KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

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FUTURE FOOD FRAMEWORK (F^3) – MODELLING GEOSPATIAL INPUTS FOR MONITORING URBAN CHANGES AND FOOD SECURITY IN GHANA- A CASE STUDY OF ADENTAN MUNICIPALITY.

By

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(B.Sc. Human Settlement Planning)

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DECLARATION

I "Kwaku Owusu Twum", hereby declare that this thesis is a presentation of my original work and that to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree or diploma at Kwame Nkrumah University of Science and Technology, Kumasi, or any other educational institution. Wherever contributions of others are involved, every effort is made to indicate this clearly, with due reference to the literature and acknowledgement of collaborative research and discussions.

The work was done under the guidance of Rev. Dr. John Ayer

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DEDICATION

I dedicate this master piece to the Lord Almighty, who has been my source of wisdom and illumination. Also, to my loved Mother Mrs. Doris Owusu and my wonderful partner and friend Miss. Eugenia M. Jorbor for inspiring me with confidence as I embarked on this academic journey, this reassurance made me more determined and committed to this study. To my cherished siblings; Nana Kwasi Adu boahene, Migieta Owusu and Diana Owusu I say thank you. My love cannot be reckoned for you all. God's favor be with you all, Amen.

ABSTRACT

Contemporary urban literature reveals the multi-dimensional character of cities, from spatial reflective analysis of the urban landscape to its evolving human interactive changes. Hence, the narrative for urban monitoring requires great attention. Unfortunately, the spatio-temporal visibility of urban changes have been less attractive, perhaps due to the unnoticed connection of its evolving patterns. Furthermore, the urban phenomenon has been centered on a unilateral approach of observing its manifestation at particular times with less attention given to its factors of complexities. This makes it erroneously difficult to significantly trace, track and transfer urban change information for policy guidance and effective decision-making. Urban change complexities transforms food security patterns in cities and has raised concerns across the globe, although its indicative multidimensionality within the local context is less discussed. Food security in Ghana has been limited to availability, with less attention given to other metrics particularly food access and equity. As urban growth intensifies, food access disparities enlarge compromising equal access. The consistent urban struggle in Ghana's sub-urban cities, validates this opinion- where a polar distribution of this urban commodity exist. Premised on this, the Adenta municipality is contextualized to explore the challenge of urban food systems of a so-called food secured state as well as address the overlooked inequality hints that exist in the urban food sub-sector. With a multi-criteria approach, geographic information systems (GIS) allowed for land use land cover changes, urban growth and density (as urban change indicators) to be synced with urban food access indicators, i.e., economic access, physical access and social access. Additionally, social vulnerability indexing coupled with resilient indicators were joined with spatial analytical tools to investigate the levels and rates of food accessibilities within the stream of modern cities. Attempts to address potential threats of the urban presence of food gaps were done by assigning weights of ranks to better model and analyze food trends. The urban food stress index was used, indicating general threats of food insecurities within the municipality but more pronounced among residents in Koose and Gbentanaa electoral area. It further exposed the level of vulnerability to food access among urban groups in the country due to their poor economic access.

The result of urban change revealed a growing transformation, especially for the built up areas – rising from 245.85 sq.km (representing 26.5 %) to 416.94 sq.km (representing 44.91 %) between 1991 and 2018. This has had an inverse relationship on food access in the municipality. The study discovered that whereas urban changes were increasing at a fast rate of about 0.4 %, food access reduced significantly with an average rate of 0.3 %. A model based on the multi-criteria and analytical hierarchy process (AHP) facilitated future predictions whereby a trend of risks on urban food in the next 7 years was forecasted. The study finally recommended that urban change monitoring and geospatial input modelling must be embraced across professional, academic and institutional disciplines towards effective urban planning and decision making for emerging complex cities.

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LIST OF ABBREVIATIONS

AdMA – Adenta Municipal Assembly

AMA – Accra Metropolitan Assembly

ASABE - American Society of Agricultural and Biological Engineers

CLGA - Centre for Local Governance and Advocacy

FAO – Food and Agriculture Organization

GAMA – Greater Accra Metropolitan Area

GIS – Geographic Information Systems **GSS**

- Ghana Statistical Service

GLSS – Ghana Living Standard Survey

GOG - Government of Ghana

LOGNet - Local Government Network

MLGRDE – Ministry of Local Government, Rural Development and Environment

MOFA – Ministry of Food and Agriculture

PHC – Population and Housing Census

UNHABITAT – United Nations Human Settlement Programme

WFS – World Food Summit

WFP – World Food Programme

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CHAPTER ONE
1.0 GENERAL INTRODUCTION

1.1 Research Background

The swift pace of global urban rise, particularly in the global south, is among the major problems for city authorities and planning institutions in the century (Mosammam *et al*, 2016). Currently, nearly 4 billion people representing 54 % of the global population live in urban spaces with an anticipated stretch of 6.3 billion by 2050 (UN, 2015). Besides, an overwhelming rate of up to 90 % of future urban population growth exists in cities from developing countries (FAO, 2012). Within the African context, Mosammam *et al*, (2016), discovers that this revolution is more alarming. Additionally, the United Nations report, (2004; 2015); confirmed that urban population has experienced an exponential growth in recent years, which seems to experience a doubling effect in its urban expansion from about one billion to almost two billion by 2044. This statistically reveals that the growth and change patterns of the urban space poses direct and indirect benefits as well as risks on the spatial and socio-economic discourse of the continent. For instance, many cities from developing countries (despite the economic and industrial transformations), have recorded volumes of disasters, food security with extreme hunger, poverty, inequality coupled with pollution, urban congestion and sprawl. Additionally, the absorption paucity and population outburst has caused urbanization to contribute to the emergence of slums and informality in cities (Satterthwaite *et al*. 2007. These urban changes have obviously among others impacted the urban livelihoods with major urban areas still recovering from these urban shocks and others constantly adapting to their new realities. A critical aspect of this is food. It is explained that vulnerability share of urban dwellers to sudden shocks in agricultural markets keeps increasing (Matuschke, 2009).

In African countries such as Ghana, agriculture is the mainstay of its economy and this is evidently seen in the fact that the sector records close to 35 % of the continent's Gross Domestic Product (GDP), provides 70 % employment, and 40 % of exports (Cheru, 2002). Nonetheless, several countries within the sub-region fail to meet the food demands of their citizenry especially within its urban areas. Ghana's agricultural sector continues to encounter food security challenges as a result of the production decline in the urban food sub-sector coupled with the competitive internal food markets (Wolter, 2008). Currently, food crisis in Ghana is somewhat seen as a nonchalant phenomenon, and has therefore received less attention. For instance, Seiler (2013) observes that, food security require more consideration, not only to resolve Ghana's agricultural problem but also take advantage of the growing need for food

across all urban groups. For instance, the urban space of the Adenta Municipality (an urbanizing district of Ghana) has practically experienced swift urban changes (from about 39000 to 78000) in the last decade and is describes to have one of the highest (4.4 %) growth rates in the region. Ghana's urban space faces constant alteration physically and socially, whereas arable land declines affecting net food production, rural -urban population in flux escalades affecting labour supply. In both ways, food availability and accessibility is threatened in the country. In addition, majority of urban dwellers in Adentan municipality and Ghana are net food buyers who spend significant shares of their disposable income on food, this defeats the national notion of food security in Ghana (Mosammam et. al, 2016). Essentially the very existence of urban residents is compromised and sustainable living has become a mirage (Oduro et al, 2015). In effect, the motivation to address these changes from various stakeholders has been strong. Government bodies, international organizations, local authorities, academics among others are constantly finding effective ways of improving the life of the local urbanite (Hagai, 2014). Despite the progress been made, with national policies such as the Planting for food and Jobs programme (PFJP), Sustainable development goals as well as numerous research findings, urban livelihoods keeps facing challenges (MofA, 2016; AdMA, 2018).

Given the coinciding existence of several factors affecting the food potential of urban regions in Ghana (including Adenta), and considering the recent societal debate on food autonomy in the context of food security and sustainability, the 'reconnection' between food demand and supply emerges at policy agendas at both the national and international level (Wascher *et al*, n.d). Tackling this phenomenon, food frameworks foregrounds urban food sub- systems as urban change settings where progressions connected to spatial and non-spatial patterns as well as food disparities are interconnected (Monaco et al, 2017). Urban districts like the Adenta municipality must therefore, be considered as a dynamic manifestation of a complex urban character. To better tackle this problem, significant monitoring, assessments and effective predictions must be well simulated. Therefore, in order to frame, communicate and manage the impacts of urban food demand and security, a string of successive, yet complementary footprint assessment tools are derived. Urban development and change models, supported by geospatial technology with augmented digital data availability, has the prospect of becoming essential tools for observing and guiding spatial outcomes as well as food security preparedness (Wray and Cheruiyot, 2015). Therefore, to attain a more sustainable urban form, scientific analytical systems are critical for urban policies and decision making. Accordingly, for a holistic future food framework, efforts should be tailored towards the need of embracing smart decision tools

(FAO, 2015). Geospatial analysis provides a geographic lens to examine many urban food issues including food access and monitoring urban changes (Deep and Saklani, 2014). Similarly, operative framework results depend on reliable and robust metrics for the key urban indicators such as density, growth, income patterns, etc. used to monitor and report on project and program performance. For improving the effectiveness of interventions and achieving the development outcomes of cities (Alexakis *et al.,* 2014), some scholars emphasized the measure of urban changes by their indicators (as mentioned above), using spatial and time-based technologies like GIS and remote sensing combined with statistical methods (Liu and Yang, 2015). This sets the pace of allowing for a systematic approach or resolving spatial issues in the country.

Additionally, the application of GIS modeling approaches is relatively rapid and convenient than unalloyed statistical manual methods (Aryee, 2018). Thus, urban information systems ought to be studied and implemented readily, so as to facilitate evidenced-based understanding of urban imbalances (Rawat *et al.,* 2013). In this manner, a reliable urban template could be designed guiding local authorities (like the Adenta Municipality) in decision making. Accordingly, sustained justifiable methods of surplus food distribution and accessibility in the urban space could be well appreciated for facilitating inclusion and empowerment even at the lower urban levels (Hagai, 2014).

