion for each of the four involved fields and a criterion for suitability was determined for each of the factors. By using Analytic Hierarchy Process (AHP) pair-wise comparisons, each criterion was assigned a weight with rainfall being considered as the most important factor. Weighted overlay analysis was performed in ArcGIS and determination of suitable food bank site was done from the summation of weight of each contributing factor. The final suitability map for proposed food banks was obtained from the results of integration of the four suitability maps. From the results, it is evident that integrating GIS with AHP Multi-Criteria Decision Analysis has been successful in arriving at a suitable food bank locations. Bearing in mind that weight assignment affects the overall results, determining which weights to be given to a certain factor is an individual judgment which is subjective and therefore may be bias was the limitation noted in the study. The study will be beneficial to needy citizen, policy makers/Government and researchers and recommends adoption of this criteria by the NGO’s in setting up future food banks as it guarantees accuracy and an easier decision making process for suitable location and effectively making use of GIS as decision support system. The major limitation was determining which weights to be given to a certain factor is an individual judgment which is subjective and therefore may be bias bearing in mind that weight assignment affects the overall results and having no similar studies done of Kenyan food banks within the study area hence no validation of the resulting suitability map.

Keywords: Food Distribution, Geographic Information Systems (GIS), Food Banks, Food Security.

CHAPTER ONE

INTRODUCTION

1.1 Background

Agriculture is a major sector in all African countries with Kenya accounting up to 40% of the total Gross Domestic Product (http://www.fao.org/kenya/fao-in-kenya/kenya-at-a-glance/en/). Despite this importance, the agriculture sector in Kenya has continuously been faced with food insecurity (https://www.usaid.gov/kenya/agriculture-and-food-security).

About 795 million people worldwide face hunger World Food Programme (www.wfp.org/hunger/stats). Across the world, a lot of food goes to waste in homes, restaurants, supermarkets and retail shops while many people are sleeping hungry as they cannot afford a meal (Schneider, 2013). Food Banks can be used to store such foods to be distributed later to the needy. Food banks promote generosity and volunteerism within individuals and corporations. Food banks are typically food storage areas and distribution depots that acquire food, distributors, retail sources, farmers, and consumers which is later distributed through established community agencies. Foods such as fruits, whole grains, lean proteins and vegetables are donated.

Digital mapping/cartography is the process by which a collection of data is compiled and formatted into a virtual image producing maps that give accurate representation of any object under review. Emeribeole & Iheaturu (2015) review advantages provided by digital mapping such as: saving time and the gain of productivity, cost saving, more credibility and authority of map production, better service, high accuracy and high consistency. These advantages can overcome the disadvantages of digital maps which are: cost-effective in some cases and requires advanced analysis tools. Digital maps are increasingly embedded within everyday practices, situated within a complex array of connected technologies: web mapping services output digital cartography via popular web map engines like Google and Bing Maps which, in turn, sit embedded on websites (Hanchard, 2000). Recent advances in processing and software technologies afford sophisticated cross-platform digital maps, ranging from popular web maps, e.g. Google Maps (including the realist Street View function) and associated API. The development of Ajax (Asynchronous Javascript and XML) alongside other Rich Internet Applications (RIAs) enables easy embedding of content within a webpage without the need to reload a page, or re-run search queries (Ying and Miller, 2013).

Digital mapping is used in diverse application that include travel planning (Rasmussen et al., 2008); learning (Mercier & Rata, 2017); land use and land cover, soil data, weather parameters, crop variety distribution (Golhani, Rao & Dagar, 2015). In the field of cartography, researchers have developed strategies for "keeping pace with evolving web mapping technologies" (Roth, et al., 2014), but Roth later argues that teaching fundamental concepts is of higher importance in a geography curriculum than focusing on the details of individual technologies (Roth, 2016)

Kenya is an emerging nation that aspires to participate fully and become a key player in emerging e-agriculture to have in place digital mapping systems that will improve the food insecurity issue. To face these challenges, there has been a growing activity around the use of digital technology for agricultural development to address the knowledge gaps. Mobile phones and internet have been introduced in rural areas as a means of improving productivity, access price and market information (Duncombe, 2016).

Kenya receives more bilateral aid than multilateral aid. Also the type of food aid distributed most in Kenya is emergency food aid. Kenya as a country has a higher number of bilateral food aid donors than multilateral. Food insecurity in Kenya can be attributed to a series of problems namely: poverty, climatic changes, poor policy implementation, political instability, and social and economic crisis and hence distribution should be carried out in an effective and accessible manner. The reliance on paper-based procedures to register the aid that beneficiaries receive is time consuming and costly to audit and ensure against inaccuracies, loss or theft. To redress these notable gaps in food distribution, NGOs are currently partnering with key players in the IT sector and designed software's for example Last Mile Mobile Solution (LMMS) software. The software is now being used to streamline the process of beneficiary registration, accountability and distribution of food aid. Distribution efforts are complex but entail sourcing /provision of transport facilities, identification of impact distribution points, deciding on the quantities to be distributed, personnel, ration size, the beneficiaries and the actual distribution exercise. There are various inputs and players who are the facilitators, actors, beneficiaries) and hence possibilities of the presence of challenges. Relief food distribution system in Kenya is face with shortcomings such as lack of participatory role of the community in engaging more actively in decision making processes and implementation of the relief food distribution programs. Lack of proper planning, implementation, monitoring and evaluation strategies in food distribution activities has resulted in little impact on improvement of food security. This is evidenced by the poverty levels in the country and the level of relief dependence.

1.2 Problem statement

Food banks potential and limitations to decrease the prevalence of food insecurity will provide a representative picture of the Kenyan food banks to its users by mapping publicly accessible data on the geographical map. Kenya does not have adequate digital mapping systems to address food insecurity. Several existing studies have focused on agricultural market information as compared to digital mapping systems (Okello, Makoka and Kachule, (2013); Chim'gonda-Nkhoma, (2013); Katengeza, (2012).

1.3 Objectives

1. Identify the most suitable ICT technologies in food security.
2. Establish the distribution gaps in food banks in Kenya.
3. Generate a suitable food bank mapping using GIS.
4. Showcase digital map of food banks in selected areas.

1.4 Research Questions

1. How is technology applied in food security
2. What distribution gaps are in Kenyan food banks?
3. How can GIS be used to digitize food banks location.
4. How can digital maps be used to showcase foodbanks in selected areas.

1.5 Rationale of Study

The study aims to demonstrate suitable digital mapping system with data using GIS for easier accessibility in times of calamities. The food security policy makers will obtain knowledge and get guidance in designing appropriate policies in regulating food distribution and enhance food security in the country. The needy citizens know how they can access food aid in the nearest food banks to their location.

The study will also assist the government to focus on the current distribution of food banks, and analyze the suitable locations that would be appropriate with recommendations given on how they can assist the marginalized communities in famine stricken areas in Kenya.

1.6 Scope of the Research

The scope of this research was limited to analysis of the current food banks in Kenya data, GPS location of the food banks and how they are distributed in the country. It looked at the socio economic and demographic data within Nairobi County where the food banks are situated. Emphasis was laid on the distribution of the food banks against the rainfall and crop intensity within the country.

CHAPTER TWO

LITERATURE REVIEW

This chapter expounds the role of ICT in food security, how food banks are beneficial in food security and the models that were used to get suitability of the food banks.

2.1 Introduction to GIS

The power of pooling high-resolution satellite imagery, geospatial information, and particularly census and statistical information for decision making and policy formulation has been recognized. Accessibility to such information is seen as an important development tool (Galigeo, 2012). Maps have been the most basic tool for people to view geospatial data. Rapid advances in geospatial information technology enable suitable access and integration of information that is location-based. This in turn has facilitated nations and leading organization when conducting GIS research in Security, Health, Transport, Agriculture, and Insurance. Due to committed research in GIS, expert systems have been developed that enable mining of crucial intelligence from location data. In order to achieve a successful location analytics system there are two basic components that are required (Galigeo, 2012), data and technical components.

2.2 Technologies in Food Security

Precision agriculture involves combining a set of technology sensors, informed management, information systems, and enhanced machinery to optimize production by accounting for variability and uncertainties within agricultural systems (Gebbers, & Adamchuk, 2010).

ICTs have a tremendous role to play in agriculture. ICTs afford the agriculture industry the opportunity to increase information flow to all industry participants at a decreased cost. ICT can bring education, capacity building and training to rural people all over the world. In effect it would be a knowledge transfer mechanism from the have's to the have not's, enabling this socially relevant development process to happen. There are a variety of existing programs in Africa that use ICTs such as voice, text, internet, and mobile money transfers (Aker, 2011). Crop improvement through breeding brings immense value relative to investment and offers an effective approach to improving food security (Tester & Langridge, 2010).

Today agriculture and food security is embedded with advanced services like GPS, sensors that enable to communicate to each other, analyze the data and exchange data among them. Agriculture cloud and ICT service provides a special skill service to farmers regarding cultivation of crops, pricing, fertilizers, and diseases detail method of cure to be used Scientist working on food security will provide their discoveries, suggestions regarding modern techniques for cultivation, usage of fertilizers can obtain the history of the region (Balamurugan et al., 2016).

Climate smart agriculture (CSA) is an integrated approach to managing landscapes, livestock's, forests, cropland and fisheries that addresses the interlinked challenges of food security and climate change (http://www.worldbank.org/en/topic/climate-smart-agriculture). The aim to continuously achieve enhanced resilience, reduced emissions and increased productivity with agriculture constantly experiences advances in technology. ICTs can be used in strengthening the role of supply chains in food security (Romero, 2009). Essentially, ICTs can be used as an enabler, both locally and globally/nationally, to ensure food security. GIS can help to establish cross-sectoral communication by providing powerful tools for storage and analysis of statistical data, and integrating databases of different sources and map projection (Moturi & Otieno, 2013).

Under the Vision 2030, the Kenyan Government has identified seven flagship projects for implementation during the next 5 years to aid food security: agricultural policy reforms, three-tiered fertilizer cost reduction, branding Kenya farm produce, establishment of livestock disease free zones and processing facilities creation of publicly accessible land registries, development of agricultural land use master plan, and development of irrigation schemes.

2.3 Role of Food Banks in Food Security

Agricultural investments play a vital role in growth of food supply in technological progress, and will be crucial for achieving a sustainable food production (Pardey et al., 2014) and food security (Balș, 2010) in the future. Low harvests from poor farming methods and drought greatly affect food storage in the food banks consequently affecting food security. Unlike the operations of food banks such as the community food bank of Southern Arizona (Community Food Bank 2009), food bank of South Jersey (2014), and the Chalmers Community Service Centre in Guelph, Ontario (Chalmers Community Service Center, 2014). However, some food banks have established relationships with community centers whereby the produce grown, is donated to the food banks. With the rapid population growth, food security in future will be the most pressing challenge. A report, creating a sustainable food future produce by the World Resource Institute (WRI) and United Nations Environmental Program (UNEP) in 2013 showed that one third of all the food produced worldwide gets wasted in consumption and production systems. Food banks are a solution to food wastage with countries such as France passing laws that bans supermarkets from wasting food near its expiry date and instead donate it to the food banks (Bazerghi, McKay & Dunn, 2016).

Rancourt et al. (2015) presents GIS models to determine distribution road network centers, which shows direct distribution of food to beneficiaries. Planning scholars, geographers, public health officials, and community organizations have created maps to better understand disparities in the food environment (Sweeney et al., 2016).

There is need to combined need assessment and population data to plan food distribution. There is need to explore various mapping technologies such as GIS, Google Maps, Mobile Phones, IoT, data mining, big data analytics to maximize distribution of food in foot banks in Kenya (Bacon & Baker, 2017).

The role of food banks in Kenya can be compared to National Cereals and Produce Board NCPB (http://www.ncpb.co.ke/) which roles include: Government's arm for grain price stabilization, procurement of Strategic Grain Reserves (SGR) and Famine Relief Stocks (FRS), providing logistics support services for distribution of SGR and FRS and a commercial grain trading organization.

2.4 Digital farming methods to improve Food Security

Stocking, (2003) wrote that Interventions to reverse declining trends in food security must recognize the variable resilience and sensitivity of major tropical soil types. "Tragedy of the commons" scenarios can be averted by pragmatic local solutions that help farmers to help themselves. According to the international food policy research institute, Africa faces a difficult challenge in meeting the main target of the first Millennium Development Goal to halve the number of people suffering from malnutrition and hunger by 2015.Use of ICTs and bridging the digital divide will not directly impact the challenge , but it can make a significant contribution (Bertolini, 2005)

Knowledge and information are important factors for accelerating agricultural development by increasing agricultural production and improving marketing and distribution. ICTs can enhance the integration and efficiency of agricultural systems by opening new communication pathways and reducing transaction costs, given greater accessibility of information on prices, transportation, and production technologies.

2.4.1 Communication Technologies

Mobile communications technology has quickly become the world's most common way of transmitting voice, data, and services in the developing world. Given this dramatic change, mobile applications (m-apps) in general and mobile applications for agriculture in particular hold significant potential for advancing development. They could provide the most affordable ways for millions of people to access information, markets, finance, and governance systems previously unavailable to them Qiang, & Esselaar, 2012).

The growth of mobile communications technology has created opportunities for social empowerment, and economic growth in developing countries. One of the areas with the greatest potential impact is in the contribution that mobile applications can make to agricultural and rural development, by providing access to information, markets, and services to millions of rural inhabitants. For both agricultural supply and demand, mobile phones can reduce waste, make delivery more efficient, and forge closer links between farmers and consumers (Qiang, et al. 2012). According to http://www.worldbank.org/ict/m-ard) report a comprehensive understanding of the development impact, ecosystem, and business models for mobile applications in ARD has indicate cases from Kenya and Sri Lanka. Other technologies that can be used include: GPS, Data mining, big data analytics, google earth and GSM.

2.4.2 Food Storage Technologies

Besides traditional thermal treatments for food preservation, many other new thermal and non-thermal processing technologies have been developed recently. These include irradiation, high-pressure processes, pulsed electric fields, UV treatments, and antimicrobial packaging (Han, 2005).

2.4.3 Farm Drive

Farm drive (https://farmdrive.co.ke/) uses mobile phones, alternative data and machine learning to bridge the digital divide that hinders financial institutions from lending to creditworthy small scale farmers. It is noted that small scale farmers lack the capital to purchase critical farming inputs that can increase their yields and revenue. Farm drive provides financial institutions with a model that can be used in risk assessment for small scale farmers. Not only will this solution unlock millions of dollars of previously risk-averse capital for smallholder farmers, it will improve the livelihoods of entire communities, thereby alleviating poverty, hunger, and inequalities.

2.4.4 ICT Technologies

2.4.4.1 Data Mining

Data mining is examining large databases, previously unknown, to generate new information. To achieve these patterns and trends, data mining relies on sophisticated mathematical and statistical models, and substantial computing power to help user convert algorithmic behavior to user understandable rules for action (decision making) and forecasts the effects of these actions. Data mining technology provides a user- oriented approach to novel and hidden patterns in the data (Ngaruiya & Moturi, 2015). Data mining is an essential step in the process of knowledge discovery in database in which intelligent methods are applied in order to extract patterns (Kharya, 2012). The process of data mining involves various technical approaches, including but not limited to: Classification, Clustering, predictions and data summarization.

2.4.4.2 Big Data Analytics

Big Data is the new experience curve in the new economy driven by data with high volume, velocity, variety, and veracity. They originate from mobile devices, social media, internet, geospatial devices, and sensors. According to Manuika et al. (2011). The government has taken initiatives to exploit Big Data phenomenon and has created in many areas such as healthcare, science & engineering, and national security. Traditional data processing and analysis of structured data using RDBMS and data warehousing no longer satisfy the challenges of Big Data.