The overall aim was to discover the connection of urban changes and food security in Ghana through justifiable urban indicators. It further setup a monitoring system to measure patterns and make calculative predictions for easy decisions. Considering the Adenta Municipality, where the pressure on urban space and systems is projected to be particularly high; this study integrated strategic inputs from geographic information systems to design easy and reliable tools for effective decision making in Ghana's urban districts.

1.2 Research Problem

Gross urban expansion combined with progressive land use changes has significant impacts on a city's structured landscape (Shalaby and Tateishi, 2007). Therefore, the need to assess urban

growth arrangements and change analysis of urban cities is crucial. Presently, the urban discourse has received some attention especially in the areas of adopting scientific techniques for monitoring and predicting urban changes (Butt *et al*., 2015). Subsequently, the diverse approaches of urban change monitoring, multiscale satellite data along with GIS and remote sensing (RS) techniques are becoming important phases of analyzing city growth and change (Dadras *et al.*, 2015). These approaches could be a sustainable remedy for mitigating adverse impacts of spatial growth and development particularly in the food and agriculture sector (LeeSmith, 2013). Conversely, the determination of food security outcomes in Ghana is less popular and poorly represented essentially due to ineffective measuring and monitoring tools (Nyanteng and Asuming-Bempong, 2003). This has contributed to the unawareness of food insecurity in our various districts and country as a whole, threatening the future of food supply and safety in the country. Urban monitoring and food security tools and methods designed to assess critical food dynamics in Ghana's urban context are essentially non-existent (Ayerakwa, 2017; Aryee, 2018).

Presently, the research and policy deliberation on whether to streamline food supply in the urban context through urban agriculture or maximize the rural potential and optimize distribution has become a topical issue discussed from both ends of the divide (ArmarKlemesu, 2000; Ayerakwa, 2017). The debates have been separated along two schools of thought, one that encourages urban agriculture as a mechanism to support and secure urban food and livelihoods, as well as becoming a pro-poor structure within urban interiors (Mwangi and Foeken, 1996; Drechsel, *et al.*, 2006; FAO, 2001). From the other side of the discussion lies the contrasting line of argument that debunks urban agriculture as not only an inefficient pro poor initiative in cities but also not a realistic pathway as it does not necessarily guarantee the poor, rights to land which is an important resource in the city to acquire for self-farming and growing own foods (Zezza and Tasciotti, 2010; Frayne *et al.*, 2014).

However, along these debate lies a component of how to determine whether one part or both of the divide has the answer to this multi-relational issue or not. It is realized that food availability and distribution dynamics in the urban space is far more concentrated on production and not necessarily on demand (Hagai, 2014). Key actors often adopt methods adapted to rural contexts which are not necessarily suitable to assess food security and vulnerability in urban settings considering the mixture of livelihoods, coping strategies and settlement patterns (Lovon, 2016). Therefore, inadequate geospatial inputs and methodology has considerably inhibited the suitability and effectiveness of urban changes and food response especially in marginalized urban settings in Ghana (Stewart, *et al.*, 2013).

Adenta municipality, a growing urban fringe in the cities of Accra, Ghana is one of the phenomenal areas that has undergone massive urban changes in the last 10 years (AdMA , 2016). For instance, according to the population census, 2010, its population had risen to 78,215 (2010 Housing and Population Census) with 62.5 % urbanites and 37.5 % from periurban / rural areas.

Again, with a growth rate of 2.6%, and a regional growth rate of 4.4% it is among the highest in the region and therefore reflects the fast developing nature of the Municipality (MLGRDE, 2014). These urban developments and local population in-flux has resulted in numerous urban challenges in the district. For instance, in June 2015, a heavy rainfall in Adentan resulted in a collateral damage in 12 communities in the municipality. A total number of 552 households were registered and 2,208 persons were affected in the disaster (Composite Budget, AdMA, 2017-2019). Similarly, urban sprawl, poor sanitation, congestion and road accidents, food insecurity and vulnerability among others, have been some of the battles the Assembly fights each day. This therefore posits the general question being asked whether the decision-making systems of the assembly is functional, whether it can stand the test of time to control and mitigate now and in the future.

According to the Adenta Municipal report, (2016) Agriculture production in the Municipality has largely reduced with farming done on subsistent basis. Presently, the average land allotment per farmer within the municipality is estimated at two (2) acres. These are mostly agricultural areas lost to residential and commercial uses as a result of significant transitional movements from the Accra city into the districts.

Food is increasingly an urban issue (Dubbeling, *et al*, 2015) for that matter the concept of urban food systems is gaining considerable popularity among local, regional and national levels as well as, international organizations, professional bodies and in academia. As part of national policy (Planting for food and jobs) for example, the Adenta Municipal Assembly (AdMA), in collaboration with the Centre for Local Governance and Advocacy (CLGA) and the Local Government Network (LOGNet), launched a project to promote the cultivation of mushrooms in the municipality promising 5,500 jobs and a projected income of GH¢4000 to GH¢30,000 by December 2020 although the process of monitoring is left out (Esson, 2017). Intrinsically, food system diagnosis further helps in critically analyzing the ground-level transformation and implementation policies within the urban food sub-sector (Dubbeling, *et al*, 2015).

This sets the discussions to chart a new and smart approach of embracing geospatial technology and its prospects as a leveraging tool to combat the multi-dimensional issues in cities. In this research therefore, the urban patterns and the food access conditions of occupants in sub-urban

cities in Ghana is analyzed with reference to their urban manifestation, local food demand, production and household distribution. How these patterns are measured and their contribution to household food access was outlined in this study. Subsequently, a predominant objective of the study was to determine the variation of a growing urban population in the country using geospatial technology with the Adenta Municipality as a case study. The study further analyzed the corresponding dynamics of monitoring these urban changes and maintaining urban food balance in the country currently and in the future. This was done by delineating the spatial variables of the urban space and analyzing their causes and effects for urban groups within the confines of food access and security. Holistically, the approach set the pace of incorporating innovative and smart tools of decision-making for cities in the global south.

1.3 Research Objectives and Questions

The ultimate interest of the study was primarily to monitor, measure and predict urban change and food security inequalities in the Adenta city.

1.3.1 Research Objectives

1. To determine and assess the urban change pattern in the municipality.
    - This was based on the multi-criteria approach of verified indicators such as land useland cover changes, urban density, annual rate of housing developments, etc. Also the extent of sprawl, and rate of land use conversions or change within the municipality.
2. To Identify and categorize urban groups and food stressed areas for integrative planning.
    - (Low, medium, high) based on social, geographic and income status, etc.
    - Low to high risk areas based on density, level of formality, food mapping, etc.
3. To Model a framework to monitor periodic changes and its effects on food access and utilization now and in future.
    - This was be based on the geospatial inputs gathered such as spatial datasets on locations, etc. a system was designed to monitor the urban in flux (from population / housing studies) and supply (from market research/ study) in the Adenta Municipality.

1.3.2 Research Questions

In relation to the research problems discussed above, the following questions are relevant, and as such, efforts were made to find laudable answers to them.

1. What is the pattern of urban change in the district?
2. How can urban changes and food accessibility be measured?
3. How can urban changes and its effects on food access and utilization be monitored and managed in future?

1.4 Justification and Significance of study

Adopting geospatial technology is an innovative, realistic and relevant tool that could help solve the multi-dimensional complex urban problems in districts if well utilized. It is more scientific, calculative and multi-applicable. It advances and improves on the traditional means of mapping areas providing intuitive knowledge on complex planning interventions and decision-making. Geospatial techniques further ensure future reliability of accurate datasets and system (considering the rapid inclination of open data, big data and cloud technology in the digital age) for practical, reliable and timely decision-making. Besides it is flexible and scalable -can be built upon anytime and thus ensures improvement of methods based on current trends leading to better policies based on accurate, reliable geospatial technology. This contributes to smart planning which leads to smart cities (the new paradigm in contemporary planning).

1.5 Research Scope

The scope of the study is divided into contextual scope and geographical scope. Contextually, the study examined urban changes and food security issues with key attention on the Adenta Municipality, a thriving urban municipality within the Greater Accra region of Ghana. Specifically, the research focused on the assessment of the rate and pattern of urban growth and its implications on the sustainable food accessibility and distribution in Ghanaian cities. It further attempted to monitor these phenomenal changes by generating urban models using GIS to streamline urban policies and facilitate decision making.

The multi-dimensional causes and implications of urban changes such as population distribution, housing supply, informality, income levels and sprawl among others was classified and programmed for structured policy making. This was further discussed in relation to urban food systems in the municipality with reference to the various indicators such as economic, physical, social, gender, etc. to better inform policy makers and other stakeholders using the potential of geospatial tools. Efforts were made to identify the specific measurement frameworks available and accessible for instituted for local authorities and institutions for monitoring and managing urban issues and food security. These local frameworks included

their statistical environmental reports, development control reports, baseline indicators, medium term development frameworks (MTDF), etc. Hence, not only did this research focus on local measures, but further adopted the systematic application of GIS to better appreciate these local methodologies. With insight from the aforementioned background, the researcher proposed specific measures and a structure possible to ensure efficient urban control and smart planning strategies.

The geographical scope of the study is the Adenta Municipal Assembly of the Greater Accra region of Ghana. It was created from the Tema Metropolitan Assembly in February 2008 under the legal instrument LI 1888 (Adenta Municipal report, 2010; PHC, 2012). Adenta functions as a dormitory town for most migrants who seek employment across sectors such as industrial, service, public institutions within the central cities of Accra and Tema (GSS, 2014). According to the 2010 Population and Housing Census, the district was estimated to have a population of 78,215 with males constituting 50.3 % and females 49.7 %. The Municipal Assembly has Adenta as its central city and lies about 10 kilometres to the Northeast of Accra, specifically located on latitude 5′ 43″ north and longitude 0′ 09″ West and has a land area of about 928 sq. km (358.3 sq. mls) (PHC District report, Adenta, 2014). It is bounded to the east with Ashaiman Municipal Assembly and north with Kpong Akatamanso District Assembly, to the west with La Nkwantanang Municipal Assembly and to south, with Tema metropolis (Figure 1.1).