2.4.4.3 Google Earth

Google Earth (https://www.google.com/earth/) is one of the newest geographic information tools available on the World Wide Web with considerable potential to enhanced methods to develop other capabilities (Patterson, 2007). Virtual globe software systems such as Google Earth are growing rapidly in popularity as a way to visualize and share 3D environmental data (Sheppard & Cizek, 2009). Google Earth, enables scientists around the world to communicate their data and research findings in an intuitive three-dimensional (3D) global perspective. Different from traditional GIS, google earth are low cost and easy to use in data collection, exploration and visualization (Yu & Gong, 2012).

2.4.4.4 GSM

Global system for mobile communication is a technology used in a huge number of applications. It's used for its internal roaming capability, transmitting mobile, voice and data and security against fraud. The technology determines an object's position by using signal strength and triangulation from base station.

The subscriber identity module (SIM) card provides the network with identifying information about the mobile user (Toorani & Beheshti, 2008)

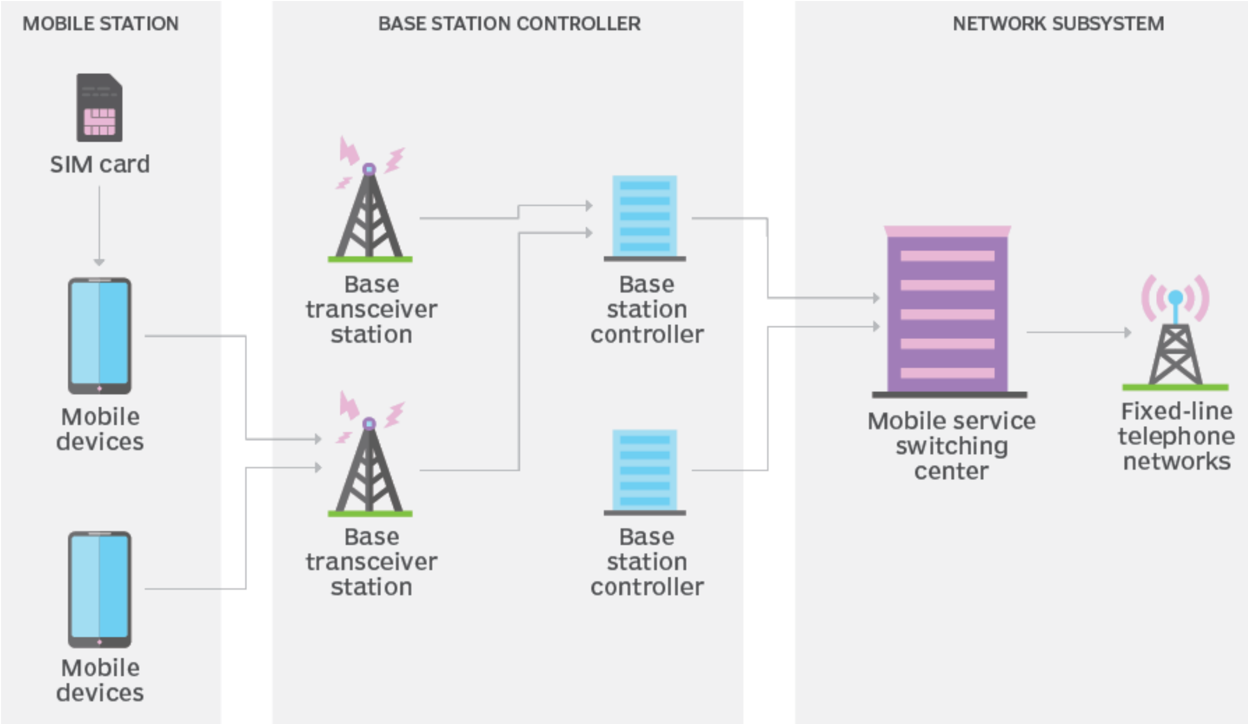


Figure 1: Global system for mobile (GSM) network, (Toorani & Beheshti, 2008)

2.4.4.5 Internet of Things

Internet of Things (IoT) provides devices with an ability to communicate, monitor and interact with each other for example: smart phones & PC's with sensors and ability to receive and send messages wirelessly. Devices connected to the internet, will reach an estimated 25 billion by 2020 worldwide. Ubiquitous sensing enables the smart objects measure, deduce and understand environmental elements ranging from the natural environments to the manmade urban environments. The proliferation of these smart objects combined with sensors and actuators has created the IoT concept and has brought the ability to easily obtain data and share the information across multiple homogeneous and heterogeneous platforms (Gubbi, Buyya, Marusic, & Palaniswam, 2013).

Verdouw, Wolfert, & Tekinerdogan (2016) reviewed the existing applications of IoT in agriculture and its enabling technologies and identified the main challenges ahead. They found that application area of food supply chains and farming are the most frequently addressed. Most studies report the results of explorative studies or they present IoT systems that are designed or implemented in prototypes and pilots. IoT applications are used through location based technologies such as RFID and GPS to help monitor perishable goods during transportation and storage. With traceability aspect of food produce wastage is greatly reduced. This helps in scheduling and addition of auxiliary automation in supply chain (Alexandratos & Bruinsma, 2012).

IoT applications ensures food security throughout the entire value chain through increased connectivity. Consumer confidence and transparency is enhanced by use of RFID detectors used for tracing and tracking. Lastly IoT is used during crop monitoring by use of sensors that monitor crop output. Production factors of radiation, quality, presence, pests and humidity are monitored regularly with communication of data. This allows farmers to undertake preventive measures way before disease occurrence promoting food security.

IoT is a paradigm where the smart object or things are equipped with tools for identification, sensing, networking and the information processing. This will therefore allow the objects to connect to one another and transfer information among them through the internet and other devices (Gubbi, Buyya, Marusic, & Palaniswam, 2013). Successful development of the IoT includes the ability to send data to the cloud through cloud computing ensuring that data is captured by smart objects and stored in the cloud enabling users to retrieve and access data from any location hence creating ubiquitous, smart systems. The smart objects provide information from their surrounding and able to relay the information in real time. IoT is characterized by pervasive "omnipresent" and ubiquitous computing concepts (Charith, Arkady, Peter, & Dimitrious, 2014) which are further enhanced by use of large actuators and sensors with unique addresses connected to the internet and can be accessed remotely. With the ability to relay information across different platforms, they help solve technological complexities and enable information about the environment to be obtained automatically with minimal or no human interaction (Bhole, 2015). RFID and WSN are the most commonly used technologies in IoT system.

IoT enables objects to share information by linking them to each other with the use of embedded sensors with the enabling technologies such as Internet applications, Networks and internet protocols. (Al- Fuqaha, 2015)

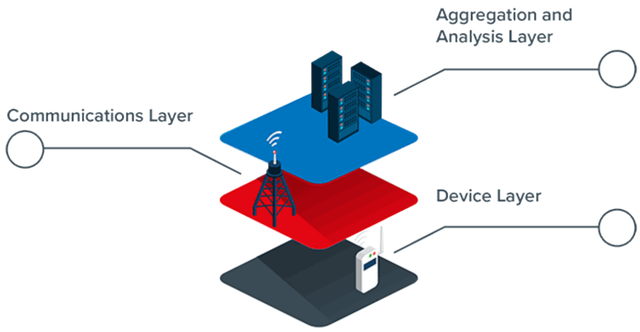


Figure 2: Rentokil IoT (Source: Tüzünkan, 2017)

The foundation has the device layer which comprises of: Tags that communicate when in range of a reader device such as RFID Sensors use for measurement for example humidity and temperature. Actuator are devices that can take action. The device layer also has input/output devices that collect data ad is transmitted to the communication layer. The communication layer uses wired and wireless systems to transmit data to a central environment for aggregation and analysis.

Table 1: Internet of Things Units Installed Base by Category. Gartner (November 2014)

Category	2013	2014	2015	2020
Automotive	96.0	189.6	372.3	3,511.1
Consumer	1,842.1	2,244.5	2.874.9	13,172.5
Generic Business	395.2	479.4	623.9	5,158.6
Vertical Business	698.7	836.5	1,009.4	3,164.4
Grand Total	**3,032.0**	**3,750.0**	**4,880.6**	**25,006.6**

The IoT movement transcends nowadays the limits of M2M (machine to machine) communication, enabling even devices that do not include the respective electronics to connect to the Internet by using an intermediary non-intrusive device. The Web of Things (WoT) is a superset of the Internet of Things where everyday devices and objects, which contain an embedded intelligent device or computer, are connected by fully integrating them to the Web. WoT system will need to combine information from IoT system with data obtained from various sources and external services to provide proposals for action, including risk analysis, so that the farmer to get maximum profit in terms of enforcing laws and protecting the environment. IoT capabilities are enhanced by the use of Semantic Web technologies (John, Takuki, Peintner, & Rumen, 2011) and EXI. These IoT elements have been summarized in a diagram (Al-Fuqaha, 2015) and are shown in figure 3.

Figure 3: IoT elements (Al-Fuqaha, 2015)

2.4.4.6 GIS

GISs are defined as information systems that perform the functions of capturing, storing, manipulating, integrating and displaying geographic or nongraphic information, gathered by observation depending on locations, to users (O'sullivan & Unwin, 2014). Geographical information system is used for acquisition of up to date data with several benefits just to mention a few, level of higher accuracy during surveys, site survey without damage, 3D modelling options, shared databases with data from other sources, complex analysis options(Geographical information software), detailed artifact recording. GIS professionals in agriculture typically employ it to examine selected geographic datasets in detail, land use and land cover (LULC), soil data, weather parameters with crop data such as variety distribution, and sowing date which are combined for the comprehensive study and analysis of spatial problems (Golhani, Rao, & Dagar, 2015). GIS is used to produce a wide range of maps but its capabilities go beyond mapping. It offers a rich set of analytical functions that can reveal hidden relationships, patterns, and trends that are not readily apparent, enabling people to think spatially to solve problems and make smart decisions (Fu and Sun, 2011).Today, Mobile GISs (MGISs) are accepted as an alternative to classical GISs as they offer some advantages such as rapid, correct and economic access and use of on-line maps. GISs are referred to as Location Information Systems by some authorities (Tecim, 2000: 3). GISs represents geographic dada in two different ways; (1) vector data and (2) raster data. The five basic functions of a GIS are as follows; (a) Collecting data; (b) Data Processing; (c)Data Management, (d) Search and Analysis and e) Visualization/Data Presentation. With software, instead of carrying out marketing research, GISs add spatial component to necessary information and marketing researches can be defined (Kanga, Sharma, Pandey, Nathawat, & Sinha, 2011). In GISs application having large volume of data, security, unity, consistency, continuity, processing performance and sharing of data are fundamental components that should be found in a GIS. (Bank, 2005).

Improving programme efficiency by processing & analyzing large amounts of data quickly; Producing a wide variety of outputs and feedback reports targeted for many levels of the foo security system from a single data set or by combined data sets; Improving analysis and information presentation to facilitate data interpretation and use for decision-making; Providing "factual information" about the location of resources (Food banks), human or natural; Analyzing the geographical distribution of the population; and Improving analysis/preparation to facilitate data interpretation and use for decision-making.

Essentially GIS provides a means of taking different kinds of information, processing it into compatible data sets, combining it and displaying the results. Some of the standard GIS capabilities include; integrating maps made at different scales, different projections or different legends; overlaying different types of maps for a particular area to make a new map that combines the attributes of the individual maps; generating buffer or proximity zones around lines or polygons on a map; changes of scale, projections, legends, lettering on maps. GIS map data is represented in either raster or vector format. In a raster or cell based system, the map is represented by a geometric array of rectangular or square cells each with an assigned value. In the vector based system, the line work is represented by a set of straight-line segments called vectors. The X,Y coordinates at the end of each vector segment are digitized and explicitly stored and the connectedness implied through organization of the points in the database.

GIS is all about special data and the tools for managing, compiling and analyzing that data. A set of sample points representing changes in landscape, population or environment can be used to visualize the continuity and variability of observe data across a surface through the use of interpolation tools. This study will use ArcGIS as it's the most popular desktop GIS among geographers and other GIS users because of its capabilities for spatial-quantitative synthesis.

2.4.5 No-till farming

This is a technology that has been adopted in Kenya as a way of growing crops/pasture year to year without disturbing the soil through tillage. It's a technique that increases the amount of water that infiltrates into the soil, the soil's retention of organic matter and it's cycling nutrients. (Derpsch, Friedrich, Kassam, & Li, 2010). The wide recognition of no-till farming as a truly sustainable system should ensure the spread of the no-till technology and the associated practices of organic soil cover and crop rotation, as soon as the barriers to its adoption have been overcome, to areas where adoption is currently still low. It has been known to have many benefits for example; prevention of soil erosion, prevention of soil compaction, prevention of soil structures and macro-prones, improves soil moisture, promotion of beneficial organisms such as earthworms. A successful farmer in Kenya (Stuart Barden) in his farm in Machakos County uses a combination of zero tillage, permanent soil cover and crop rotation harvesting one thousand Kgs of green grams from an acre, with crop taking 150 – 160 days to reach maturity and 1,100 Kgs for chick peas after 140 days.

2.4.6 Urban Agriculture; Roof Top agriculture & urban greenhouse

Growing crops in a controlled urban environment is advantageous as includes the lack of animal vectors that transfer pathogens to the food via untreated manure; less susceptibility to weather-related disasters; and less likelihood of genetically modified rogue strains entering the plant habitat. Using sustainable farming practices, urban crops could be organically grown, decreasing the use of herbicides, pesticides, fertilizers and eliminating agricultural runoff (Chamberlain, 2007).

2.5 Food Banks in Kenya

Food banks are charitable community based food assistance programs that distributes public and corporate food donations. In most countries they are the primary response to hunger. Food banks are intended to make food which would be otherwise waste or surplus available to organizations to be put into good use. Food banks collect and distribute food thorough four ways; interagency cooperative food buying agreement, centralized warehouse approach, direct feeding programme and direct food supplier to social agency (Tarasuk, & Beaton,1999).

Food Bank utilization is thought to be indicative of household food insecurity and nutritional vulnerability. Arguments that food banks are an inappropriate response to hunger problems are centered on social stigma associated with their use. (Valerie Tarasuk, George H. Beaton, 2003). Food banks benefit food corporations whose donations produce positive public relations and community capital, but who at the same time save on the costs of disposing food waste and are themselves engaged in political economies of low pay and unstable employment (Dowler, 2013; Riches, 2011)

In Kenya there are several food banks which are international with Kenyan local branches. They include;

a) Food Banking Kenya (http://www.foodbankingkenya.org/) which aims to alleviate hunger and enhance the sustainability of the vulnerable through sourcing and distribution of food in addition to enhancing affordable income generating projects. The organization has established donation network of local growers, retailers, wholesalers, and processors in different parts of Kenya. This has created projects that enable vulnerable communities to sustain themselves. They aim to collect over one million dollars of food, training and investment resources, and increase collection amount by 20% each year.

b) Food banking regional network (http://www.foodbankingregionalnetwork.com/about-fbrn/)
FBRN focuses on ending hunger problem through creating a diversity of long term development, awareness, educational and feeding programs. FBRN has been established as a social enterprise, nonprofit umbrella organization for food banks established in the region. FBRN works on regional and international levels to unite and coordinate food and nutrition relief efforts, activating them within a general framework of joint action.

c) Kapu Africa (https://kapuafrica.midwestfoodbank.org/home).
Is a faith based organization whose mission is to alleviate hunger and poverty by gathering and distributing food donations to non-profit and disaster sites without cost to the recipients. It focuses on generating funds to support sustainable, nutrition-based initiatives facilitating food distribution from corporate donors to those in need and providing nutritious meals to faith-based schools.

d) Sri Guru Nanak Food Bank (http://www.unitedsikhs.org/Guru_Nanak_Food_Pantry_Page/).
This a local food bank founded by Sikh Community members as a grass roots attempt to feed the impoverished and underserved population.

e) World Food Bank (http://www1.wfp.org/countries/kenya).
WFP Kenya works with the Kenyan government to strengthen its ability to provide its own food security and nutrition assistance programmes, such as activities supporting poor smallholder farmers. As part of this work, WFP supports institutions such as the National Drought Management Authority, working on hazard analysis and early warning to help improve the country's preparedness and response to emergencies. **1°13'56.1"S 36°48'50.4"E**

f) Prophet Reward Foundation (http://prophetrewardfoundation.org/).