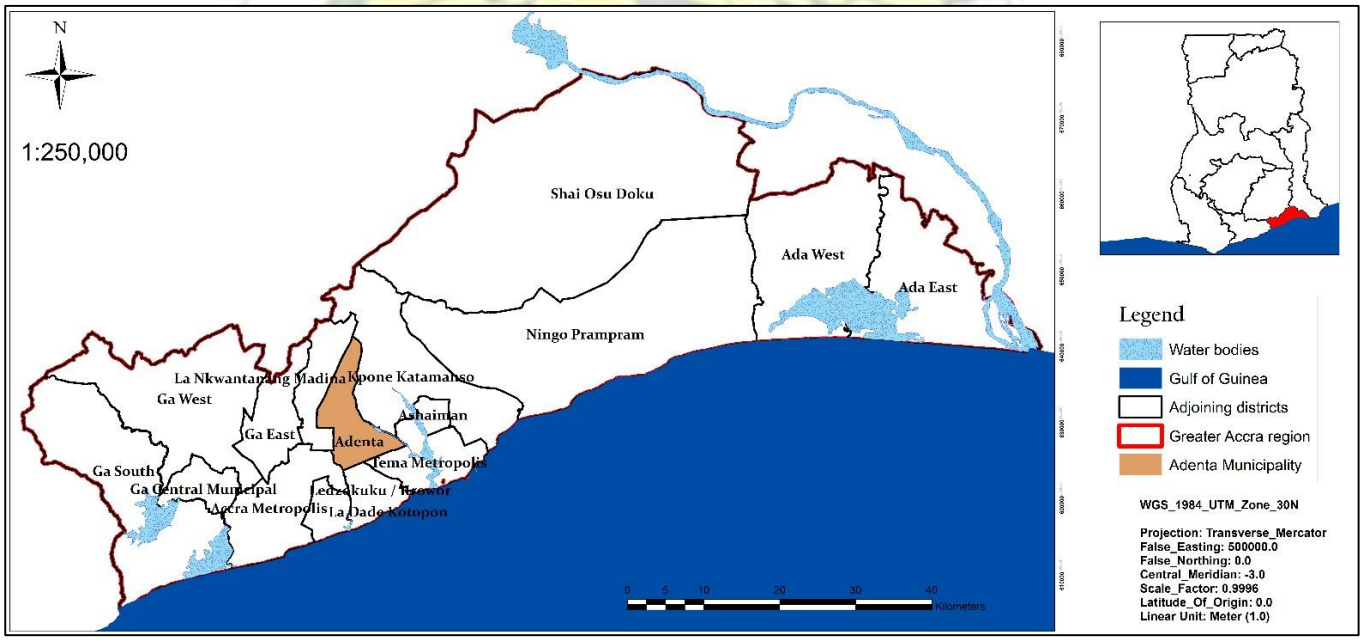

Figure 1.1: Adentan Municipal Assembly and surrounding districts

Source: Author's Construct, November, 2018.

1.6 Thesis outline

The study was structured in five (5) chapters. Chapter One focused on the background of the study, research problem statement, research objectives, the scope - both contextually and geographically, the relevance or justification of the research, and how the entire study was be organized. Chapter Two then concentrated on an in-depth review of literature, considering the objectives of the study which served as the thematic areas of discussion for the chapter. Chapter Three gave credit to the Research Scope, Methods and Materials. The profile of the study district and communities, the research design and sampling, the data collections mechanisms, as well as data analytical paradigm which were also considered. Chapter Four was dedicated to the empirical chapter of the study where data results were presented and thoroughly discussed in connection to the objectives. The findings were further deliberated in the light of reviewed literature in Chapter Five, also serving as the concluding chapter. It provided a general overview highlighting its significant results, recommendations based on the outcomes of the study and a concluding report, which brings the entire study to an end.

CHAPTER TWO

2.0 URBAN CHANGE AND FOOD DYNAMICS MODELLING

2.1 Understanding the urban change and food systems

The regional and global manifestation of urbanism has been astronomical in this millennia (UN-Habitat, 2004). The world is becoming progressively urbanized. For instance, by 2050, a predictable percentage (60 %) of global populaces will reside in cities asserts Sova, (2016) making it an alarming concept that has gained fame recently. The increasing rate of urbanization of communities point out optimistic benefits that include collaborative industrialization and scale of production, upgraded transport systems as well as prospects for better housing, education, medical care and jobs (Oduro et al, 2015). However, its adverse effects such as inordinate congestion, pollution, disease, crime, income disparity, poverty, hunger among others cannot be overlooked (FAO, 2017). Whereas urban world changes rapidly, Tefft *et al*, (2017) remarked that influence and demands such as pressure on resources, job competition among others are exerted on cities including food systems, affecting their functioning, management and performance.

Urban growth patterns have been multi-dimensionally observed in literature by many including

Goodchild (2001) and (Anselin, 1989). In Goodchild's (2001) report, he ascribes urban areas as a heterogeneous space with spatial dependence and manifold points. Again, Anselin, (1989) indicated that urban space could be positioned as a living system with its spatial descriptions serving as its building cells for survival. Every potential outcome in an urban space is as a result of the spatial changes and inter-activities. Therefore, for a proper diagnosis of the rapid urban problems across the globe, a coherent scientific approach should be welcomed (Ilieva, 2017). Also, urban food issues are critical elements of a cohesive urban-rural development agenda, since it contributes to diverse outcomes such as hunger, poverty, job creation among others if not well addressed (Bhanjee and Zhang, 2018). Generally, agricultural production from the rural market has managed to meet the rapid and continuous burdens placed by the urban proportion where food production is far less. This has largely resulted in a robust change in food demands with possible indications for imported foods and even genetically modified foods-GMOs (FOA, 2017).

However, over millions of urban inhabitants still face food challenges currently, and this is far more associated with a threatened residual income size and food expenditure than to a capacity deficiency to produce food (Beaulac *et al*, 2009). Therefore, the processes involved in what and where people eat and how food is grown, and how it is distributed has a direct bearing on the affordability and access to food (Chen *et al*, 2008; Larson *et al*., 2009). Again, this chain of variables could be well appreciated if closely related to space and analysed using suitable spatial models and techniques. Accordingly, the varying geospatial relationships between urban productions, spatial implications and food systems have narrowly been researched on (Stevano et al, 2018). Whereas, it needs more attention, geospatial technology promises a better approach to solve the multi-scale nature of urban issues in the world (Tokody and Mezei, 2017). Besides, it strongly instructs further strategies for managing urban food systems as it evolves (Faye *et al*, n.d). Presently, most studies connected to the urban food environment have largely concentrated on its physical, economic and social components as well as the rural- urban differentials of food production and demand (Treuhaft and Karpyn, 2010; Walker *et al*., 2010). Research has also been conducted extensively on the land use-land-cover patterns with spatiotemporal methods for monitoring urban patterns (Meyer and Turner, 1996). Whereas, food security also receives social scientific approaches such as qualitative data focusing on food access in areas that are rural and poor such as the Northern part of Ghana (Alkon and Agyeman, 2011).

On the other hand, attention on urban agriculture as the solution to food security has often been challenged, considering urban areas in the south- forgetting that urban agriculture is expensive,

and limited to people who have the means (Matuschke, 2009). In typical informal urban spaces; where the poor and marginalized bracket keeps intensifying, food security is not only viewed from its availability but its accessibility as well. Nonetheless, this discourse has received less visits whereas its stakeholders (vulnerable informal urban poor) are poorly represented in literature and practice worldwide.

This research reflects on the observation by Meenar and Hoover, (2012) that urban food assessments at the scale of urban districts need to go beyond food availability and access analysis by including issues influenced by the urban food framework literature. Likewise, it embraces a coherent blend of spatial inputs (such as, land use- land cover changes, vegetation assessments, and others) with non-spatial inputs such as population studies, food habits, income levels, vulnerable inhabitants and places, informality and social inclusion) to effectively address the multiscale challenges of urban changes and food security. For that reason, the adoption of geospatial technology is an innovative, realistic and relevant tool that could be well utilized in this regard to solve the multi-dimensional complex urban problems in districts. This is because it is more scientific, calculative and multi-applicable (Hagai, 2014; Larson *et al*., 2009). Hence, it goes beyond the traditional means of mapping areas and providing intuitive knowledge on complex planning interventions and decision-making. To record precise and timely information about urban space and its variations on urban areas is crucial for effective urban management and decision-making. Therefore, decision makers and municipal assemblies must embrace the approach of geospatial systems and technology for better monitoring and representation of urban expansion and its effects on local and national development (Coskun, 2008).

This research underscores the significant challenges arising from the deficiency of data on and empirical analysis of urban changes and food systems. It institutes a major contribution of advancing studies in this new and diverse area as it aims to address the lack of consistent, comparable and relevant data with the weak knowledge base in urban communities in Ghana (Cobbinah and Aboagye, 2017). Further, it represents a major priority and pre-condition for future predictions and forecasts in effective decision making.

As an attempt to meet this challenge, this research considers two steps: first, identifying and prioritizing the data, analysis and information needs in urban communities. In this case, the Adenta Municipality, a typical urban setting in Ghana is considered as it manifests a range of urban changes such as land use, population, and others. Again, provision is made to present empirical evidence of sprawling patterns in the study area; by exploring data on the built-up

areas and population densities based on geographic information systems (Bhanjee and Zhang, 2018). This then allows for a more nuanced depiction of urban changes through distinguished spatial data sets. Secondly, it discusses the spatial variables described earlier and relates it to one of the essential urban indicators for development – food security. There is a mounting interest in understanding how urban food systems function and perform, given their strong influence on many issues that are important to cities across the world, namely; food security, employments, nutrition and health, resilience and sustainability (Hagai, 2014). It is for this reason that an urban diagnostic tool and a metric framework are proposed for present and future decision making within the domain of urban monitoring and food system diagnostics. Consequently, identifying spatial inputs and pioneering ways to collect information is the core objective of this study for a nascent urban food agenda. Building on the urban system theory, an introduction to a smart approach of responding to emerging multiple containments of cities is discoursed (Meenar, 2017).

The next section provides a conceptual basis for potential urban monitoring indicators, their data supplies and eventually the varied methods of gathering data for monitoring and assessment functions in future for effective decision making.