It has programs structure covers in all the 47 counties in Kenya. The charitable body deals with education, community development and empowerment activities, environment and food security programs and all humanity services to poor community. **1°15'58.9"S 36°51'04.1"E**

The impact about the crisis on the prospects for achieving the first Millennium Development Goal (MDG) "to end poverty and hunger" are also very high (Ludi, 2009). Research on food banks and food security has focused on understanding why the number of food bank users is on the increase, and on improving diets at food banks by serving nutritious foods (O'Brien 2004; Moldofsky 2000; Hand-forth et al. 2013; McPherson 2006). (Hunger Project 2013a) provides training and tools to increase income generating activities, empowering partners to create and manage their own food banks. A food bank is "a centralized warehouse or clearing house registered as a non-profit organization for collecting, storing and distributing food (donated/shared), free of charge, to front line agencies which provide supplemental food and meals to the hungry" (Riches & Graham, 2002) This signifies that food banks makes food that would otherwise be wasted, available to storage areas. Food Bank of Singapore (2013), on the other hand, looks at itself as a place where companies or people can come to deposit their unused or unwanted foods, which will then be allocated to the needy via Voluntary Welfare Organizations (VWOs). Most studies reveal that food bank uses have diverse characteristics and problems. However, the common factor is that they are usually food insecure people who also often face financial insecurity. Studies in New Zealand, for example, reveal that frequent bank users were recipients of state benefits (NZC- CSS 2005; ftériault & Yadlowski 2000; Mackay 1995). These findings are in line with Starkey *et al.* (1998), who found that 83.5 per cent of food bank users in Montreal, Canada, were also in receipt of social assistance. Different food bank models exist due to the different understandings of food bank operations. The simple model employed by traditional food banks is the "hunger-alleviation model" (Husbands 1999). Despite of food banks contributing to food security, food bank personnel have been persuaded to actively promote more nutritious products (Handforth, 2013). Some food banks offer nutritional education to users (Food Bank of Delaware 2011).

2.6 Farming and Marketing Decisions that influence food security

Organizations like One Acre Fund is delivering proven tools to smallholders in remote areas of Sub-Saharan Africa where yields and access to financing have lagged behind. It uses a model to assist the farmers make more yields and train on markets availability.

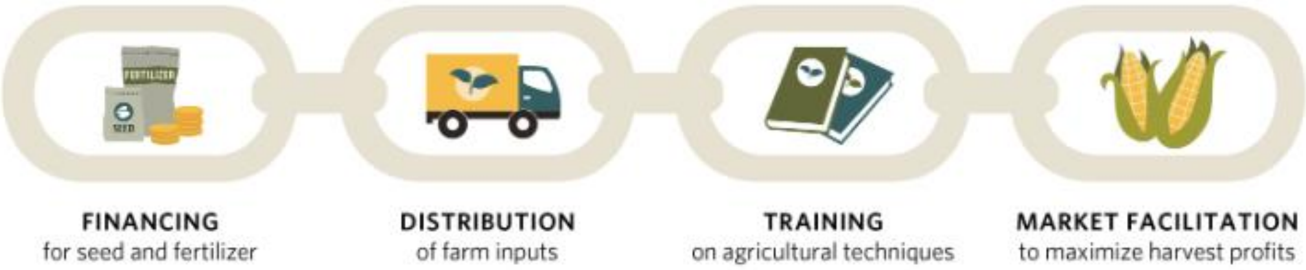


Figure 4: Market based strategies to fight food insecurity. Source: (One Acre Fund)

2.7 Food Distribution Technologies

The food industry faces critical changes in response to consumer needs, which demand high quality standards of diverse food products. The monitoring should allow establishing a better knowledge, detecting weakness, and optimizing the whole process, all things that potentially would have a significant impact on the supply chain. Products can be tracked and traced from the field to the industry. Food aid supply chains s are composed of several main warehouses located in strategic regions where primary storage infrastructure is available which serve mostly as storage facilities and transshipment hubs. The food is then transported to distribution centers from the warehouses, where it is informally stored and directly handed out to the beneficiaries. The Distribution centers are temporary depots such as shelters, schools, and community facilities which are often located in remote regions, depending on the population need.

2.7.1 Cold Chain Monitoring and Traceability

Refrigerated transport system is required for perishable foods, hence temperature is a critical factor when prolonging the shelf life of perishable foods. The primary concern of the industry Studying and analyzing temperature gradients inside refrigeration rooms, containers, and trucks is a. The supply chain management of fresh foods requires fast decisions because goods are forwarded within hours after arrival at the distribution center. Alarms should be triggered and quality problems detected quickly when temperature gradients cross a certain threshold. Even if direct access to the means of transport is not possible, online notifications offer new opportunities for improved transport planning. The use of wireless sensors in refrigerated vehicles can host a variety of sensors to detect, identify, log, and communicate what happens during the journey, monitoring the status of perishable products in transport. Qingshan, 2004)

2.7.2 Drones

One of the latest developments is the increase in the use of small, unmanned aerial vehicles (UAVs), commonly known as drones, for agriculture. Drones are remote controlled aircraft with no human pilot on-board. These have a huge potential in agriculture in supporting evidence-based planning and in spatial data collection. Drones are used in various fields ranging from the military, humanitarian relief, disaster management to agriculture. A recent PwC report (PwC, 2016) estimates the agriculture drone market to be worth USD 32.4 billion. The United Nations has experimented with drones in various areas of its mandate ranging from humanitarian crises to agriculture. For example, the World Food Programme (WFP) has joined with the Belgian government to deploy drones in humanitarian emergencies (WFP, 2017). The usefulness of drones to facilitate quick data collection with greater accuracy together with providing a safer monitoring system in emergencies was a key element in testing this in the field during challenging humanitarian crises. The United Nations Children's Fund (UNICEF) in partnership with the Government of the Republic of Malawi has set up a humanitarian drone testing corridor (UNICEF, 2017) that would facilitate testing in three main areas; imagery, connectivity and transport.

2.7.2.1 Drone Applications in Agriculture

The use of drones in agriculture is extending at a brisk pace in crop production, early warning systems, disaster risk reduction, forestry, fisheries, as well as in wildlife conservation.

Mid-Season Crop Health Monitoring - The ability to inspect in-progress crops from about 100 meters height using Normalized Difference Vegetative Index (NDVI) or nearinfrared (NIR) sensors is, thus far, the premier application for drones in farming. This was a task traditionally performed by often-reluctant college interns walking into the fields with a notepad. Present generation drones, allow more surface area coverage in a shorter time period, as well as the capturing of data that cannot be seen by the human eye (Puri, V., Nayyar, A., & Raja, L, 2017).

Irrigation Equipment Monitoring - Managing multiple irrigation pivots which could be laborious, especially for large growers

Mid-Field Weed Identification - Using Normalized Difference Vegetative Index (NDVI) sensor data and post-flight image processing to create a weed map, farmers and their agronomists can easily differentiate areas of high-intensity weed proliferation from healthy crop areas growing right alongside them. (Puri, V., Nayyar, A., & Raja, L, 2017).

Figure 5: Example of food delivery drone. Source: (Puri & Raja, 2017)

2.8 Food Distribution in Kenya

The agricultural sector comprises of six subsectors where major crop and livestock production can be tripled by using modern technologies.

Maize is the most important cereal crop in Kenya. Most Kenyans prefer white corn flour to produce "*ugali"* which is a thick porridge of maize meal that is usually eaten with a sauce of vegetables or meat, for their daily intake. Wheat is the second most important staple food in Kenya, which accounted for 17% of staple food consumption. Beans are the third most important staple food nationally; accounting for 9% of staple food calories and 5% of total food calories in the national diet with other common foods being potatoes, plantains and rice. Kenya has to import wheat and rice, as the country has shortage of food (FAO, 2017). In Kenya the average food intake is 2,155 Kcal/person/day.

An example of beans as the major source of dietary protein in Kenya but mostly grown in eastern and the Central regions hence there is a need to redistribute in other regions of the country.

2.9 Applications of Digital Mapping

Digital technology has also penetrated in all aspects of the mapping process, from raw data collection through map compilation and design to final production. Advancement in mapping technology has replaced the conventional stereo plotters with digital imaging systems. Map making has been made accurate and more efficient through technological advancements.

2.9.1 Soil Digital Mapping

Digital soil mapping uses statistical and mathematical methods to predict and map soil properties or soil classes from easily obtained and exhaustive environmental variables (McBratney et al., 2003). It has been widely used to map soil spatial variation at a range of scales over landscapes.

2.9.2 Community and collaborative work

This is made possible through wearable technology used for mapping applications to engage the community. Two of the more popular products available through iTunes and Google Play are the mobile apps Wheel Mate, Be my eyes, Vizwhiz and Wheel Map. Both apps rely on participatory contributions from their users to mark accessibility information on community maps, such as toilets, parking spaces, and building entrances.

Digital mapping systems have been developed for facilitating travel planning. For example, travel-planning Internet websites are commercially available and well known. Such websites typically permit a user to input a query with a requested location so that a map associated with the requested location may be provided to the user.

2.10 GIS Data Models and Technical Components

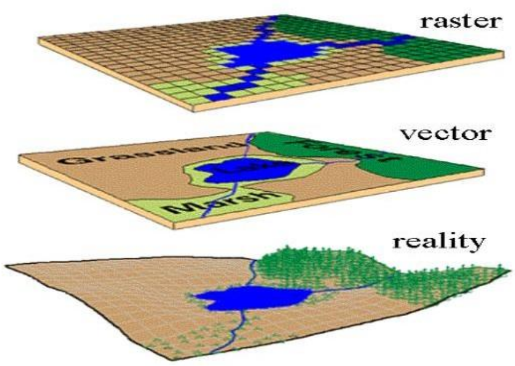
Galigeo,(2012) indicated that data models and technical components can be found in the Business Intelligence repository and the GIS Server. These data are Geographic or spatial in nature. Data stored in the warehouse can be analyzed to tell on the "where" factor like clients demographics by postal code. GIS data also referred to as spatial data consists of points, lines, and areas along with associated attributes in tabular format i.e. point of locations by street address, lines between those locations and areas representing administrative boundaries.

2.10.1 Data Models

Data in vector layout format can be represented in GIS software like SIGEPi while GIS data based on raster layers is represented in software like AccessMod. Every GIS Data set has two components (Goodchild, et al., 2005);

The feature component- the spatial representation of real-world features (e.g. trees, roads, rivers, towns...) in other words the map components.

The attribute component - the non-spatial data that describe the features.



The above diagram represents comparison of raster and vector data structures and how they represent real-world features. Complex shapes such as polygons are better represented in vector data. Note that as the pixels in raster layer get smaller (i.e. Finer resolution or fine scale), the better they would be representing complex features

2.11 GIS Analysis Methods, Tools and Algorithms

We have three stages in Geo-analytics (Guagliardo, 2004);

Figure 6: Diagrammatic representation of the two models of GIS data set components. Source: (Goodchild, et al., 2005)

a. Data Capture, Storage and management- of spatial or attribute data. This is usually done using Digitization of analogue maps, Geo-coding, Satellite imagery or remote sensing, Data from existing databases or warehouses, aerial photos or airborne laser scanners, existing reports. Databases can range from advanced Relational Database Management systems like Oracle, MS SQL Server, and Sybase to simple ones like Access and Spreadsheets.

b. Mapping and visualization tools to communicate the results of analysis-These are basically done through the applications and packages developed for this purpose. Some of the application are AccessMod, SIGEPi, Arc-GIS, Maptitude-GIS, Galigeo, and Quantum-GIS among others.

c. Algorithms for main Analysis of Vector and Raster data-In this stage a number of algorithms are applied for analysis such as buffering, classification, overlay, proximity analysis, shortest path, data smoothing, clustering and raster Cost-distance analysis

Spatial smoothing applies data from all areas within a set radius from a specific location, weighted by its distance to the center, this helps to achieve a desired level of credibility and reduce sampling error. To develop new rating territories Clustering techniques can then be used. Apart from its use as an effective analytical tool, GIS is a great communication medium for visualizing analytical results on a map to communicate to a wider audience. Advanced GIS and spatial econometric techniques are useful in analyzing spatial interactions and developing a predictive model that accounts for local factors to determine annual premium rating estimate.

2.12 Multi-criteria Analysis Techniques

These are techniques used when handling information that is complex to assist in decision making. In decision making they are used to identify a single, most preferred option from a shortlist of a limited number or options i.e. to distinguish acceptable from unacceptable possibilities. All Multi-criteria Analysis (MCA) approaches make the options and their contributions to the different criteria explicit and all require the exercise of judgment.

There are many MCA techniques and their number seems to be increasing with time because of the following reasons:-

The many different types of decisions which fit the broad circumstances of MCA

Organizations administrative culture vary and thus warranty a variety of MCA techniques

The analytical skills of those supporting the decision may vary.

Variation in the availability of time to carry out the analysis.

The amount of data available to support a given decision context may vary from one firm to another.

There are several multi-criteria analysis techniques used in decision making. This include:- Simple additive weighting(SAW),Analytical hierarchy process(AHP),The value or utility functions methods, The ideal point methods, Outranking methods, Ordered weighted average(OWA),Goal programming, Compromise programming(Malczewski,1997) In this project the analytical hierarchy process (AHP) will be used.

Analytical hierarchy process (AHP)

AHP uses hierarchical structures in representing problems and developing priorities (Saaty, 1980). Saaty has shown that the weighting activities in multi-criteria decision making can be effectively dealt with via hierarchical structuring and pair wise comparisons. Integration of GIS and AHP has been widely applied in land suitability and the results are similar to those that were founded by Srdjevic et al (2010) whereby they Combined GIS and AHP process for evaluating land suitability for irrigation. Dai (2016), terms integration of AHP with GIS as an efficient and user friendly method of solving complex problems, due to its combination of decision making support method and tools which have powerful capabilities of bulk data computation, visualization and mappingIn pair wise comparison, judgments are formed between the particular elements rather than attempt to prioritize an entire list of elements (Saaty, 1980).

NB: according to Saaty (1977)

Another name for Priority weight is normalized Principal Eigen Value

The cell is divided by its column total in order to normalize the values

Priority weight is calculated by determining the mean value of the rows

CHAPTER THREE

RESEARCH METHODOLOGY

This chapter expounds the research philosophy, research design, data sources & data sets, data collection and analysis techniques.

3.1 Research Philosophy

Galliers (1991) identified two major research philosophies in the Western tradition of science, namely positivist (sometimes called scientific) and interpretivist (also known as antipositivist).Realism and pragmatism are also other philosophy methods identified. In this research, positivism will be used as it is highly structured, uses large samples mostly uses quantitative measurement method (Dudovskiy, 2016). Descriptive case study research was used to draw inferences from this data.

3.2 Research Design

Research design is the overall plan a researcher chooses to integrate different elements of a study in a logical and coherent way (Maxwell, 2012). A case study of selected food banks in Kenya was the most appropriate since it ensured the description of the current food banks and how they are distributed in Kenya. The GIS design will provide a tool to explore spatial relationships within and between data (Chang, 2016), and there is a growing trend of internet-based GIS (i.e., GIS designed for operating online over the World Wide Web) (Moretz, 2008). The application of internet GIS through mapping (the process of designing, generating, and delivering maps on the internet) provides a number of advantages over traditional desktop-based GIS (Neumann, 2008). Maps can deliver up to date data, can be generated using a low-cost software and hardware infrastructure, and facilitate inexpensive map distributions. In addition, mapping enables the integration of different data sources and collaborative mapping (e.g., Google Maps, Openstreet Maps) (Moretz, 2008; Neumann, 2008; Fu & Sun, 2010; Clarke, 2014). The mapping will offer greater accessibility and allow for user-driven interaction (Peterson, 2008). The advancement of smartphone applications linked to mobile based maps will provide an avenue to involve broader audiences in the natural sciences and a convenient tool for scientists to disseminate their research (Teacher et al., 2013; Marchante et al., 2017).

3.3 Data Sources and Tools

3.3.1 GIS hardware

These included a laptop (Lenovo X260, 240 GB hard disk memory, 2GB RAM) and flash disk. The handheld Garmin GPSmap 60cx GPS receiver with an accuracy of between 3-5 meters was used to pick the locations of the food banks. The data consisted of grid coordinates referenced by the UTM (Universal Transverse Mercator) WGS 84 Zone 37 0 S projection. Once the location of a food bank was observed, it was stored within the GPS and downloaded later.

3.3.2 ArcGIS 10.5

In the study, the major software used was ArcGIS version 10.5 including its extension Network Analyst. The three main applications of interest in ArcGIS 10.5 were ArcToolbox, ArcMap and ArcCatalog. ArMap was used to display spatial data. It was used to create, edit, query and analyze the maps. It offered many ways to interact with maps such as exploring, analyzing and present the results. ArcCatalog was used for accessing and managing data. It was also used to move, rename and copy datasets as well as preview geographic and attribute data. ArcToolbox provided access to advanced geoprocessing functionality and was also used for data management, data conversion and geocoding the food banks. Arch Map was selected over other open source software's due to its MS windows friendly, well written specs and SLA, better graphical user interface (GUI) and support. In terms of self-development purposes, ERSI has large pool of freely available resources to learn, get support, watch videos and download code.

The datasets used in this research project was obtained from different sources and have various characteristics as summarized in table 2

Table 2: Datasets and data sources: Source:(Researcher)

Dataset	**Characteristics**	**Data source**
Current food Banks coordinates	Number and Location	Google earth
Nairobi County data	Data from 2009 National Population census	Ministry of Planning
Major Road network	Shape files	Survey of Kenya
Nairobi County Administrative Boundaries	Shape files	Survey of Kenya
Rainfall	Raster Data	Kenya GIS open data
Population	Shape file	Kenya GIS open data

3.4 Data Collection

Several options of data collection were considered by examining the ability of the tools to effectively and efficiently collect required data putting into consideration duration of data collection, minimize bias and low cost. The first step was identification of relevant datasets for the study. In this study, four key factors (Roads, major towns, rainfall distribution, and population) were applied in the study. These were the main factors considered in the suitability analysis for optimal distribution of the food banks. There are several more factors that could be incorporated (climatic conditions, point of production and consumption, security) in the study but due to the limited time available and data set limitations, these four factors were considered sufficient.

Based on collection of relevant data sets, data editing and creation of a database was done. The factors influencing the location of food banks were processed, standardized, weighted and overlaid to produce individual suitability map for the four data layers. A final suitability map was generated by integration of the layers.

3.5 Current Food Banks in Nairobi County GPS location

Food Banking Kenya: Operates a warehouse facility which store donated or rescued food for distribution. The program actively solicits food and other crucial resources from local food growers, retailers, wholesalers, and processors. In addition, the program collects food donations from restaurants for immediate distribution to highly exposed groups within the country. The program's focus is to identify and utilize resources for food in the counties in order to eliminate hunger among low and no income individuals and families in the target areas. (*1°18'29.6"S 36°46'28.5"E)*

KAPU Africa: combines dry foods, bagged meals of rice, beans, textured vegetable protein and chicken-flavored seasoning. It serves non-profit organizations such as food pantries, school kitchens, homeless shelters, churches and other non-profit organizations helping their community. Each month, a certain amount of time is set aside at each location for distribution. During that period, organizations can come pick up food from the Food Bank location which they then distribute to people in their communities. Through direct disaster relief efforts and agency partnerships, over 3.6 million people impacted by disaster are served each year.

Prophet reward foundation: PRF Food Banks & (Feeding Program) is a charitable trust organization in Nairobi, offering charitable work in non-profit, orphanage, children care, volunteer, feeding program, youth, urban, rural, international and community development. It provides basic needs (Food, Clothing, Shelter, and Education) to marginalized communities. Its programs structure covers all our 47 counties in Kenya and beyond horn of Africa countries.

World food Bank: Assists millions of people displaced, rendered homeless or deprived of basic resources by cataclysmic events whether man-made or natural. WFP provides refugees living in Kenyan camps in Garissa and Turkana counties with unconditional food and nutrition assistance through cash and food transfers, while investing in solutions that increase refugees' self-reliance including supporting livelihoods diversification. WFP requires USD 11.5 million to fund all its activities in the first half of 2019 under the new Country Strategic Plan. Due to funding constraints, WFP is only able to provide 85 percent of the overall food ration required for refugees (*1°12'38.4"S 36°47'40.9"E)*

Sri Guru Nanak: UNITED SIKHS set up the first SRI GURU NANAK FOOD BANK in Kenya to respond to a severe drought situation. Food is stored in the form of maize meal bags, red beans, rice, sugar and salt. Food is distributed in trucks to drought stricken areas. (*1°16'12.3"S 36°50'31.3"E***)**

Demographic Data (e.g. census on Population and populated places)

This data was acquired from Survey of Kenya. Populated areas especially where rainfall intensity is low will be targeted.

Road Network

Data on road network was acquired in form of shape files. This data was acquired from Survey of Kenya. The suitability of food banks was in areas not far from the roads.

Administrative Boundaries

Data on administrative boundaries comprised of Kenya counties. This data was used for setting of boundaries for the population density and populated places adjusting the population grid. This data was collected from Survey of Kenya.

3.6 Data Analysis

3.6.1 Methodology Overview

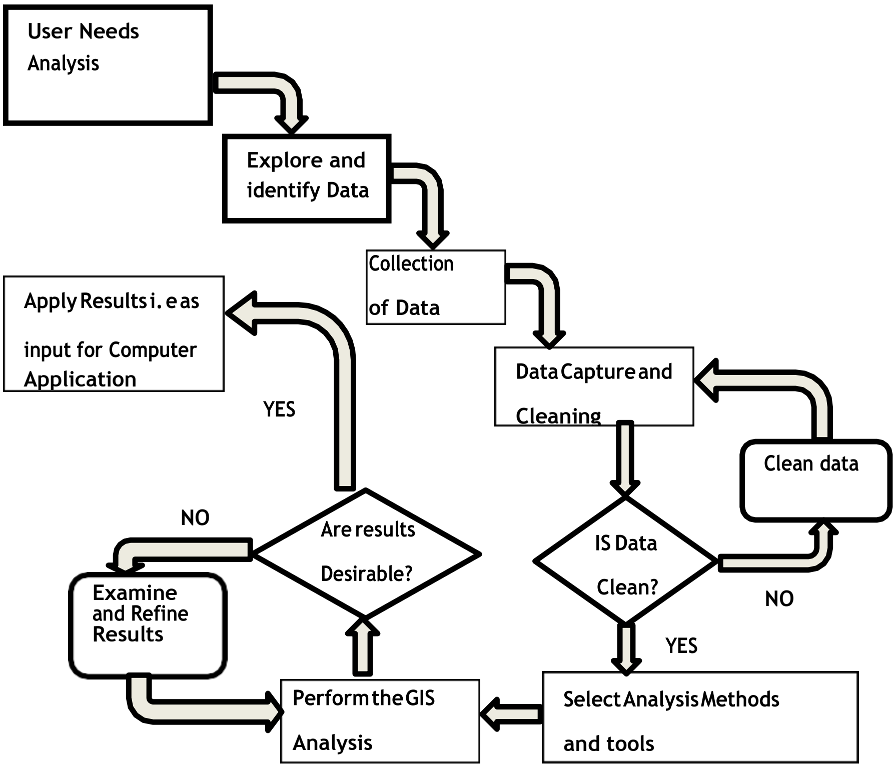


Figure 7: Methodology. Source: (Researcher)

During data identification various datasets necessary for carrying out the analysis were identified such as; Population data, rainfall data, road network, and major towns in Kenya data. Data collection was from sources such as Kenya GIS open data, Survey of Kenya headquarters, ministry of planning and google earth. This involved spatial data and attribute data. Data cleaning was done by editing unnecessary data and calculating the necessary averages required for the GIS analysis. ArcMap and surface interpolation tools were identified for the GIS analysis. Four factors were identified to assist in finding the most suitable food bank distribution zones. Weighting of the four factors identified was done by pair wise comparison technique of analytical hierarchy process (AHP).

3.6.2 Detailed Procedure for the Analysis

ArcGIS was used for the overall analysis and presentation of the research findings. The main processing and analysis steps followed for the application of the method implemented in preparation for the ArcGIS analysis for example Standardization of databases to UTM 37 S projection and datum WGS-1984

A number of criteria's influencing the distribution of food banks were identified; Population Factor, Rainfall Factor, Proximity to roads factor, Proximity to major towns, Crop intensity

3.6.3 GIS Data Capture and Processing

The process of data capture into a GIS database for analysis was systematically carried out as demonstrated (figure 8)

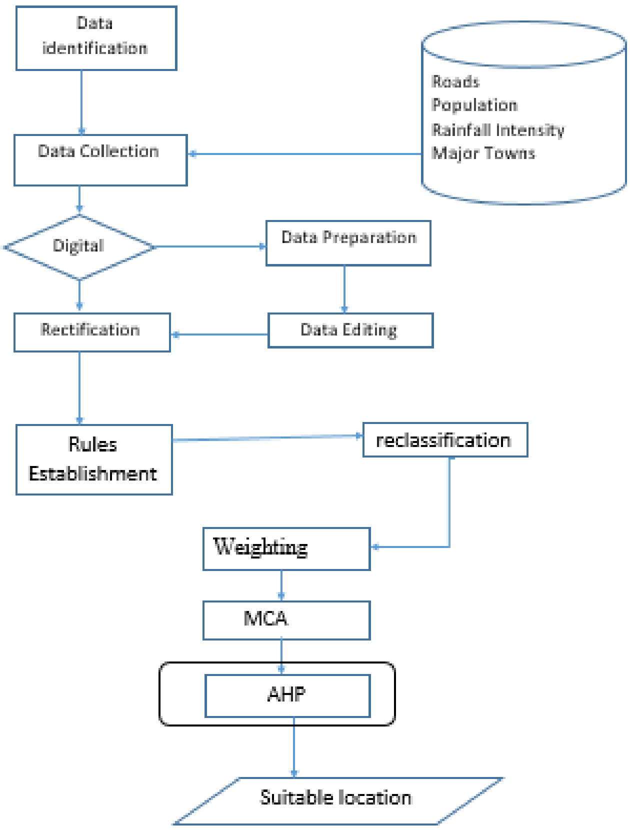


Figure 8: Data capture and processing flow chart. Source: (Researcher)

3.6.4 Data Identification.

Assessment of evaluation factors was carried out in order to identify the map layers needed for GIS analysis. The data sets relevant for creation of map layers were then identified. (Table 3)

Table 3: Map layers and relevant data sets. Source: (Researcher)

Evaluation factor	**Map layer**	**Raw data needed**
Population factor	Population layer	Topographical map
Rainfall intensity factor	Rainfall layer	Rainfall intensity map
Major Town centers	Major Towns layer	Topographical map
Proximity to roads factor	Roads layer	Topographical map

3.6.5 Data Acquisition

Table 3 formed the basis for data acquisition. The sources of the above datasets were identified through research. Arrangements were then made for acquisition and the data was obtained as shown in table 3

3.6.6 Data preparation/processing

Projection was done for the data to same coordinate system. This was followed by preparation of map layers. The contour layer was added to ARC GIS 10.5. The following steps were adopted;

Population of buffer zones using Euclidean distance tool

3.6.7 Reclassification of the buffer zones

Decision on features for analysis in inclusion or exclusion usually require substantial knowledge together with modeling experiences (Forkuo, 2011). Values must be prioritized even within a single raster. This is because values in a particular raster may be fit for your purpose while others may be undesirable (ESRI, 2017). Classification was done with the help of Spatial Analyst Tools in ArcGIS. During the classification, the rank for each criterion was given based on its estimated implication in site selection. Each input layer has potential different ranges of values as well as diverse styles of numbering systems, which necessitates reclassification or transformation into a common ratio scale before they are combined for analysis (ESRI, 2017). To perform the reclassification, each raster dataset was reclassified into a common scale of 1 to 4, With 4 being more favorable hence has the highest influence for food bank location selection and 1 with the lowest influence.

3.6.8 Weighted overlay

Weighting of the four factors identified was done by pair wise comparison technique of analytical hierarchy process (AHP). The method was chosen because it deals with inconsistent judgments and provides a measure of inconsistencies. Each factor was assigned a weights which determined their significance to the study. Several online programs are available for calculating AHP priority weights which includes Microsoft Excel, BPMSG AHP Online System (BPMS, 2017) among others. The program used for this study was Microsoft Excel as described by (Bunruamkaew, 2012).

When weighing the factors the following steps were followed to rank criteria in order of importance. The basic procedure followed was:

1. Developed ratings for each decision alternative for each criterion used.

Developed a pair wise comparison matrix for each criterion

Normalized the resulting matrix

Averaged the values in each row to get the corresponding rating

Calculated and checked consistency ratio

2. Developed weights for the criteria
3. Calculated the weighted average rating for each decision alternate. Choose the one with the highest score

The AHP scale for pair wise comparison is shown in table 4.

Table 4: The AHP scales in pair wise comparisons (Saaty & Vargas, 1991)

Intensity of Importance.	**Meaning**	**Description**
1	Equal Importance	Two activities contribute equally to the objective
3	Moderate Importance	Experience and judgment slightly favor one activity over the other
5	Strong Importance	Experience and judgment strongly favor one activity over the other
7	Demonstrated importance	An activity is strongly favored and its dominance is demonstrated in practice
9	Extreme importance	The evidence favoring one activity over the other is of the highest possible order

With AHP we can measure the degree of consistency; and if unacceptable, we can revise pair wise comparisons.

If perfectly consistent, the consistency measures will equal n and therefore, the CIs will be equal to zero and so will the consistency ratio.