2.2 Conceptualizing Urban change

Global residents are increasingly shifting towards urban regions with its trends of urbanization leading to growth concerns and mindful distresses on food security outcomes. The logic is even further challenging especially in the midst of disasters and destructions thus becoming a cumulative tendency of concern in the urban circumstance (Lovon, 2016). While rapid urbanization is considered a problem, other studies like Mercer, (2017) state otherwise; revealing its associated benefits like infrastructural, economic and social expansion. Essentially, countries with higher tones of urbanization are likely to experience a greater average life expectancy rate, literacy rate with a forceful democracy, especially at local or district levels (Mercer, 2017). Interestingly, beyond all the calculable measures, urban centres also serve as hubs of multi-cultural, social, and political invention arguably. Moreover, the African continent among the global regions stands to record the highest urbanization rates in the world following Asia, particularly due to rapid economic expansion, industrialization, and mass migration from rural areas to cities (Organization for Economic Cooperation and Development, 2017, Oduro *et al*, 2015). As African countries swiftly urbanize, urban growth and sprawl becomes a pressing concern for both urban practitioners and academic researchers, especially in major metropolis (Cobbinah and Aboagye, 2017). This has standardized the

demand for studies into areas for better innovative mechanisms to abate emerging gross urban issues.

Obviously, the phenomenon of food security is widely popular and recognized. For instance, its means of measurement, accessibility and vulnerability of traditional livelihoods in rural settings especially have received great attention recently (FAO, 2012). However, these dynamics exhibited in the urban stream are much less understood principally in this dispensation of urban population growth (Satterthwaite *et al*., 2010). This has led to the critical embrace of notable scholarly attempts to essentially address the complexities of urban changes and their impact on built-up development. Compared to the total world inhabitants, Ilieva, (2017) deduces that the share of urban space in developing countries has risen remarkably from 29 % in 1950 to 50 % in 2008, making it the most sort after locations across social, economic and cultural scales. This reasons for potential exponential urban growth which produces existing and future anonymous difficulties and tasks for people-functioning cities. Hence, creating a more sustainable and liveable urban system is crucially important in the long run, to facilitate the multiple complexities of cities in Sub-saharan Africa (Tokody and Mezei, 2017).

2.3 Urban change assemblage and change indicators

Residential, occupational and other human developments, have altered the structural landscape of the surviving natural lands (Mertes, 2014). This process largely contributes to the change pattern of the urban background. According to Bhatta (2010), the outlook of cities is measured through evolving physical features coupled with functional or economic characteristics. In emerging regional science, the urban philosophy is more concentrated with concepts of space and less with time. For instance, the location theory, to be precise coupled with the landuse rent theory (Alonso, 1964), is virtually grounded on the concepts of accessibility and balance of demand and supply. However, the urban discourse completely losses sight of the modification processes essential to attain that stability (Wegener *et al*, 1986; Pijanowski and Robinson 2011). In effect, addressing these complexities relies on solidly defining the components of urban change patterns vis-à-vis their measurement arrangements to make practical decisions.

There are various ways of defining or categorizing the urban space and for that matter the urban change pattern. For instance, in the same manner that urban sprawl or growth has diverse definitions, so there exist variations in measuring the phenomenon of urban changes (Larson, 2006). Conversely, Bowyer, (2015) suggests that urban changes and sprawl is a multifaceted phenomenon with no multi-definitions. This therefore allows for urban change to be defined per certain verified indicators in urban literature. For instance, Lambin *et al*, (2000) defines urban changes per the attributes of land-use land cover changes and agricultural land

depreciation. In the same urban discourse, scholars such as Bowyer, (2015); Galster *et al*. (2001) and others also describe urban change patterns based on an array of physical, social and economic factors such as density, accessibility and transportation, land use and cover changes as well as population increase. These indicators are known to be recurring quantified processes that can be traced over time to provide information about continuity and change with respect to a particular phenomenon (Godin, 2003). The indicators set the pace of practically assessing the growth and change patterns of urban systems (Chong, 2017).

Urban changes results from an evolution of a non-urbanized space into an urban space of complex uses, substantially and functionally (Cheng, 2003). Further, the physical representation of spatial changes, coupled with aspatial (human dimension) variations is important for this study. Descriptions of urban changes and urban expansion are a critical component of any urban mapping methodology (Mertes, 2014). Particularly, these indicators promise the outcomes of displaying the spatial interactions between the natural and human systems.

2.3.1 Urban change growth rates

Urban growth contributes to the land use and cover changes in many areas around the world, especially in developing countries (Bowyer, 2015). The unparalleled occupant growth combined with existing haphazard developmental activities in Ghana results in gross changes in the urban landscapes of developing countries, particularly Ghana. Urban change growth rates are one of the key metering systems for describing the relative change of any given human space. Accordingly, this compares the proportion of variation visible in an urban area in relation to its residents (Jat *et al*. 2008; Hammann 2012). Consequently, rapid population growth without its corresponding structural developments and sufficient supply of essential services with its direct commercial prospects is conducive to urban disorders. Thus a spatiallybalanced system through the monitoring of urban growth populations promises a better way of its management. Urban population change patterns need regular monitoring and seen as a geospatial input so that it can be modelled for accurate assessments and predictions (Bowyer, 2015).

2.3.2 Urban Density

This is also one of the popular indicators as part of urban growth and change that measures the definition of the fraction between the expanse of a definite urban feature (e.g. residential units) relative to the extent in which it occurs (Knaap *et al*. 2005; Lowry and Lowry 2014). It helps to aggregate the number of people or unit per land area to appreciate the growth or decline

trend of the area. Urban densities determine the concentration of the built up area as well as the intensity of detailed land uses within the urban setting (Galster *et al*. 2001). What describes the urban scene and makes it different from other natural terrain is the high section of man-made functions and variations of external constituents (Song and Knaap 2004). Murcko, (2017) describes these agglomeration of artificial impervious surfaces coupled with human activities as built-up areas. He further defines urban built-up areas as regions which contain structural information about the urban domain, including buildings and open spaces, such as roads and parking lots. Usually, urban densities are calculated using ratios of population, number of activities or residential units per sub-area of development. These densities are gross or net, where its gross density is calculated per the total area whereas the net density is calculated per the unit area. Population density is also a causative indicator on food access and insecurity status of districts recognized under food security (Mwangi and Foeken, 1996; Hagai, 2014). Research studies have indicated that high population density may barely result in agricultural growth through intensifications or results in agricultural stagnation, involution and environmental degradation (Kates and White, 1993). However, spatial intensity increases with population density to around 600 persons per km^2; beyond this population threshold, farm yield, incomes, household assets, and input intensification declines. Higher population concentration is also found to be associated with smaller farm sizes and reduced fallow land, other issues being constant (Jayne and Milu 2012). Urban density commands an exclusive area of the urban literature as it critically and copiously examines the relationships and dynamics within the urban scale. Furthermore, it is sometimes used as a metric to determine sprawl and informality in a given urban area (Xiao et al, 2010).

2.3.3 Urban Land use and Land cover changes

Every urban form is shaped in space. This means that the relativity of its changes directly guided by the change pattern of its use. According to Reis *et al*, (2014), urban change can easily be experimented through the observation of conversion forms from non-urban into urban land use over time, or by assessing the coverage change of green areas or pervious surfaces.

Currently the ecological characteristics and the socio-economic dynamics are modelling the land use structure (Yeboah,et al, 2017; Ferencsik, n.d). Conversely, these elements are not in isolation within space and time, thus co-dependently illustrate the spatial structure (Potere and Schneider, 2007).

The expressions of land use and land cover have gained popularity and often used interchangeably in geospatial literature (Li, 2014), though they symbolize different things.

Notably, the term land cover refers to the visible cover of the land. It is explained by Turner *et al*. (1995) and Murcko (2017) as the bio-tangible state of the internal and external face of the earth including vegetation, soil, topography, water and human developments. On the other hand, urban land use could be described as the human dimension of the land cover type (Skole, 1994). It is precisely explained as a social purpose and not a set of physical extents (Cheng *et al*, 2017). Foody (2002) proposes that whereas land cover is an essential variable that influences and links many parts of anthropogenic and physical settings; Land use is a more complex term. Therefore, it is projected as human modification and control of a land cover and particularly seen as the culture of land exploitation to meet human demands (Meyer & Turner, 1996) such as, industrial, commercial, residential and others (Li, 2014).

Land use land cover diversity evaluation checks whether an urban settlement is more mixed or mono-functional, usually calculating the number of different land uses present. It also addressed by combining other variables, the monitoring of the trend of urban change contributing to better policies and projections in future.

Therefore, with the application of remote sensing and Geospatial techniques, urban changes with LULC indicators can be detected quantitatively, and this visibly identifies how much different urban land cover trends have changed over time. However, throughout the process of urban change, land use and cover patterns is just one criterion of the changes that have occurred. Only describing urban change differences cannot identify urban expansion dynamics clearly, (Zhang, 2016). This suggests the essence for a multiscale spatial system to monitor this complex discourse if practical decisions are to be made.

2.3.3.1 Classifying land use land cover (Built upon and non-built upon)

Urban Land use and cover changes are classified in various ways. For the purpose of this research, urban change within the LULC spectacles is defined by their spatial extent. This is popularly known as the built-upon area and also called building coverage; development coverage or impervious surfaces. It is defined by the American Planners Dictionary complied by Davidson and Dolnick, (2004) as that "portion of a development that is covered by impervious or partly impervious cover including buildings, pavement, asphalt roads and parking spaces, recreational facilities, etc". On the contrary, water areas such as swimming pools are known as pervious or described as non-built upon areas. It should be noted that *Impervious surface* in this regard is well-defined as hard-surfaced, man-made area that does not readily absorb or retain water, including but not limited to building roofs, parking and transport routes, graveled areas, sidewalks, and paved recreation areas (Davidson and Dolnick,

2004). Therefore, areas that may be for residential but has not experienced any hard surface infrastructure were all categorized as non-built areas.