If this ratio is very large (> 0.10), then we are not consistent enough and the best thing to do is go back and revise the comparisons. The next step is to use similar pair wise comparisons to determine the appropriate weights for each of the criteria. While the intensity of importance is allocated to criteria ***i*** when compared to criteria ***j***, the reciprocal value is assigned to criteria ***j*** as intensity of importance. For example, from the above matrix, ***i*** (slope) =9 while ***j*** (Proximity to Road) =1/9. After comparison between all possible criteria pairs is complete, the Weight (W) of criteria ***i*** is calculated using equation 1 (Dai, 2016). table 7 below for the calculated weight (W).

$$W_i = \sum_{j=1}^{n} P_{ij} / (\sum_{i=1}^{n} \sum_{j=1}^{n} P_{ij})$$

Equation 1: Calculation of weight (source **(**Dai, 2016))

Where P_{ij} = Relative importance in pair-wise comparison of criterion i compared to

criterion j n = Number of factors

i &j = Criterion

W = Priority Weight

Table 5: Pairwise comparison matrix. Source: (Researcher)

Factor	**Rainfall**	**Towns**	**Roads**	**Population**
Rainfall	1	7	7	9
Towns	0.142857	1	3	7
Roads	0.142857	0.333333	1	5
Population	0.111111	0.142857	0.2	1
sum	1.396825	8.47619	11.2	22

Table6: Normalized Comparison Matrix. Source: (Researcher)

Factor		**Rainfall**	**Towns**	**Roads**	**Population**
Rainfall		0.715909	0.825843	0.625	0.409090909
Towns		0.102273	0.117978	0.26785714	0.318181818
Roads		0.102273	0.039326	0.08928571	0.227272727
Population		0.079545	0.016854	0.01785714	0.045454545
sum		1	1	1	1

Table 7: Consistency Analysis. Source: (Researcher)

Factor	**Rainfall**	**Towns**	**Roads**	**population**	**TOTAL**	**Average**	**CM**	**CV**
Rainfall	0.715909	0.825843	0.625	0.409090909	2.575843	0.64396067	0.715405436	1.110945847
Towns	0.102273	0.117978	0.26785714	0.318181818	0.806289	0.2015723	0.133025064	0.659937209
Roads	0.102273	0.039326	0.08928571	0.227272727	0.458157	0.11453925	0.093087827	0.812715508
Population	0.079545	0.016854	0.01785714	0.045454545	0.159711	0.03992777	0.058481673	1.464686723
Sum	1	1	1	1	4	1		1.012071322

- Consistency measure (CM)
- Consistency vector (CV)
- Average consistency vector (ACV)

AVC= average CV = 1.012071322

- Consistency index (CI)

CI=(AVC-n)/(n-1) = -0.995976226

where n=4

- Consistency Ratio (CR)

CR =CI/RI = -01.094479369

where RI (Random Index) = 0.91

According to Saaty (1977), the value of CR is compared to 0.1 which is the maximum CR value for an acceptable pair-wise comparison. The resulting CR for this analysis is -01.094479369 which is less than the acceptable maximum CR value recommended in AHP and therefore this consistency is accepted.

Table 8: Multicriteria weighting. Source: (Researcher)

FACTOR	**PRIORITY (%)**	**RANK**
Rainfall	65	1
Towns	20	2
Roads	11	3
Population	4	4

CHAPTER FOUR

RESULTS AND DISCUSSIONS

This chapter outlines the results and discussions which were obtained to get a suitable food bank proposed location.

4.1 Results

To find the most suitable locations of the food banks Arc GIS software system was used that contains a variety of analysis tools used in this project. After mapping data from current food bank, figure 9 shows food banks in Nairobi County and their location.

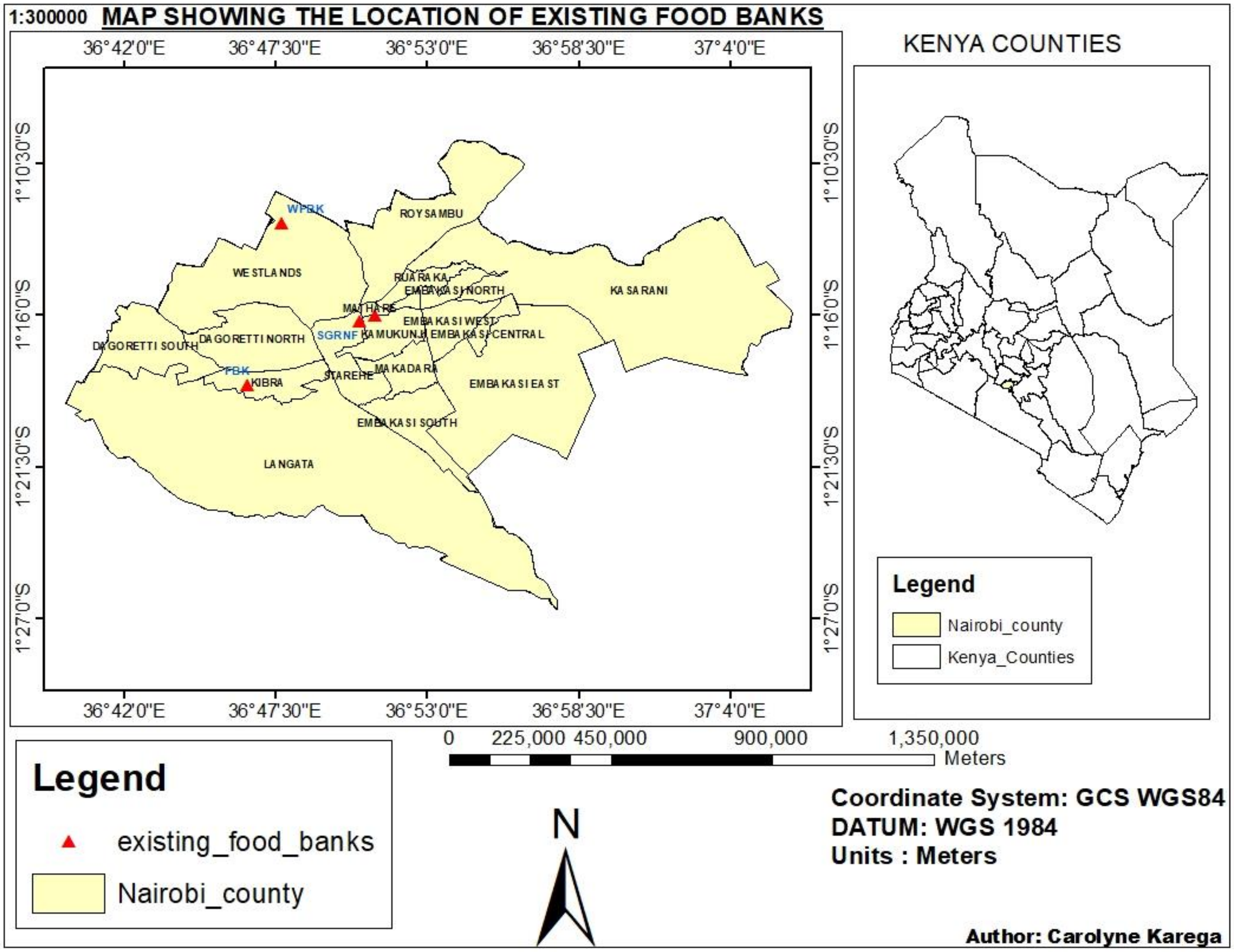


Figure 9: Map showing food banks in Nairobi County the area of study. Source: (Researcher)

Suitable food bank distribution area results

To find the most suitable distribution areas a digital model was created to assist compute the weighted overlay. After a stepwise overlay of the four factors the results were obtained for the individual factor maps. Kenya towns and roads were converted using Euclidean distance and Kenya population data rasterized. The output was reclassified using the special analyst tool (reclassify)

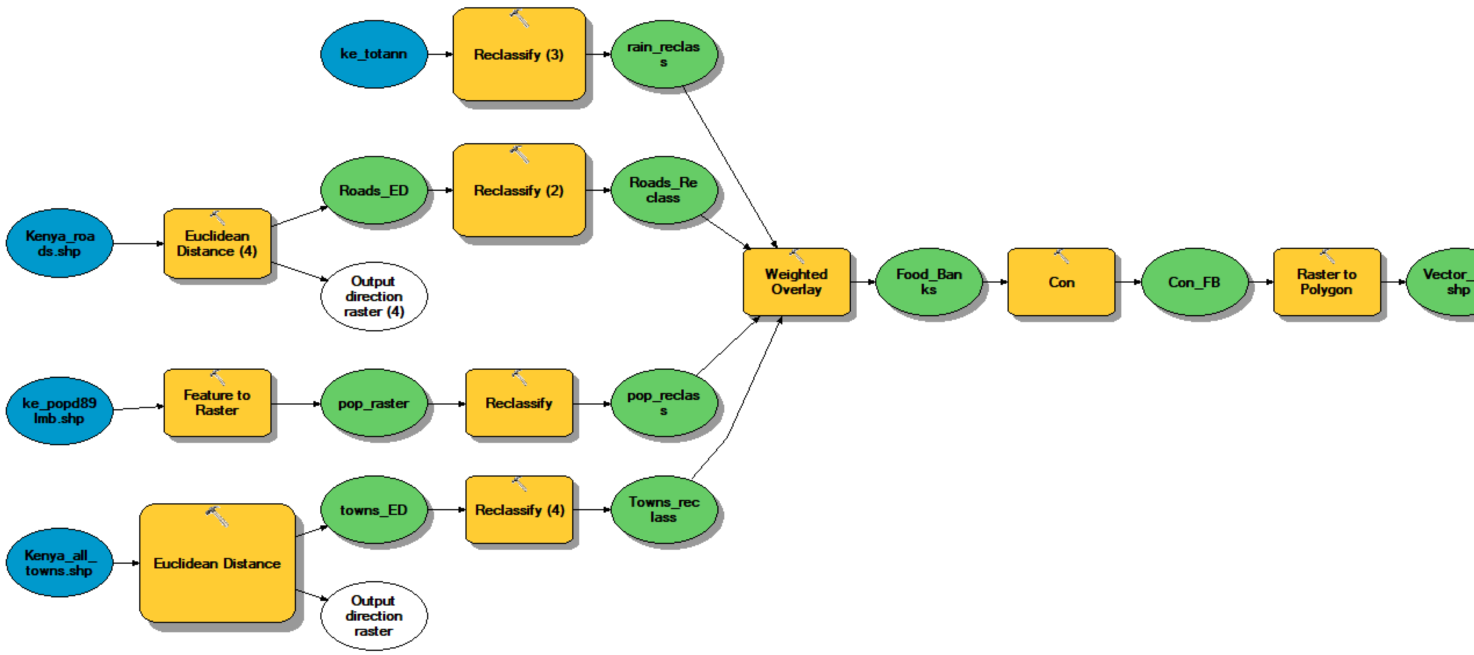


Figure 10: Suitability Model. Source: (Researcher)

4.2 Weighted suitability model results

This technique solves the problems of a binary/weighted suitability model and combines the different factors (Rainfall intensity, roads, towns and population). This model uses GIS layers to find the best location for any site. All the values in the layers have relative importance. The model runs suitability values on a scale of 1 to 9 for each cell, where 9 is the best. The reclassified layers were combined in map. Each reclassified layer is multiplied by its relative importance, expressed as a percentage of the total score. The weighted layers were added together. They must add up to 100. The weighted suitability model was used in this project and the general approach used for the determination of the most suitable location for the food banks is shown in the maps below.

4.3 Food bank suitable location based on major towns

Major towns are associated with more people hence ability to access food in figure 11.

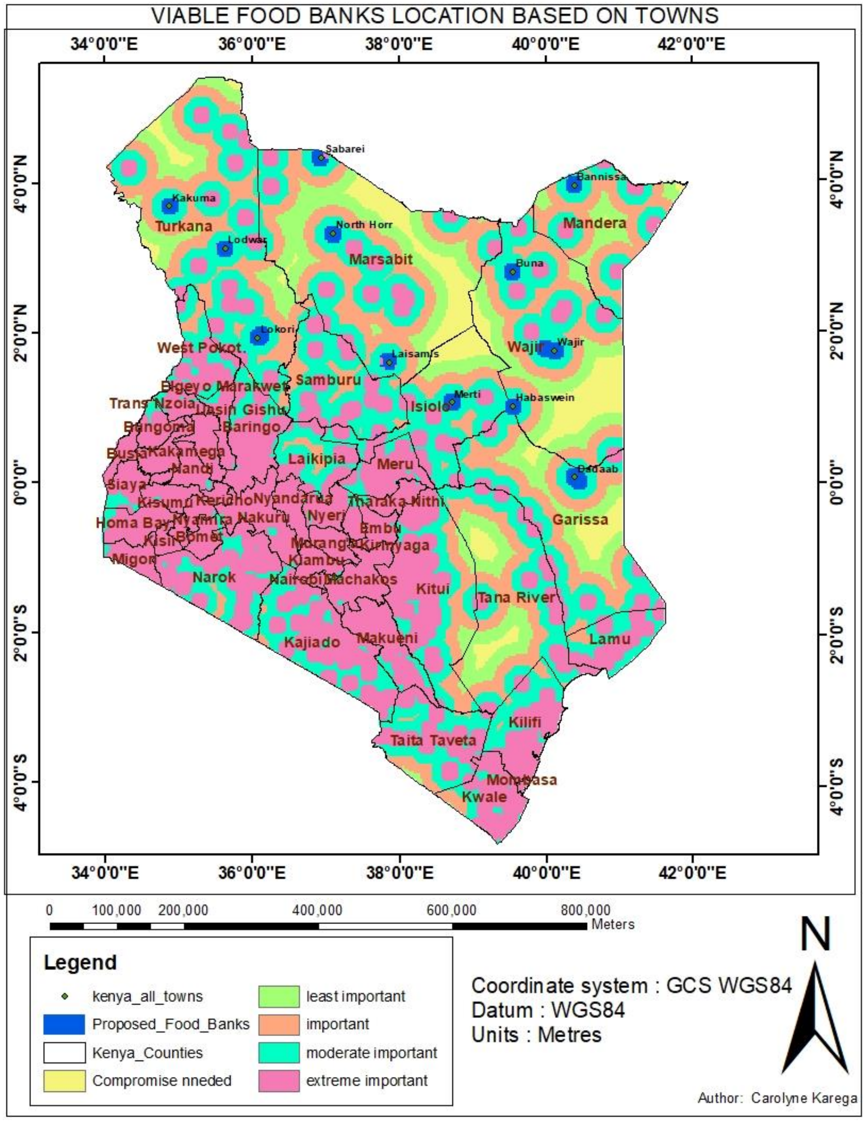


Figure 11: Food banks location based on towns. Source: (Researcher)

4.4 Food bank suitable location based on population.

Population has not been given much weight because it does not determine whether there is rainfall neither crop production. People tend to be more in urban areas or near towns as shown in figure 12.

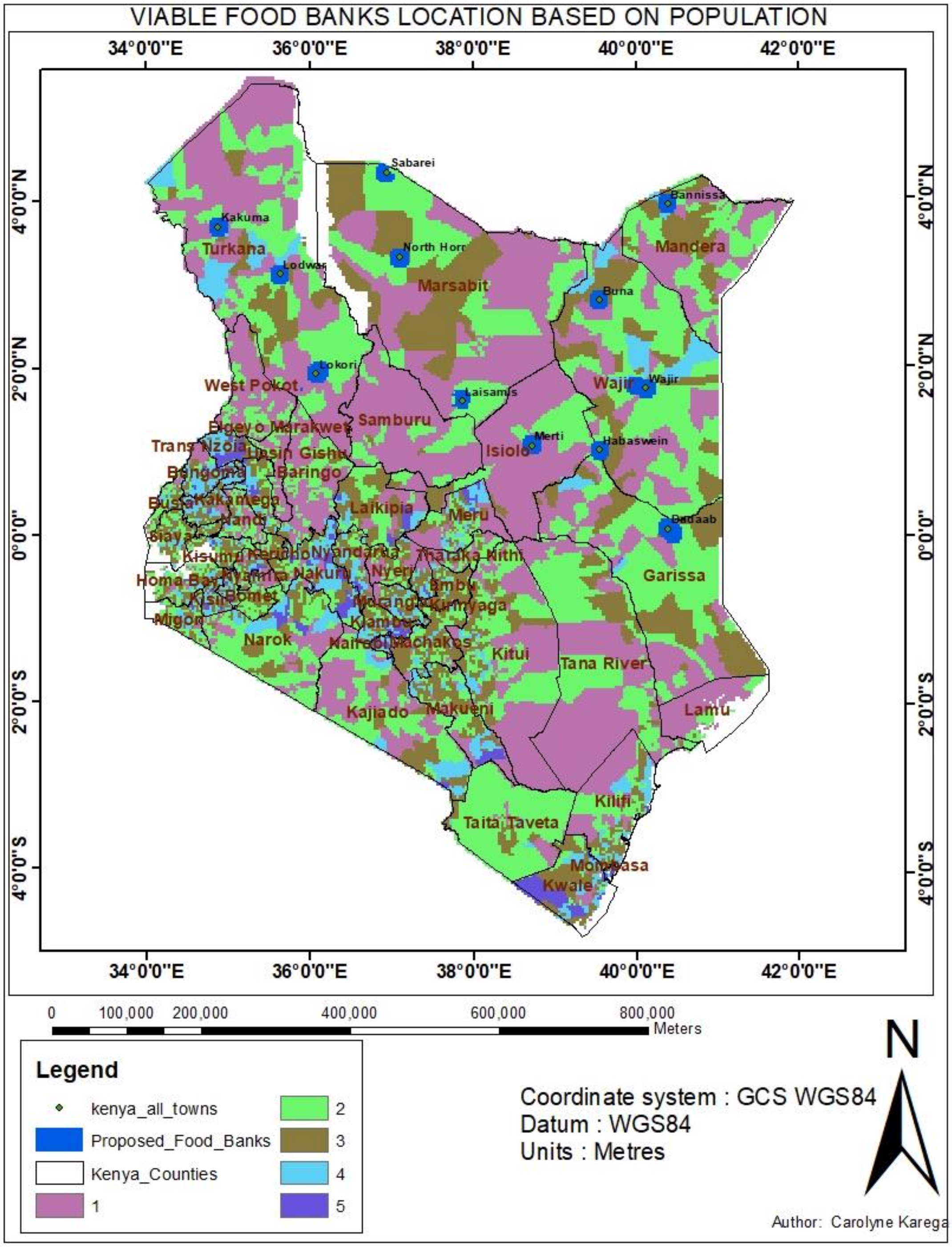


Figure 12: Food banks location based on population. Source: (Researcher)

4.5 Food bank suitable location based on rainfall intensity.

Figure 13 shows the viable location points after analysis of rainfall intensity in the country with the areas with less rainfall having more weight. This is because less rainfall results to poor crop growth.

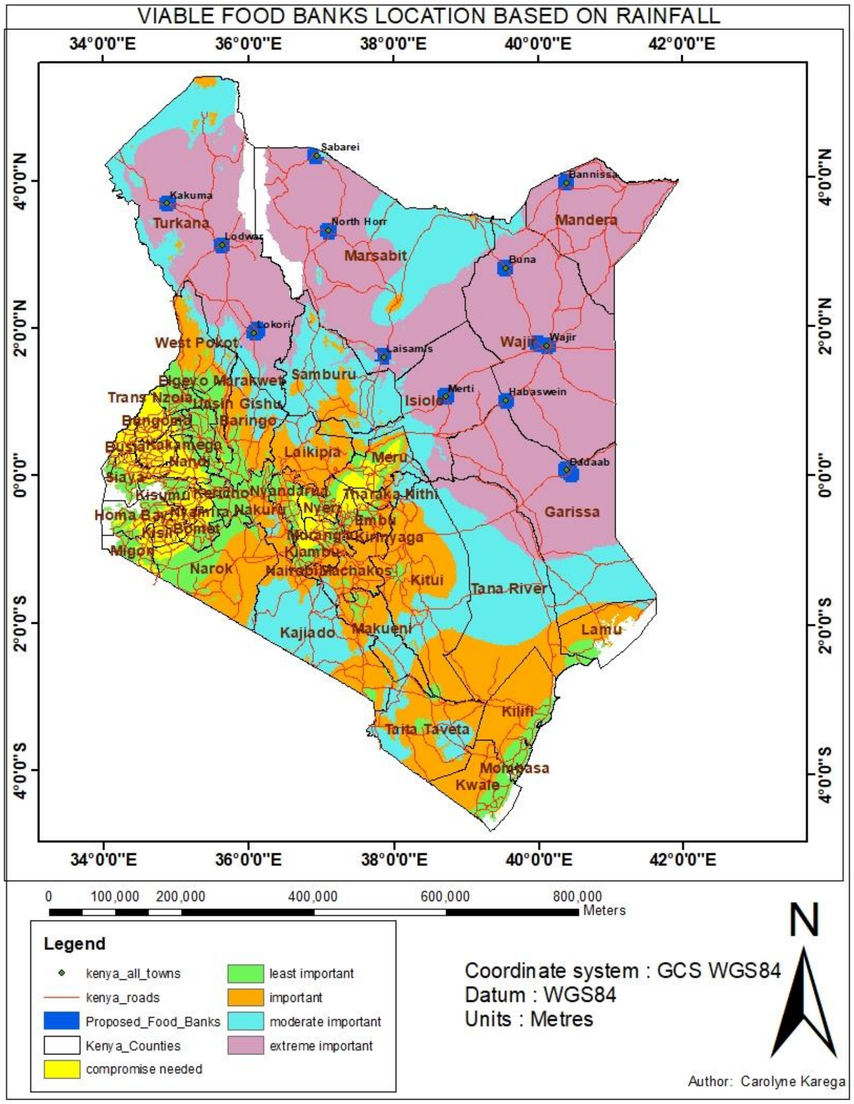


Figure 13: Food banks location based on rainfall intensity. Source: (Researcher)

4.6 Food bank suitable location based on roads

Proximity to roads is important due to transportation of the food items to reduce cost of transportation of food from point of production to point of consumption. Siting a food bank near existing road network will minimize the creation of new roads. Figure 14 shows results obtained after a 500 m buffer was created around the road features to define the restricted areas termed as inaccessible areas.

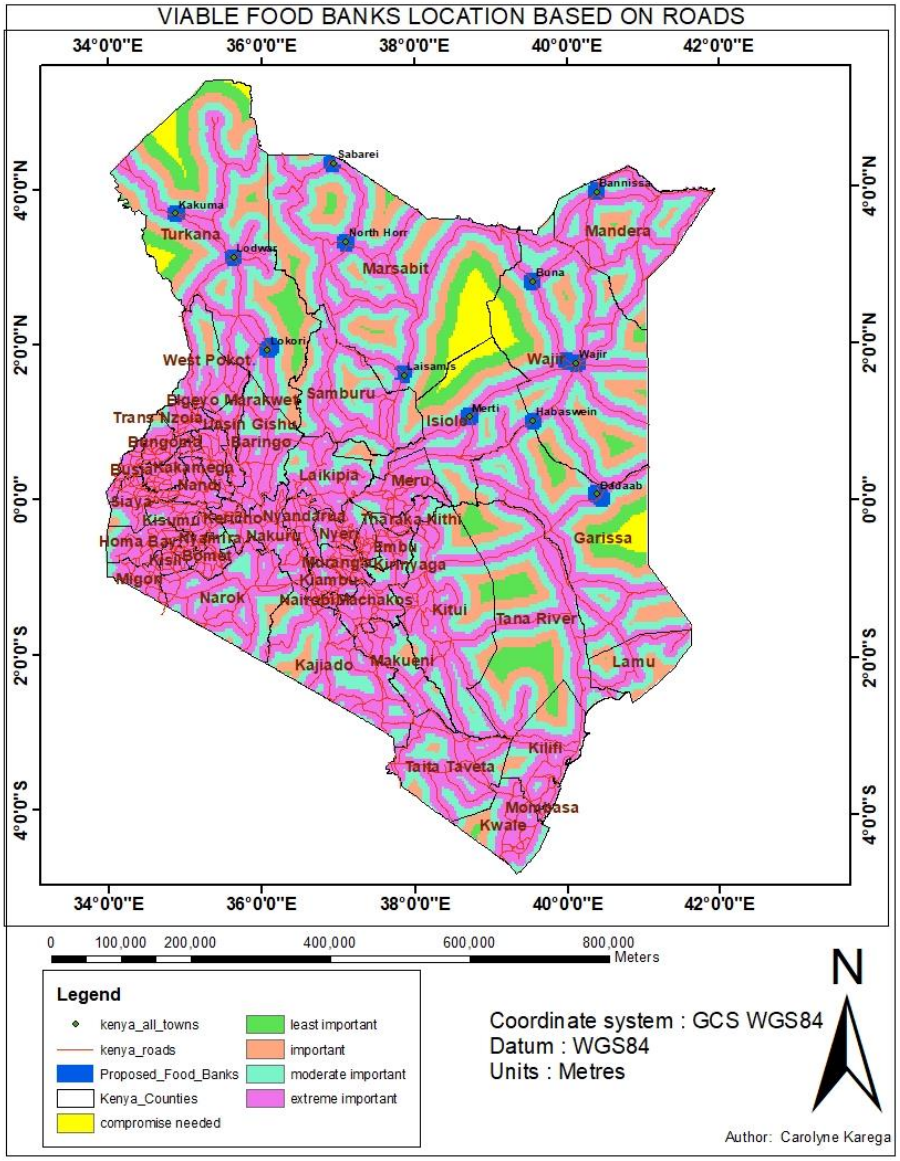


Figure 14: Food banks location based on roads. Source: (Researcher)

4.7 Food bank suitable location based on crop intensity

The areas where the food banks have been proposed show crop intensity is minimal (Figure 15) hence more probability of need of free food.

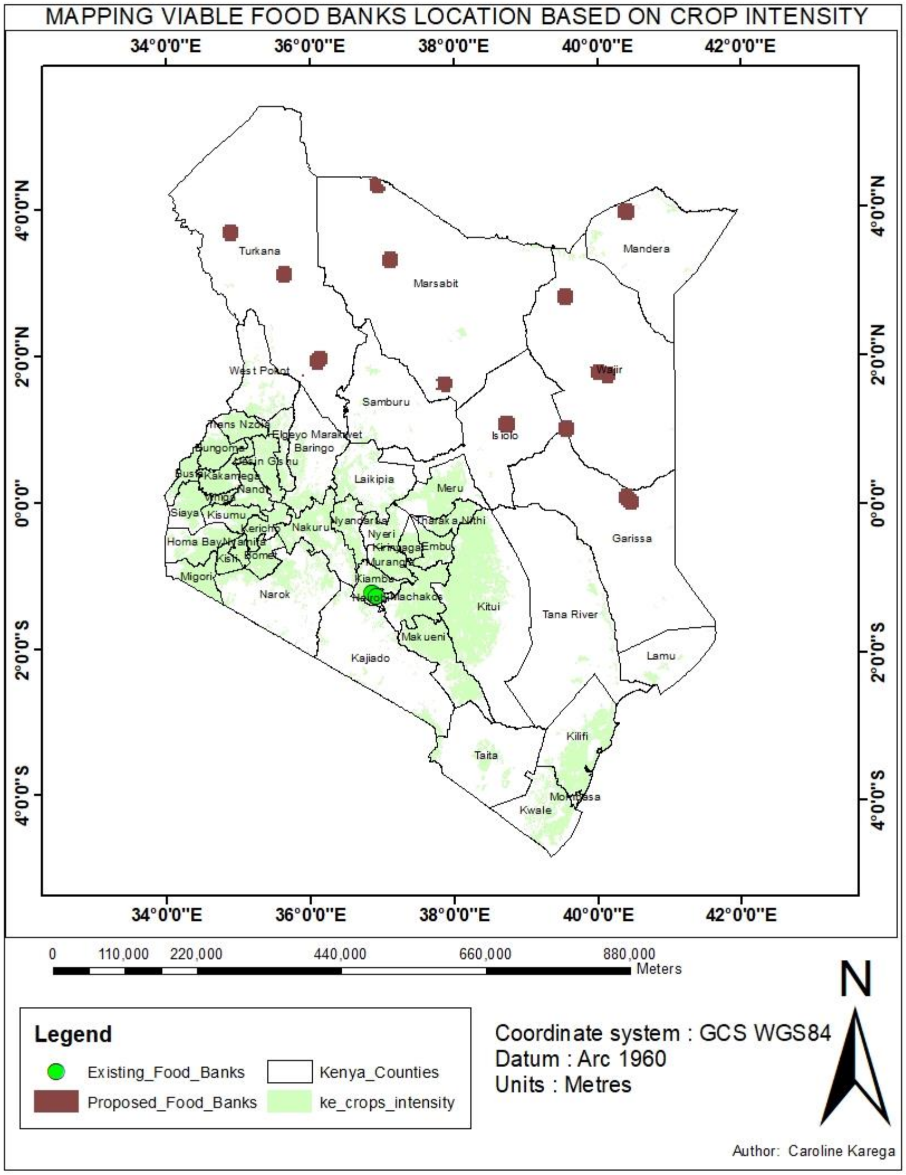


Figure 15: Food banks location based on crop intensity. Source: (Researcher)

4.8 Proposed viable food bank locations based on rainfall intensity

Figure 16 shows areas which are more favorable which receive less rainfall hence likelihood of crop production is minimal.

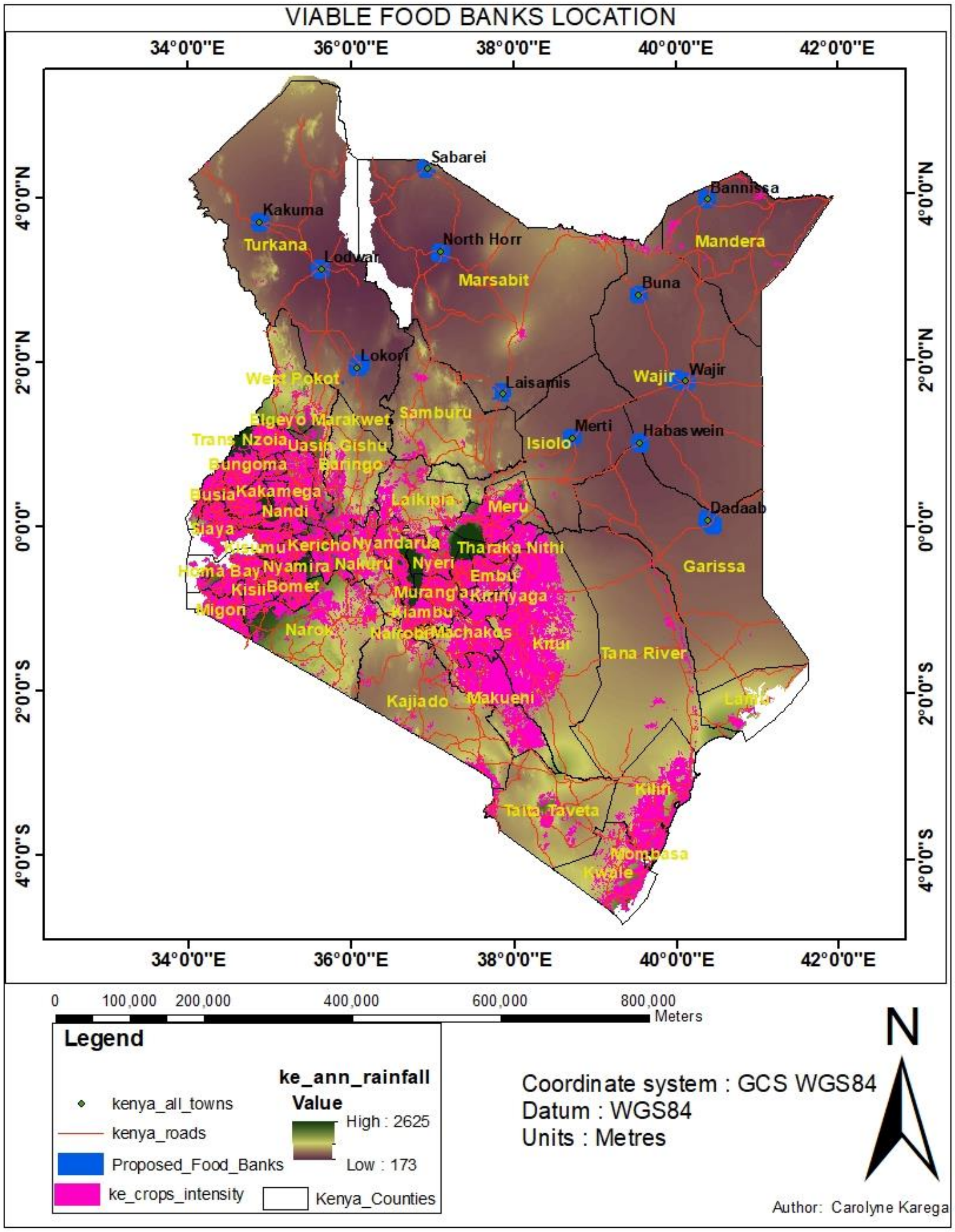


Figure 16: Proposed viable Food bank location. Source: (Researcher)

Example figure 17 of maize and sorghum, where it is produced and where it is needed most. I choose maize and sorghum because they are among the major food crops in Kenya.