2.3.4 Urban footprints (accessibility/ mobility)

This is another remarkable urban indicator that determines the arranged and non-arranged movement that shapes urban forms (Reis et al, 2014). In fact, the level of accessibility determines the rate and level of urbanization in every country (Lowry and Lowry 2014). For road transport networks, areas that are highly motorable are well placed for various uses, thus attracting higher populations and uses. This further simulate the moving nature of urban growth since new development attracts locations of high accessibility. Subsequently, a good transport system increases land accessibility (Reilly *et al*., 2009). Copiously, the urban residents through mobility require access to public facilities in order to utilize their occupation (commercial) areas and satisfy their economic needs (Song and Knaap 2004). Typically in cities, transport and mobility do not only connect lives and uses, but also transform the landscape of urban footprints considering its various level of impact and potential to attract people and development (Knaap *et al*. 2005). Urban accessibility development therefore plays an important role in molding the urban growth pattern. They are the most unpredictable manifestations of urban change, yet the most easily observable (Batty, 2008). However, one major challenge associated with accessibility is mobility and its management (Simmonds et al, 2013). This pattern of urban change aggravates concerns with traffic congestion including automobile dependency, increased water demand, and increased energy demand. This is common in developing cities and the Adenta municipality is no exception. As population rises and land uses incline especially towards economic uses, congestion and overcrowding occurs leading to sprawl and slums. This informal urban systems, have become one of the canker that gained notoriety as places of poor sanitation and congestion – a major concern for city authorities. Thus with a systematic urban change monitoring, urban decision makers could be well informed to plan ahead of time to capture projected outcomes when designing future plans and frameworks (Rimal et al, 2017).

2.3.5 Urban Timescale / Spatial geometry

The formation and assembling of cities is directly influenced by its rate and time factor (Reis *et al*., 2014). The expansion rate of the urban place as well its shrinkages is determined copiously by its changes over time. Therefore, in the discussions of monitoring the urban pattern and change determination possibilities, the element of time is essentially required. This urban indicator freely narrows down the scope of urban theory as a remarkable component

which is notable with the interest in temporal patterns taken by related disciplines (Torrens and Alberti 2000).

This urban dimension strategically measures the linear arrangement and composition of elements in urban areas. Whereas some scholars define this criterion to be isolated but discrete and uneven, with a composition for predictability (Knaap *et al*. 2005), others interpret it as a process which is viewed in three successions or tempos. These are slow, medium-speed, and fast processes (Wegener *et al*., 1986).These underscores the urban assemblage to also assume a temporal state that could be measurable upon its degree of configuration (Lowry and Lowry, 2014). These urban timescale forms are loosely defined as the spatio-temporal heterogeneity of land changes which permits the identification of fast and slow areas. Urban expanses are regions with a high level of spatial dynamism where their size keeps increasing rapidly. Therefore, a set of descriptive dimension of urban change process indicators have been developed at centers on a stimulus-reaction structure.

The first dimension specifies the process itself, or the stimulus. The second one identifies which standard is affected by the change (Song and Knaap, 2004). The first urban timescale component is the slow process and this involves the construction stage, where the physical construction of cities shows a significant constancy over time dominating even after major destructions such as wars, natural or human induced disasters such as fires, floods etc. have occurred. This change usually rise in with slow times. Subsequently, there are constructional changes concerned with capital-operative arrangements which has an average lifetime of over 50 years (Batty, 2008).

The next stage is the medium speed of change characterized by economic, social and technological change for which the urban variation are more rapid and less predictive. These changes principally reveal the material conversion of the production system from primary and secondary to tertiary industries triggered by technological innovation and changing consumption patterns (Simmonds et al, 2011). Additionally, this phase of urban change has features of regional economic framework trying to respond to externally imposed economic variation, although local resistances form the labour market (in the growth case) or union power and government controls (in the recession case) delaying the urban amendment process (Batty, 2008).

This affects different facets of the urban fabric particularly the economy, the social composition of the population, the communication systems, among others.

The third and final stage is the fast speed urban scale which is mainly characterized by mobility. They comprises of the transport of people, goods, and information within given buildings and

communication facilities. These variations range from job relocations and moves to the daily pattern of trips and messages. For instance, companies relocate from a particular zone for vacant building space, employees decide to accept jobs more expediently located to their place of residence, households move into vacant residences which largely leads to sprawl and informality in the cities. These types of mobility involve substantial costs and effort and are therefore normally undertaken every 5 or more years (Wegener *et al*., 1986). They do not change the delivery of activities, but affect the composition of vacant and occupied stock, i.e., workplace and housing occupancy. Conversely, average regular trips have no impacts at all on any distributions in the urban system, since they begin and end at the same place (Simmonds *et al*, 2011). However, their linkages, daily occupational and social trips, have a vague temporal arrangement: since they form habitual arrangements that do not change much faster than commercial and household settings. Therefore, they are clearly less influenced in urban choices in the short term, but in the long term they play an essential role for location decisions through the accessibility they create (Batty, 2007).

Over the years, efforts to reform the urban fabric from a space-time range of activities have received less attention and gained low followers for discussions. However, for a coherent achievement of a better urban decision model, it is imperative to track the urban changes from the time scale perspective (Simmonds et al, 2011).

Urban growth monitoring as a process of dotting the differences in the urban state by remotely observing it at different times, aids in observing results from anthropogenic forces that has resulted in modification of the environment which requires its relevant temporal dimensions (Hegazy and Kaloop, 2015).

2.3.6 Urban Beauty/ Aesthetics

Urban literature has narrowed patterns of the urban change to the physical expanse that loosely describes the rate of change in its appearance and aesthetic form. Many urban schools of thought have focused on the green landscape with traces that makes reference to the depletion and frequency of green destruction. Incidentally, the position of the urban outlook reflects various dimensions of the visible urban space which conforms to the structural, environmental and the attractiveness that simulate economic benefits as well (Bretagnolle, et al, 2006). Besides, the urban fabric is woven in a way that creates in itself a pattern and level of acceptable look. It has been widely assessed and observed that although occupant surveys and landscape (change) evaluations defines models of urban change patterns; (e.g. Torrens and Alberti (2000)

nevertheless, to measure, quantify and track the pattern or change of the urban system, it is imperative for its aesthetical component to be considered (Frenkel and Ashkenazi ,2008).

2.4 Complexity of urban change systems

In constructing urban change as a system of theory, we are particularly considering it as a complex system (Cheng, 2003). In fact, Batty and Torrens, (2001) describes the systems of urban change as a unification of varied agents and entities within the urban stream. Subsequently, this complex system is shaped by the heterogeneous nature of socio-economic occurrences which obviously translates into diverse spatial and temporal characteristics. Conversely, patterns are derived as a result of these complexities of natural and anthropogenic impact on the urban space. These patterns have received academic attention in urban analysis, precisely within habitation trends (I-Shian, 1998), demographic and economic patterns (Ingram, 1998), land cover change patterns (Wu and Yeh, 1997), land use change patterns (Kiril, 1998; Yeh and Li, 1998), and mobility interaction patterns (Jun, 1999; Simmonds *et al*, 2011) as described earlier. These studies concentrates on the spatial array of physical and functional objects (Wegener *et al*, 1986; Cheng, 2003).

Comparatively, despite the great attention given to urban change components, its spatial patterns interpretations and complexity modelling is still deficient, specifically from an urban planning perspective (Bretagnolle et al, 2006).

Generally, urban change complexities are identified with various spatial outcomes (Bhatta, 2010) across diverse measures of social, economic and environmental tenets. This definitive attribute given to the urban space pattern is also described as urban dynamic systems. Parker *et al*. (2003) further regarded complex systems as dynamic structures that present distinguishable forms of organization across spatial and temporal scales. This describes the multi-variability of urban change patterns posited by various scholars (Veldkamp, 2001; Stein *et al*., 2001). Therefore the complexity of urban outcomes occurs from both the decision making and the spatial features of the city environment (Parker *et al*., 2003).

Besides, cities are complex bodies that a little transformation in one component considerably affects the states of the other constituents that are potentially connected (Li, 2014). The essence of urban change as a complex system to be regarded from a multi-dimensional point of view is critical. Presently, multi-scale analysis of the urban domain has attracted more and more consideration in pattern modelling (Kok *et al*, 2001).

Urban systems theory is a modern innovative approach within the geoscientific setting essentially adopted for urban planning and decision modelling. It can be adopted as an

investigative tool for configuring the relationships between urban collective components, its behavioural system as well as in diagnosing their spatial interactions.

For instance, Batty (2009) proposed that urban complex systems are characterized with "unexpected and unimagined or surprised behaviours although visible in patterns. Consequently, these complexities expresses some level of change patterns that if well modelled could help address the dynamic nature of urban problems, make accurate future predictions to resolve future outcomes and inform better decision-making, as well as produce sustainable living spaces for human habitation.

Therefore for an effective urban decision making, complexity modelling of urban change patterns is required to discover the collective and exclusive characteristics by way of discovering the spatial and temporal processes of spatial transitions. Geospatial inputs through Geographic Information Systems (GIS) can thus offer quantifiable evidence to aid decision making in urban planning and sustainable food management (Chen, 2003).

2.5 Analyzing urban change and food system complexities

2.5.1 Analyzing urban change systems in Ghana

The conception of the urban space phenomenon, embraces the ideals of urbanization and resource allocations such as food to households and/or individuals (Hagai, 2014). Satterthwaite *et al*., (2010) hypothesizes urbanization into two perspectives: thus the level of urbanization and the rate of urbanization. Subsequently, the levels of urbanization are described as the share itself, and the rate of urbanization as the frequency or speed at which that share is changing.

This definition makes the effects of urbanization distinct from those of urban population growth or those of the physical growth of urban areas, both of which are often treated as identical with urbanization. It rather identifies with the term "urban change" as a collective spatial and temporal difference that occur in the urban setting.

In 2000, the expansion level was only 37.9 %, it is now estimated to reach 54.5 % by 2030. Urban population is thus expected to grow from 297 million in 2000 to 766 million in the next 30 years (Songsore, 2009; GSS, 2014). This implies that the number of residents in cities within the global south alone accounts for an augment from 1 billion to 4 billion people. This striking modification towards a more urban world demands a cross-institutional and stakeholder collaborations, pragmatic market synthesis, infrastructure and food reform policies as well as geospatial innovations to tackle the multi-dimensionality of modern urban complexities (Joerin et al, 2001).