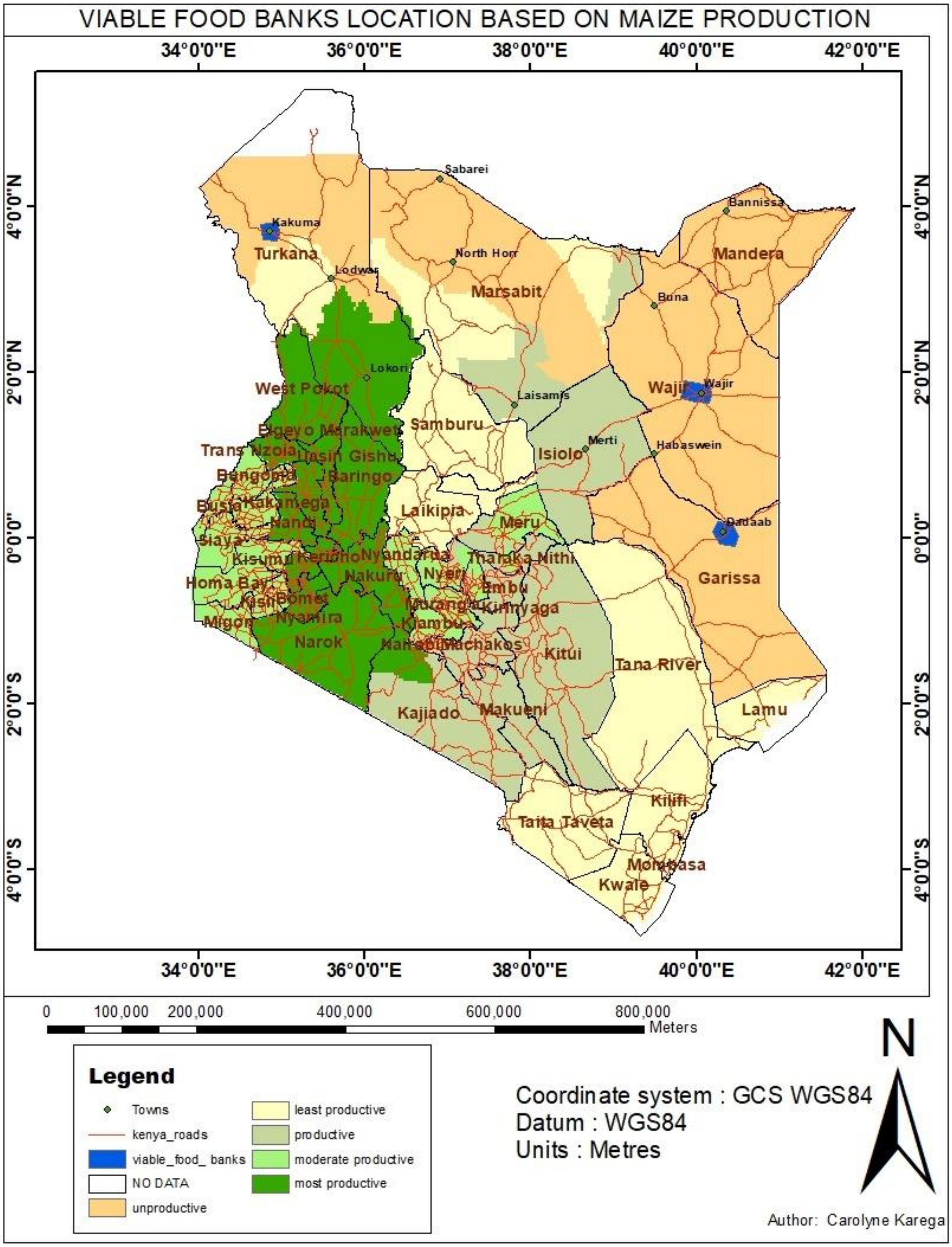


Figure 17: Proposed viable Food bank location based on maize distribution. Source: (Researcher)

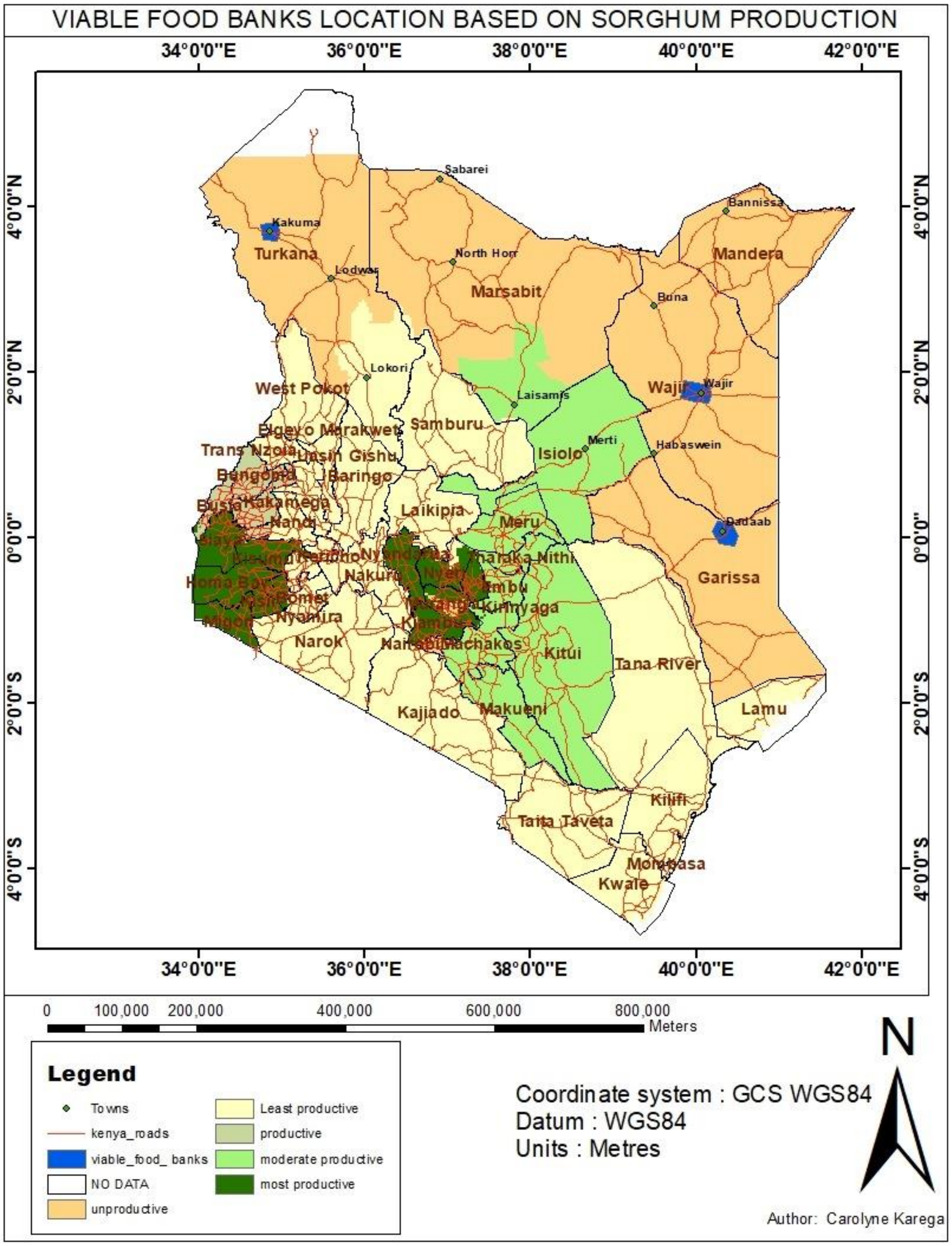


Figure 18: Proposed viable Food bank location based on Sorghum distribution. Source: (Researcher)

Maize is mainly grown in Trans Nzoia, Nakuru, Bungoma and Uasin Gishu counties. From the map, the results show that maize should be distributed in Turkana, Marsabit, Wajir and Garissa counties as they show no production of the crop. With Sorghum being grown in wester, Rift Valley, Eastern and some parts of Central, distribution should be done in the northern Kenya region.

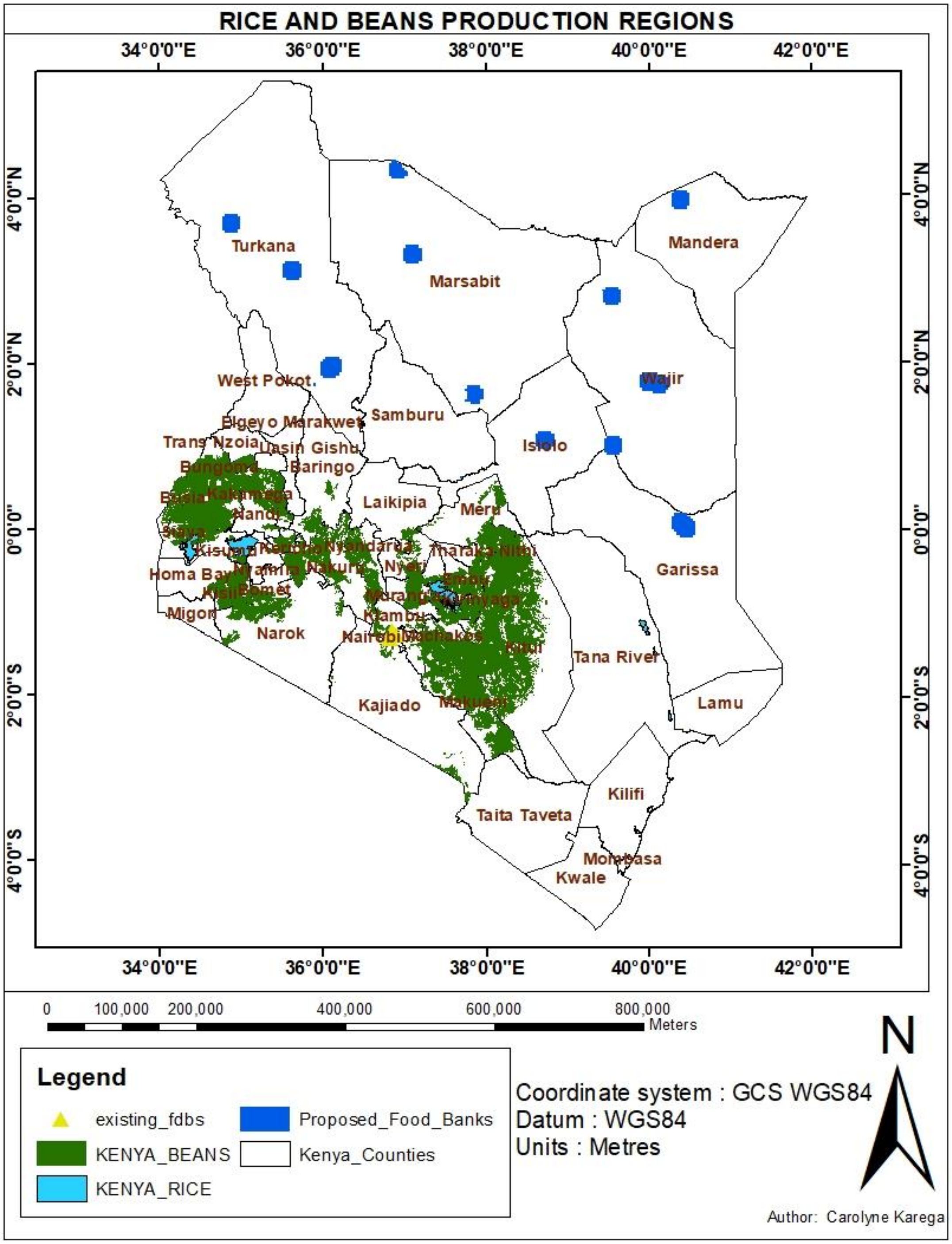


Figure 19: Beans and Rice high production regions. Source: (Researcher)

4.9 Discussion

To achieve sustainable food production, recent agricultural methods, food storage facilities need to be adopted. Food banks assist in food distribution especially in regions where there is need and distributed for free. Kenyan food banks are run by NGOs unlike other countries where they are operated by the Government. Viable location areas for the food banks were achieved from analyzing different factors and coming up with suitable regions in the country where the foodbanks would be more suitable. Nonetheless, even though suitable areas have been selected, there are areas of limitations which need to be pointed out such as:

1. Bearing in mind that weight assignment affects the overall results, determining which weights to be given to a certain factor is an individual judgment which is subjective and therefore may be bias.
2. There were no similar studies done within the study area and therefore there was no validation of the resulting suitability map.
3. Data for this study has been collected from various sources and therefore, the quality and accuracy of the datasets used for this study and their corresponding information depended on how they were collected, created and processed. Quality of data is vital in providing more accurate, reliable and sufficient information useful for decision making.

GIS has brought together a collection of data that mainly affect food bank distribution into a map view enabling some quick analysis that can lead to some quick decision making. In general integration of GIS with AHP has been helpful in arriving at a suitable locations for food banks. Therefore both are proficient and supportive tools for decision-making process Analysis resulting from the visualized GIS maps can be used in food security to understand where certain types of crops in in plenty and where the demand is high. Apart from helping in food distribution planning, the findings can be used to form a basis of other related research.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Summary of Achievements

Objective 1: Identify the most suitable ICT technologies in food security

The research identified the most suitable ICT technologies in food security as: food distribution technologies, communication technologies, urban agriculture methods; no-till farming, roof top greenhouse, farm drive all which aid in alleviating food shortage. ICTs can enhance the integration and efficiency of agricultural systems by opening new communication pathways and reducing transaction costs, given greater accessibility of information on prices, transportation, and production technologies.

Objective 2: To establish the distribution gaps in food banks.

The research has mapped the existing food banks which are located in Nairobi County, while the need for food is mostly high in the northern part of the Kenyan region and coast of Kenya. Also specific food crops have been covered by demonstrating where they are produced in plenty for example maize and beans and how they can be distributed in other areas not produced but required. An example of beans as the major source of dietary protein in Kenya but mostly grown in eastern and the Central regions hence there is a need to redistribute in other regions of the country.

Objective 3: To generate a suitable food bank mapping using GIS

Proposed foodbanks were mapped based on various related data: rainfall, roads, and crop intensity as demonstrated in chapter four. GIS was used because it’s a powerful tool that can deliver up to date map data, can be generated using a low-cost software and hardware infrastructure, and facilitate inexpensive map distributions. ArcGIS 10.5 was used. The three main applications of interest in ArcGIS 10.5 were ArcToolbox, ArcMap and ArcCatalog. ArMap was used to display spatial data. It was used to create, edit, query and analyze the maps. It offered many ways to interact with maps such as exploring, analyzing and present the results. ArcCatalog was used for accessing and managing data. It was also used to move, rename and copy datasets as well as preview geographic and attribute data. ArcToolbox provided access to advanced geoprocessing functionality and was also used for data management, data conversion and geocoding the food banks

Objective 4: Showcase digital map of food banks in selected areas.

This has been achieved through researching and identifying main GIS spatial and attribute data that affect food security using food banks geographic location and corresponding appropriate GIS tools for analysis and visualization. The existing food banks have been shown in a map and the locations. With the current food banks located in Ruaraka, Westlands, Kibera, Embakasi west, Kamukunji and Parklands, The research has demonstrated the proposed foodbanks to be located in Turkana, Marsabit, Wajir, Isiolo, West Pokot and Mandera.

5.2 Conclusion

Food insecurity in poor families is mostly as a result of lack of infrastructure including limited access to public water supply and poor guilty secondary roads.

Given the narrow margins in grocery retailing, an efficient transportation planning is necessary (Hübner et al., 2013; Agrawal and Smith, 2015). Grocery needs to be stored and transported from warehouses to the outlets in different temperature zones (for example, deep-frozen, cold, and ambient). The specific temperature requirements in transportation need to adhere legislative regulations. Due to these specific temperature requirements, trucks have usually been customized for exactly one product segment with the mandatory temperature.

Kenya has been experiencing periodic drought seasons however, we have learnt very little from the challenge. Kenya is currently the region’s economic powerhouse, yet in the past few months, farmers were complaining that the National Cereals and Produce Board was unable to buy maize from them because the national stores were full.

Poor planning is the cause of hunger in Kenya. Kenya has very many rivers and with water bodies being left idle. North African countries that rarely experience rainfall have food security compared with Kenya. Countries that are worst hit by drought, such as Turkana and Baringo, are allocated the highest amount of devolution funds, it is sad to note that they have not laid enough strategies to avert the crisis. Lack of storage facilities is one of the problems. Kenyan farmers have their maize rotting in their home stores. Experts state that over 10 million bags were lost in the last harvesting season due to post- harvest losses caused by infestation by armyworms.

5.3 Recommendations and Further work

Having demonstrated that GIS can be used to visualize varying geographical nature of food banks the following recommendations were made;

The government and non-governmental organizations should incorporate use of GIS in carrying out food distribution research.

Use of relevant strategies, policies and prioritized operational interventions which are required across the country. This will help provide reassuring insights that will help decision and policy makers prioritize their communications and interventions amongst organizational stakeholder groups involved in food security and food supply chain contexts. The value of the research is to raise the importance of food security amongst differing stakeholder community groups at the organizational and national level. Policies should tackle poor food distribution networks and reliance on rain-fed production.

Value addition and seeking new markets. More research is needed in communication technologies to farmers who may be producing surplus but lack the information on markets where it's needed hence food goes to waste. For example through mobile phones which local farmers can easily have access. Kenya needs the right regulatory and legal regime, supply of specialized information and knowledge, good infrastructure and access to finance to enable producers to invest in non-traditional, niche and fresh products.

Adoption of efficient and cost effective food distribution networks for example drones which will greatly help reach those in remote regions, investing more in multi temperature compartment vehicles. In inaccessible and insecure regions high altitude airdrops can be used to distribute pallets as has been successfully implemented in warzones for example Syria.

REFERENCES

1. *Aker, J. C. (2011). Dial "A" for agriculture: a review of information and communication technologies for agricultural extension in developing countries. Agricultural Economics, 42(6), 631-647.*
2. *Al-Fuqaha, M. M. (2015). Internet of Things: A Survey on Enabling Technologies, Protocols, and Applications.*
3. *Amitava, G., Rapeepat, R., Bishwarup, M., Nitin, M., & Tim, T. (2010). LTE-advanced: next-generation wireless broadband technology [Invited Paper]. IEEE Wireless Communications.*
4. *Ángel, A., Álvaro, M., Rubén, B., & Roberto, C. (2014). Protocol and Architecture to Bring Things into Internet of Things. International Journal of Distributed Sensor Networks, 1- 18.*
5. *Atzori, L., Iera, A., & Morabito, G. (2010). The internet of things: A survey. Computer networks, 54(15), 2787-2805.*
6. *Avison, D. and Heje, P. - (2005) Research in information systems. A handbook for research supervisors and their students, Heinemann, Oxford: Elsevier Butterworth.*
7. *Balamurugan, S., Divyabharathi, N., Jayashruthi, K., Bowiya, M., Shermy, R. P., & Shanker, R. (2016). Internet of agriculture: Applying IoT to improve food and farming technology. International Research Journal of Engineering and Technology (IRJET), 3(10), 713-719.*
8. *Bandyopadhyay, D., & Sen, J. (2011). Internet of Things - Applications and Challenges in Technology and Standardization. Wireless Personal Communications.*
9. *Bazerghi, C., McKay, F. H., & Dunn, M. (2016). The role of food banks in addressing food insecurity: a systematic review. Journal of community health, 41(4), 732-740.*
10. *Bertolini, R. (2005). Making information and communication technologies work for food security in Africa (No. 566-2016-38945)*
11. *Bhole. (2015). A review of emerging technologies under Internet of Things. International Research Journal of Engineering and Technology (IRJET), 1612-1615*
12. *Bordel, B., Alcarria, R., Robles, T., & Martín, D. (2017). Cyber–physical systems: Extending pervasive sensing from control theory to the Internet of Things. Pervasive and mobile computing, 40, 156-184.*
13. *Chan, J. O. (2013). An architecture for big data analytics. Communications of the IIMA, 13(2)*
14. *Ciaghi, A., & Villafiorita, A. (2016, September). Beyond food sharing: Supporting food waste reduction with ICTs. In Smart Cities Conference (ISC2), 2016 IEEE International (pp. 1-6). IEEE.*

15. *Delmonteil, F. X., & Rancourt, M. È. (2015). Analysis of Space-based Technologies Deployment in Emergency Operations Management: A Case Study of the Post-2010 Haiti Earthquake Response. CIRRELT, Centre interuniversitaire de recherche sur les réseaux d'entreprise, la logistique et le transport= Interuniversity Research Centre on Enterprise Networks, Logistics and Transportation.*
16. *Derpsch, R., Friedrich, T., Kassam, A., & Li, H. (2010). Current status of adoption of no-till farming in the world and some of its main benefits. International Journal of Agricultural and Biological Engineering, 3(1), 1-25.*
17. *Dlodlo, N., & Kalezhi, J. (2015, May). The internet of things in agriculture for sustainable rural development. In Emerging Trends in Networks and Computer Communications (ETNCC), 2015 International Conference on (pp. 13-18). IEEE*
18. *Dudovskiy, J. (2016). The Ultimate Guide to Writing a Dissertation in Business Studies: A Step-by-Step Assistance. Pittsburgh, USA.*
19. *Galliers, R. D. (1991). Strategic information systems planning: myths, reality and guidelines for successful implementation. European Journal of Information Systems, 1(1), 55-64.*
20. *Gebbers, R., & Adamchuk, V. I. (2010). Precision agriculture and food security. Science, 327(5967), 828-831*
21. *Giusto, D., Iera, A., Morabito, G., & Atzori, L. (Eds.). (2010). The internet of things 20th Tyrrhenian workshop on digital communications. Springer Science & Business Media.*
22. *Godfray, H. C. J., Beddington, J. R., Crute, I. R., Haddad, L., Lawrence, D., Muir, J. F., ... & Toulmin, C. (2010). Food security: the challenge of feeding 9 billion people. science, 327(5967), 812-818.*
23. *Golhani, K., Rao, A. S., & Dagar, J. C. (2015). Utilization of open-source Web GIS to strengthen climate change informatics for agriculture. In Climate change modelling, planning and policy for agriculture (pp. 87-91). Springer, New Delhi.*
24. *Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M. (2013). Internet of Things (IoT): A vision, architectural elements, and future directions. Future generation computer systems.*
25. *Han, J. H. (2005). New technologies in food packaging: Overiew. In Innovations in food packaging (pp. 3-11). Academic Press*
26. *Hanchard, M. Digital maps and anchored time: the case for practice theory. OGRAPHIC TEMPORALITIES, 154*
27. *Hong, I., Park, S., Lee, B., Lee, J., Jeong, D., & Park, S. (2014). IoT-based smart garbage system for efficient food waste management. The Scientific World Journal, 2014*

28. *http://www.fao.org/save-food/resources/keyfindings/en/*
29. https://farmdrive.co.ke/
30. *https://www.esri.com/en-us/arcgis/products/arcgis-network-analyst*
31. *Irani, Z., & Sharif, A. M. (2016). Sustainable food security futures: perspectives on food waste and information across the food supply chain. Journal of enterprise information management, 29(2), 171-178.*
32. *J.A.Stankovic, "Research Directions for the Internet of Things", Internet of Things Journal, vol.1(1) pp. 3-9, 2014*
33. *Kanga, S., Sharma, L., Pandey, P. C., Nathawat, M. S., & Sinha, S. (2011). Geospatial approach for allocation of potential tourism gradient sites in a part of Shimla District in Himachal Pradesh, India. Journal of GIS Trends, 2(1), 1-6.*
34. *Katengeza,S. (2012). ICT-based market information services, operational environment and performance: The case of Malawi agricultural commodity exchange and food and nutrition security joint task force*
35. *Kharya, S. (2012). Using data mining techniques for diagnosis and prognosis of cancer disease. International Journal of Computer Science, Engineering and Information Technology (IJCSEIT), Vol.2, No.2, DOI : 10.5121/ijcseit.2012.2206 55*
36. *Kubasu, L. N., & Wachira, H. (2010, May). Tackling cattle rustling menace using RFID/GPS livestock traceability applications in North Rift Kenya: assessment of the options and way forward. In IST-Africa, 2010 (pp. 1-8). IEEE*
37. *Lopez, T. S. S., & Kim, D. (2007, March). A context middleware based on sensor and RFID information. In Pervasive Computing and Communications Workshops, 2007. PerCom Workshops' 07. Fifth Annual IEEE International Conference on (pp. 331-336). IEEE.*
38. *Madakam, S., Ramaswamy, R., & Tripathi, S. (2015). Internet of Things (IoT): A literature review. Journal of Computer and Communications.*
39. *Magrini, E., & Vigani, M. (2016). Technology adoption and the multiple dimensions of food security: the case of maize in Tanzania. Food Security.*
40. *Maumbe, B. M., & Okello, J. J. (2013). Uses of Information and Communication Technology (ICT) in agriculture and rural development in sub-Saharan Africa: Experiences from South Africa and Kenya. In Technology, Sustainability, and Rural Development in Africa (pp. 113-134). IGI Global*

41. *Maxwell, J. A. (2012). Qualitative research design: An interactive approach (Vol. 41). Sage publications.*
42. *Maxwell, J. A. (2012). Qualitative research design: An interactive approach (Vol. 41). Sage publications.*
43. *Milan Zdravkovi_c, MiroslavTrajanovi_c, Jo~aoSarraipa, Ricardo Jardim-Gon_calves and MarioLezoche, "Survey of Internet-of-Things platforms, 6th International Conference on InformationSociety and Techology, ICIST 2016, Kopaonik, Serbia, pp. 216-220, February 2016*
44. *Mintsis, G., Basbas, S., Papaioannou, P., Taxiltaris, C., & Tziavos, I. N. (2004). Applications of GPS technology in the land transportation system. European journal of operational Research, 152(2), 399-409*
45. *Moturi, C. A., & Otieno, B. (2013). ICT and Food Security: Case of GIS in Food Emergency Response. International Journal of Applied Information Systems, 6(1).*
46. *Mucherino, A., Papajorgji, P., & Pardalos, P. M. (2009). A survey of data mining techniques applied to agriculture. Operational Research, 9(2), 121-140.*
47. *Ngaruiya, N., & Moturi, C. (2015, May). Use of data mining to check the prevalence of prostate cancer: Case of Nairobi County. In IST-Africa Conference, 2015 (pp. 1-11). IEEE.*
48. *O'sullivan, D., & Unwin, D. (2014). Geographic information analysis. John Wiley & Sons.*
49. *Patterson, T. C. (2007). Google Earth as a (not just) geography education tool. Journal of Geography, 106(4), 145-152.*
50. *Puri, V., Nayyar, A., & Raja, L. (2017). Agriculture drones: A modern breakthrough in precision agriculture. Journal of Statistics and Management Systems, 20(4), 507-518*
51. *Qiang, C. Z., Kuek, S. C., Dymond, A., & Esselaar, S. (2012). Mobile applications for agriculture and rural development.*
52. *Rancourt, M. È., Cordeau, J. F., Laporte, G., & Watkins, B. (2015). Tactical network planning for food aid distribution in Kenya. Computers & Operations Research, 56, 68-83.*
53. *Rasmussen, J. E., Rasmussen, L. E., Taylor, B. S., Norris, J. C., Ma, S., Kirmse, A. R., ... & Laforge, S. M. (2008). U.S. Patent No. 7,379,811. Washington, DC: U.S. Patent and Trademark Office.*
54. *Saaty, T.L. (1980). The analytic hierarchy process. McGraw-Hill, New York*
55. *Sheppard, S. R., & Cizek, P. (2009). The ethics of Google Earth: Crossing thresholds from spatial data to landscape visualisation. Journal of environmental management, 90(6), 2102-2117*

56. *Simmet, A., Tinnemann, P., & Stroebele-Benschop, N. (2018). The German Food Bank System and Its Users—A Cross-Sectional Study. International journal of environmental research and public health, 15(7), 1485.*
57. *Tester, M., & Langridge, P. (2010). Breeding technologies to increase crop production in a changing world. Science, 327(5967), 818-822.*
58. *Toorani, M., & Beheshti, A. (2008, September). Solutions to the GSM security weaknesses. In Next Generation Mobile Applications, Services and Technologies, 2008. NGMAST'08. The Second International Conference on (pp. 576-581). IEEE.*
59. *Verdouw, C. N., Wolfert, S., & Tekinerdogan, B. (2016). Internet of Things in agriculture. CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources.*
60. *Wang, N., Zhang, N., & Wang, M. (2006). Wireless sensors in agriculture and food industry—Recent development and future perspective. Computers and electronics in agriculture, 50(1), 1-*
61. *www.wfp.org/hunger/stats; Accessed on October 21, 2018*
62. *Yajie, W. A. N. G., Bing, Y. A. N. G., Yan, L. U. O., Jinlin, H. E., & Hong, T. A. N. (2015). The Application of Big data Mining in Risk Warning for Food Safety. Asian Agricultural Research, 7(8).*
63. *Yu, L., & Gong, P. (2012). Google Earth as a virtual globe tool for Earth science applications at the global scale: progress and perspectives. International Journal of Remote Sensing, 33(12), 3966-3986.*
64. *Zhu, Q., Wang, R., Chen, Q., Liu, Y., & Qin, W. (2010, December). Iot gateway: Bridgingwireless sensor networks into internet of things. In Embedded and Ubiquitous Computing (EUC), 2010 IEEE/IFIP 8th International Conference on (pp. 347-352)*