Intensifying urban changes within the context of urbanization, is a principal driving force, which is affecting strains on many African economies. With an average growth rate of 3.71 per cent, Africa is the fastest urbanizing region in the world (Oduro *et al*, 2015).

Accordingly, in reviewing the regional urban differential, Ghana's urbanization process plays a key role for discussion. Ghana's 2010 population and housing census discloses that over half of Ghana's occupants (50.9%) live in urban communities (GSS, 2013). In addition, urban changes in Ghana varies regionally particularly from as high as almost 91 % in the Greater Accra region to as low as 16 % in the Upper West region (Kassang *et al*, 1996, GSS, 2012) Ashanti region comes next to Greater Accra as the most urbanized with almost 61 % of its residents living in localities classified as urban in 2010 (GSS, 2012).

Realistically, Accra's high urban rank is expected, considering its situation as the national capital city, whereas it also unites with Tema as the Ghana's largest economic hub. Consequently, the trend in urban change in Ghana appears that the regions with the minimum urban proportion also doubles as regions that are well-known for high volumes of out-migration (GSS, 2014). This submits that migration also plays a crucial role in the rate of urbanization in any geographic region (Songsore, 2009).

Whereas urban expansion presents lots of potential benefits, it also commensurate prospective urban adversities. Ghana's urban landscape has increasingly developed over time, allowing it to experience economic transformation (such as constructional growth, good road access, better social service and health care, etc.) which has impacted urban livelihoods of the citizenry (Ayerakwa, 2017). However, the conception of UN-HABITAT, (2011) states otherwise. According to them, urban changes in Ghana has resulted in high unemployment rates, environmental deprivation, poor structural developments, crime inclination, poverty and food inequalities among others. It further argue that "the benefit from urbanization and urban changes are yet to materialize"; implying a strong deflation of the hype between urban relevance and urban living particularly in modern development literature. Additionally, the urban process is somewhat skewed to certain locations breeding over concentrations and accounting for the urban mess observed earlier. For instance, there is an ill distribution across the national territory of Ghana with its four leading cities alone accounting for over 50 % of the national total urban population. Besides, though it is now classed as middle income, its cities are growing rapidly particularly at 1.6 million and 1.2 million respectively within the dominating cities of Accra and Kumasi. Consequently, sprawling effects, collective pressure on urban resources, sporadic disaster events as well as disruptive urban food systems in Ghana has become quite alarming (Charreire *et al*, 2010).

Eventually, as Ghana's urban areas continues to gain great prominence (for both the good and bad) the appropriate tools of identifying, recording and effectively managing its large problems proves to be a herculean task for researchers (Devereux *et al*, 2004). The challenge likewise, consists of selecting valid and reliable sets of manifest indicators of urban trends such as population influx, housing deficits, resource pressure, sanitation and waste management, food insecurity among others; and further transform these data sets into a unidimensional scale of analysis (Bhatta, 2010). Although various techniques exist, (such as statistical and theoretical analysis tools), the adoption of Geographic Information Systems (GIS) has been poorly embraced in Ghana and other developing countries-for inferring urban measurement scales from a list of urban management indicators indicated above (Aryee et al, 2018).

2.5.2 Understanding the food dynamics in urban Ghana

The rapidity of urban changes across the globe is significantly driving recent local and international discourses on food systems. Urban food systems in Ghana are equally shifting, along with fast urbanization and growth in household returns (Andam et al, 2018). For instance, whereas Tefft *et al*, (2017) observes urban residents to have remarkably risen from a staggering 2 % in the 1900 to a progressive shoot of 50 % in 2017 and an alarming projected 67 % in 2050; Ghana's inter-censal regional data rather indicates an amplified version of change. Observing from the Greater Accra Metropolitan Assembly (GAMA), according to (PHC, 2012) the urban overflow of GAMA's population growth outside the original borders of Accra (central city) expresses that Accra's urban share of GAMA's total population growth had significantly declined from an accommodating 70 % to a depressing 40 % within 1960-1970 and 2000-2010 inter-censal periods (Oduro et al, 2015). The speed of population growth on the peripheries of Accra has resulted in an equivalent surge in claim for land to reside, infrastructure and commercial hubs to trade, food to satisfy, etc. causing a profound swelling of the urban populace. This has subsequently influenced the urban change pattern of Ghana's capital, which is overwhelmingly moving towards previously peri-urban districts such as Adenta, Ashaiman, etc. that surrounds the Accra city. In effect, the express changes has altered the physical and socio-economic features of communities (Yankson, *et al*, 2004; Oduro *et al*, 2015). Similarly, a key component of this change is the urban food dynamics that follows up. For instance, before the recent re-demarcation of districts, the official confines of Accra covered only 300 sq. km, or 7.4 % of Greater Accra Region's entire land area with the rest possessing agricultural dominance (Twum-Baah, 2000). However, due to the limited ability to contain the swiftly emerging urban population and economic activities, Accra's substantial spill over into peri-urban settlements has drastically reduced its vegetative presence and resulted in

affected farmlands and vegetative zones within the region (Ayerakwa, 2017). Conceptually, food security represents the availability and accessibility of food in its sufficient measure, safe for consumption and having the right nutritional values for everyone every time for a well and lively life (WFS, 1996). This positions the food security literature in a place where it features a multiple component system and therefore embraces various aspects for it to be complete. Confirmed by Napoli (2011), food security is therefore a complex concept to measure, considering the broad relationships with the production, delivery and consumption of food. Hence this is very characteristic within the urban district of Adenta, where despite its available foods such as cassava, maize, vegetables and others, there exist a growing variability in its food access economically and physically. From this background, it is noted that most urban residents' access food outside the district with gross dependency on internal and external food imports (Hollinger and Staatz, 2015). This and other factors come to play within the urban food milieu, hence, the struggle with modern challenges of complex food systems particularly in developing economies like Ghana is fierce. As a matter of fact, whereas people in Ghanaian rural areas are obviously capable of producing their own food, urban residents are predominantly rather constrained. This is because they depend on rural food imports with a few engaged in urban agriculture (Ayerakwa, 2017). Ghana's food conditions is connected to diverse causes and effects and therefore makes it more challenging to solve. Food security in Ghana and other related developing countries could be easily contextualized as a multidimensional phenomenon (Clay, 2002), where numerous indices of measurement such as urban growth and density, land use changes, urban food demand and supply, income and social status, informality, gender among others; could be adopted for effective decision making (Clay, 2002). As a result, specific research is required across district, regional and national food systems, prior to change patterns and the capacity of its food stability policies (Andam et al, 2018).

Until lately, urban planners and scholars in Ghana and major parts of the continent have paid little attention to urban changes and their relationships with food security and frameworks, rather highlighting conventional urban priorities such as public mobility, climate change and housing (Cabannes and Marocchino, 2018). For instance, in the Adenta Medium term development framework, emphases are made on the congestion, road accessibility, sanitation, unemployment, etc. however, food security is randomly discussed and less addressed. Equally, ever since the start of the current millennium, major organizations , professionals ,city authorities, etc. have realized the unusual recognition towards urban changes and food systems

modelling, which, paradoxically, was the attraction for innovative city planning a few decades ago (Cohen, 2014b.;Cabannes and Marocchino, 2018).

Incidentally, food insecurity on the other hand offers a more voluntary pattern to its measurability and analysis. This means that it is easy to identify ways of measuring the level of food insecurity of a place. In other instances, food security have been misinterpreted as food scarcity or famine and hunger. However, scholars have widely emphasized that food security and famine and hunger are not to be confused (Maxwell, and Frankenberger, 1992). Whereas food security considers obtainability of food, famine and hunger are results of the inaccessibility of food, in other words, the outcomes of food insecurity (Napoli, 2011; Cabannes and Marocchino, 2018). In other words, food security involves subsystems such as accessibility, delivery, and consumption which if one subsystem is not well operational, there will be a problem of food insecurity (Ratnasari and Kusumawardani, 2015). Accordingly, food insecurity and hunger (extreme form), exist within the context of inaccessibility to nutritional and safe food adequacy. For instance, despite food produced within the boundaries of Accra such as crops (cereals, vegetables, tubers), livestock, fish, and non-traditional food (mushrooms, grasscutters, snails); figures from several studies and from the latest Ghana Living Standard Survey 6 (GLSS-6, 2014) submits that, apart from the large quantity of the supply, the overall quantity and variety of local food does not support urban dwellers to meet their nutritional requirements and food preferences (Marras *et al*, 2016). However, Webb *et al*. (2006) distinguishes that food insecurity is linked to, yet distinctive from the concepts of poverty and malnutrition, besides involved at a range of spatial scales from households to regions, with variety of time levels. Confirmed in their report, Ghana is described to be an agrarian economy with more than half of households (51.5%) possessing or operating a farm (GSS, 2014). Nonetheless, this figure comprises a ratio of 82.5 % of rural households share to 17.5 % in urban households. This food disguise is quite misleading as its paints the picture of food abundance, whereas only a fraction actively engage in the urban areas. Furthermore, this situation has been poorly assessed due to the restricted geo-information systems and unpredictable urban change data which influences local food dynamics in the country (Gareau, 2004). The overall concern has is it that for a common comprehensive measure of urban food patterns to be accepted for both local and international settings, its multiplicity must be considered (Heidhues and von Braun 2004).

In this study, urban food access embraces the mechanisms of city system indicators and food dynamics with an attempt to monitor and measure its multi-dimensional features for better

predictions and decision making. Therefore, within this background, the term "urban Food system/ security" is theorized as a suite of diverse relationships between and within the urban biophysical and anthropogenic landscape; coupled with its influence on the growing, processing, distribution, preparation and consumption of food (Gregory *et al*, 2005).

Additionally, the urban food literature is challenged backed by the case study of Adenta Municipality to revolutionize the existing methods of support in addressing accessibility, stability, consumption and the other dynamic component accompanied with urban change dynamics and food relationships. This could be resolved through: a collection of identified indicators covering urban food security scopes: availability, access, utilization and stability (Napoli, 2011); an effective system of urban food measurement derived through geographic information systems which provide the roadblocks on the way to efficient food modelling and decisions.

2.5.3 Conceptualizing urban food security in Adenta Municipality

2.5.3.1 Urban Food Systems (UFS) in Adenta Municipality

Food Security is explained by the World Food Forum 2006 as "A situation whereby everyone have access to sufficient, safe and nutritious food at all times to maintain healthy and active life". (Gill et al, 2009; Hagai, 2014).

Hereafter, food accessibility and its multi-faceted connections with evolving urban dynamics and food security especially in developing countries is of great concern. According to the Adenta Municipal report, (2016) Agriculture production in the Municipality has largely reduced with farming done on subsistent basis. Presently, the average land holding per farmer in Adentan is estimated at two (2) acres with most farmlands lost to construction of residential facilities due to significant urban changes from Accra (MOFA, 2016; AdMA report, 2017). Food is increasingly an urban issue (Dubbeling, *et al*, 2015) for that matter the concept of urban food systems is gaining considerable popularity among local, regional and national levels as well as, international organizations, professional bodies and in academia. As part of national policy (Planting for food and jobs) for example, the Adenta Municipal Assembly (AdMA), in collaboration with the Centre for Local Governance and Advocacy (CLGA) and the Local Government Network (LOGNet), has launched a project to promote the cultivation of mushrooms in the municipality promising 5,500 jobs and a projected income of GH¢4000 to GH¢30,000 by December 2020 although the process of monitoring is left out (Esson, 2017). Intrinsically, food system diagnosis further helps in critically analyzing the ground-level

transformation and implementation policies within the urban food sub-sector (Dubbeling, *et al*, 2015).

For the first time in decades, developing cities like Adenta are taking steps in food policy initiatives (such as the PFFJ-indicated earlier) that seeks to re-focus food as an urban system where sustainability is strongly associated with other urban sub-structural components—from transportation, to housing, water and waste management (Ilieva, 2017).

In the case study of Adenta Municipality, the concept of urban changes are not only derived but also traced to a development outcome, particularly one of the most important indicators which is food-for effective urban modelling. In their report, FAO, (2017) submits closely that for an enabling urban food management system to thrive in this urban dispensation, a strong empirical knowledge base is particularly important. Applauding the attempts of the Adenta Municipality to facilitate food accessibility in their locality, it is essential to note the unfortunate circumstance where the food subsystems within the context of rapid changes has been relegated and ill focused. It is thus imperative for the system changes within the urban food context of Adenta to be well determined through strategic measurements.

For instance, urban food systems strategies (UFSS) is identified by Ilieva, (2017) as a measuring tool strives for an all-inclusive assessment of the local food management pattern in regions. Moreover, it provides an integrative policy framework that relates prevailing and proposed programs, institutions, and decisions. In simple terms, to achieve food balance in the municipality, an urban food system strategy can support by providing a footprint of current urban food structure and a future improvement guide for local urban development. This makes the urban food system an essential concept for examination especially for such a thriving complex municipality like Adenta.

Again, urban food systems has an influence on all people. In fact, food security is a topic that is not explicitly understood by all, but regardless of whether or not one study it, everyone is affected by its presence or absence (Larson, 2006). Therefore, the narrative surrounding its constituents is equally essential in this research to better appreciate the dynamic changes for monitoring and modelling, as well as assess the relationships of attributes that are relevant for ensuring food functionality at the national and regional levels (Maxwell and Slater, 2003). For example, compared to rural food systems in Ghana, urban food systems are more incorporated into economies at the local and global levels (Ilieva, 2017; Tefft, 2017). This supports and pressures urban populations at the same time. In Adenta, agriculture production is estimated to cost the assembly £660,000, although it could facilitate the local economy and create

employment opportunities for women, youth and people with disabilities (PWDs) (Esson, 2017).

Subsequently, the interaction between urban changes and globalization and their joint effect on urban food systems is vital to better comprehend urban food security. For instance, some scholars argue that cities will always be dependent on cross food systems; that is, they will continue to outsource food, from further locations, global food chains and nearby rural, peri urban and urban producers (Zsigmond et al, 2018). Although urban residents in Adenta municipality are entitled to various food options, (such as processed foods, street foods, fresh foods, imports, etc.), the over reliance on external food supply systems, has amplified food access vulnerabilities and risks with a rippling effect on local economies.

Urban food systems are thus prone to a range of socioeconomic and agro-climatic shocks if food systems and urban measurements are trivially recognized. This underscores the relevance of diverse management measures through geospatial inputs for proper monitoring and prediction of the multifaceted urban food challenges. Successively, this could enhance resilience and decrease vulnerabilities (Bellagio Communique, 2017).

Nonetheless, having the ability to examine urban change and inequalities and understanding their connectivity between disparate urban centers, as well as how they facilitate or hinders urban food security is a considerable challenge (Ilieva, 2017). The study therefore sets the pace in an attempt not to only connect the "complex dots" but to also model a simulated guide to enhance urban solution for city authorities in Adenta municipality, Ghana.

2.5.4 Urban food systems indicators (UFSI) in Adenta Municipality

Food systems issues have traditionally been addressed at national and regional levels; to date, they have not been closely among the priorities considered by municipalities and metropolitan districts (FAO, 2017; Matuschke, 2009). This is beginning to change. Attention to urban food systems and the increasing arrangement of cities and metropolitan districts in food issues are growing swiftly, largely due to the significant role urban areas like Adenta play in the food production and consumption pattern, and the localized collaboration that can sustainably help fight poverty and hunger in our cities (Drechsel *et al*, 2014). Technically, three categories of food systems dominate the urban and peri-urban sectors according to Tefft, (2017); this includes: the traditional food system; the swiftly emerging contemporary and globalized food system; as well as the informal food system (common to low-income urban inhabitants). All three systems exist in diverse degrees within most types of cities, overlapping and sharing phases of urban food demand. However, they are varied with respect to actors, organization

and operations. Reflecting from the Adenta Municipality, urban food systems are sub-grouped into three main systems: (a) market-oriented irrigated vegetable farming; (b) semi-commercial and subsistence-oriented backyard gardening; and (c) semi-commercial and subsistenceoriented seasonal crop farming (Marras *et al*, 2016; Cofie *et al*., 2008, 2005). These systems were further analyzed with their indicators such as food availability/ accessibility, food stability, food vulnerability, etc. to determine an inclusive way of theming the urban food background of Adenta.

2.5.4.1 Urban Food Accessibility

FAO (2006) explains food accessibility as the extent for which food is supplied for householdsobtained from local shops and markets and in their adequate measure and quality. Amid other factors, food availability is determined by the physical presence of food from domestic food production (Hagai, 2014). However, food production depends on various factors such as climate variability (average rainfall and temperature), fertility of soil, urban growth and density, pests and diseases, farm inputs and technologies. Food accessibility in Ghana is said to be satisfactory. Darfour and Rosentrater, (2016) in fact describes the Ghanaian economy as an agriculture led. In fact, they estimated that whereas, 51% of cereal, 60 % of fish, and 50 % of meat are locally produced to meet requirements, less than 30 % of agro-based industries' raw materials are locally produced which accounts for 23 % of Ghana's Gross Domestic Product (GDP) as at 2012 (FAO & FAPDA, 2015). This indicates that there exist availability gaps within Ghana's food sector where availability levels is heavily reliant on rainfall throughout and between growing seasons, which has a direct bearing on food accessibility (ASABE, 2016).

Food accessibility is among the four cross-sectional pillars of food security comprising the physical, economic and social access to food (FAO, 2015; ASABE, 2015). It includes domestic food supply that takes into account households' ability to also have access to the essential resources of acquiring food as well as having the financial capacity to consume right and affordable foods (WFP, 2009). Marras *et al*, (2016) recorded in 2013, that the total household spending share on food purchased (respectively 64.2% and 35.8%) in urban areas is higher than that of home produced food. Ghana experiences profound unrealized food insecurities and inaccessibilities as the average yield keeps declining (ASABE, 2016). Hitherto, it was noticed that over 90% of the households in Accra purchased food they consumed (AMA-FAO, 1998; Maxwell et. al., 2000).

The availability of green foods (fruits and vegetables), protein foods (meat and fish), and carbohydrates (cereals, etc.) that serves as balanced food requirements serves an essential roles regarding respectable supplies that can facilitate food access equity and poverty reduction within the municipality. That is, about 60% of vegetable are produced outside the Adenta Municipality, while 40% are within the local assembly (MoFA, 2016). Hence, food accessibility is gradually reducing and affecting food sustainability within the municipality. This has largely been due to the excessive demand for external imports and the swift urban change in the country. Affirmed by De Zeeuw and Dubbeling, (2009), for close to twenty years, the import of foreign foods, and food support have extended to about 4.7% of food demands whilst urban households engaged in farming in Accra staggers at 13.6% (ASABE, 2016). This makes it essential to equally address the stability and sustainability of food systems in the municipality.

2.5.4.2 Urban Food Utilization and Stability (UFU/St)

Food demand, insufficiency and continuous agricultural land loss, are matters of global concern. City authorities are therefore adopting policies aimed at food-sufficiency and stability for all through the management of urban food utilization and sustainability (Shalaby and Gad, 2010). To ensure the security of food, the entire structure of food access must be stable, i.e., food should be locally available and accessible as well as well utilized every time. Food stability is essentially considered as a crucial element for food security assessments. It denotes the temporal dimension of urban food systems. That is, it considers the time-base component, through which food insecurity influences at local levels are deliberated considering its effects on urban systems.

On the other hand, utilization is an assessment of a resident's capacity to access enough dietary consumption and nutrition in-take at a given time (ASABE, 2016; Hauck & Youkhana, 2008). This implies that food accessed must also meet the right nutritional value for the consumer, which is occasionally realized in the district. For instance, due to rapid urban demand and economic development, many residents from emerging cities at least relatively count on food from non-domestic food value chains. They include a combination of traditional (such as street vendors, small-scale importers) and modern actors (such as supermarkets, food producers, restaurant chains) (Andam et al, 2018). Urban dwellers within the Adenta municipality are indeed more dependent on purchased foods than rural inhabitants, who generally can rely more on self-produced food (Drechsel *et al*., 2007). Arguably, this makes it quite expensive to afford food at all times with the right nutrients by these urbanites since most resort to street foods or

already processed food. Gómez *et al*. (2013), observes similar situation in South Africa, for example, indicating that a substantial share of its residents within the informal (19.4 %) and formal (16.7 %) urban areas consume foods from street vendors or snack-areas at least twice a week.

From the background, it can be copiously identified that the urban food system in the urban district of Adenta and Ghana is complex. Food stability therefore emphasizes the need for to mechanisms put in place to ensure the availability, access, and utilization which is subjected to urban changes with risks (ASABE, 2016). Besides, many aspects unite against achieving food security, particularly with the prevalence of informality, gender disparity, income inequalities and vulnerability to disaster (UN-HABITAT 2007; 2011). To address these food complexities, geospatial systems need to be promoted and supported, ensuring sustainable predictions in urban food development, and improving local governance (Ayerakwa, 2017).

2.5.4.3 Urban Food Informality and Vulnerability (UFI/V)

This research additionally attempts within the sensitive areas of vulnerability and informality traces that emerges in the urban food spectrum. Discovered by Darfour and Rosentrater, (2016) close to 2 million people are prone to food insecurities, this suggests that there exist unanticipated natural or human-induced shocks that can greatly affect the chain of food consumption in the district. Food is arguably available in the country (MOFA, 2016), however not accessible to all segments of the populace, especially the vulnerable (FOA, 2015). Within some parts of the country, whereas food can be accessed proper utilization is missing. This has put about 1.2 million people into acute food insecurity and a further 2.07 million becoming vulnerable to food insecurity (WFP, 2009). Incidentally, food insecurities are traced within rural and urban areas that are lowly measured due to inadequate household food supplies. Subsequently, informal areas which are characterized with significantly less food production for home consumption, heavily depending on food imports and others. Notably, (73.3%) of the employed urban inhabitants in Greater Accra fall within the informal sector of employment. Economically speaking, the women of Adentan Municipality progressively dominates its informal sector (MLGRDE, 2013). They are principally into various economic ventures such as small scale enterprises, trading, traditional hand jobs, food vending services and the swift emergent of commercial food retail centres popularly known as “provision shops”. Potentially, this SUB-sector is experiencing a major explosion due to the gross food demands whereas more women are becoming interested in this sector and considering it as a major economic choice. This is equally earning the municipality economic revenue.

Conversely, most household heads in the Adentan Municipality are women particularly as a result of the high rate of single parenthood. Besides, these women are forced to raise their children single-handedly (AdMA, 2017; GSS, 2013). Hence, they constitute a majority of household leaders who ensure food security at home levels. This leaves a heavy burden of urban survival on the women and children despite all the developments to make their lives better in the municipality (MLGRDE, 2013, GOG, 2015). Additionally, most resort to informal job opportunities particularly in the food sector, an area that seems to be of great priority to the survival index of the Adenta Municipality and Ghana.

According to the AdMA medium term report, (2016), the agriculture sector employs a lot of women in the municipality with 80 % involved in food production. Nonetheless, with the recent urban changes (that is, the farming land conversion to residential areas) the food vulnerability situation in the district has escalated. Thus the women who used to farm on these lands for commercial purposes have resorted to subsistence farming, induced labour & other means of survival so that they can earn a living. Likewise, these women lack the required support such as access to and control over land which remains one of the fundamental sources of power defining women's status, identity and opportunity in many communities in Adentan municipality. This does not only question the so called security status we boast of but also alerts us on the complex nature of this phenomenon that needs a multidimensional approach to solve its effects through GIS.

2.6 Gaps of research studies

2.6.1 The rural "hype" and rate of urban changes

Predominantly, research has been conducted expansively on the rural-urban share and changes of spatial units in development communities. Many scholars have identified the rapidity of urban movements and eruption of the rural space in the 21st century with frequent in-migration rates and population growth. The study of urbanization, urban trends and rural changes has received gross attention and with references made to the loss of agricultural land and food disconnect. The study of rural and peri-urban agriculture in African cities is recently loosing interests, since the urban domain is obviously depending on other means of food options as well (Bhanjee and Zhang, 2018). Farming serves as the lifeblood of most rural economies in Ghana and serves as a crucial force in the urban food chain, yet present day cities are assuming other forms of food dependency, despite rural supply taking dominance. For instance, the situation of Accra is no different, many rural centers around the capital supply its inhabitants

with food. Additionally, the rate of population in-flux particularly in Africa cities like Accra has been grossly associated to the rural agricultural decline and food availability issues.

However, the relationship of rural-urban differences are overly concentrated on and obviously implies an over reliance on rural sector hence its failure always leads to immediate effect of urban complexities and food insecurities. Although this school of thought has a strong stance, others (Ayerakwa, 2017) have revealed that food disconnects in the urban areas are not only due to rural reliance, but several factors come to play, such as consumer preferences, food pricing, poor distribution and access, among others.

On the other hand, others have moved on to measure the results of this changes using statistical and socio-economic variables to address food inequalities. The use of land use and cover changes and vegetation cover variations, have been adopted to better appreciate the spatial differentials that have received proportional attention. However, to fully address the situation of urban patterns and food inequalities in urban economies, there is the need for practically diagnose the multi-scale problems associated with urban changes and food security. Besides, the argument also exist in the urban areas being encouraged to adopt farm practices to supplement rural supply of food. Note that this phenomenon is noted in urban areas, where the poor and marginalized are equally profound and hunger and poverty is increasing (Stevano et al, 2018).

2.6.2 The economic disappointment of urban agriculture)

Food security has been considered within the urban stream as a survival index and contributor to holistic development. Besides, it has been constantly proposed that for this to be achieved especially in cities, inhabitants must be encouraged to adopt urban agriculture. In fact some even prefer that laws and strict guidelines from city authorities must possess components that ensure urban agriculture. According to this school of thought, the only way to supplement and ensure food balance in the urban segment is to allow for the phenomenon of urban agriculture (Crush *et al*, 2011).

However urban changes arises alternate stresses on urban agrarian lands for infrastructural development such as residential and commercial buildings, transport routes, among others for public usage (Ayerakwa, 2017). Studies and policy deliberations on whether to allow or exclude urban agriculture has established varied responses from both policy extremes (Sova, 2016). Thus realistically, this phenomenon perhaps could only reside in theory.

For instance, the principal share for farming in the urban spaces of Accra, like Adenta is located away from the house. As a matter of fact, about 26 % farm producers cultivate on highly insecure public spaces and bear various forms of risks of eviction (Drechsel *et al*., 2007). Again, in the transition areas, farming is predominantly done in smallholding gardens, with less commercial focus (World Bank, 2013). Vegetable and maize production is the most important production system in urban Accra, with a smaller %age of the producers growing staples or keeping small livestock (Darfour and Rosentrater, 2016). Intrinsically, it has become somewhat a debate as to if urban agriculture is truly the way forward in ensuring urban food security.

Categorically, whereas some focus on food access in areas that are rural and poor such as the Northern part of Ghana; others also focus on urban agriculture as the solution, considering urban areas in the south (Ayerakwa, 2017). However, forgetting that urban agriculture is expensive, and limited to people who have the means mostly informal areas not considered.

2.6.3 The remedy of urban modelling, monitoring and food frameworks.

Accordingly, the ability to understand the change systems of urban areas and monitor its patterns is a right direction to address urban complexities and food insecurities. Potentially, attempts have been made by various national and international bodies to face urban issues and food security the technological way (FAO, 2015). Like (Hagai, 2014), this paper follows a similar pattern in coupling the diagnoses of urban changes and their relationships with food systems in the district using geographic information systems. These dynamics have been unnoticed in several studies on urban food security (Marras et al, 2016; Ayerakwa, 2017), but recently even international bodies like World Bank, RUAF, FAO, etc. are all moving towards the direction of Future Food Frameworks (F^3). The impact of non-food producing areas should be well explored to investigate the dynamics of urban changes and food inequalities in these districts and its impact on development especially if we really want to eat what we produce.

This research attempted to model the process of food security assessment using Geographic Information Systems (GIS) tools, based on data representations on urban change and food system indicators. These were in the form of GIS layers and was well integrated using the Multi-Criteria Decision Model approach.

Additionally, the application of GIS modeling approaches is relatively faster and convenient than statistical manual methods, urban change and food systems Information ought to be executed readily, so as to facilitate evidenced-based understanding of food imbalances, thereby

guiding city authorities in decision making with regard to designing equitable methods of food frameworks and urban models for effective local decisions.

2.7 Sustainable urban change and food framework

The urban narrative has introduced subjects of concern in predicting the trend of urban transitions (Osaragi and Kurisaki, 2000). Most positions have held the ideas of concentrating on land use changes whereas others observe that spatial changes have intrinsic complex components that needs some form of system for tracking and projecting outcomes to inform decisions. Conversely, monitoring and making predictions of urban changes without a scientific support system denotes a definite level of ambiguity due to the many unfamiliar aspects involved (World Bank, RUAF, FAO, 2017). This may cause associated risks of urban management decision-making. With the swift change of the century, extensive research is being conducted in the urban and regional sustainable food system community with various approaches and plans been invented by city authorities particularly in the Global North without much leverage in the South (Ilieva, 2017). For instance, Dubbeling *et al*, (2015) recounts that over 100 cities globally are setting examples for the first time in global urban food frameworks. Consequently, built-up cities are leading food strategies and seeking steps to re-imagine food as an urban sub-system whose sustainability is firmly knitted with that of all other fundamental urban systems such as mobility, housing, utilities and waste management (Ilieva, 2017). The concept of livable cities with healthy, equal, and ecologically comprehensive urban food structure is progressively receiving recognition as a matter of local policy therefore becoming a major responsibility for national and international government organizations (Tefft *et al*, 2017; Ilieva, 2017). Thus the urban food phase has evolved from the Agrarian-dependent perspective to a complex modern theory. Accordingly, the projections of urban changes and food security are not only concerned with its generation, but the reality of modern socioecological functions expressed by urban societies such as Adenta Municipality. A significant solution to these difficulty may be to construct a tougher analytical linkage between a series of methods and information inputs that has the potential contributing to food insecurity assessment and vulnerability monitoring (Tefft *et al*, 2017). In this regard, the recognition and implementation of a multi-functional framework in land management influences its sustainable spatial use (World Bank, 2013; Tefft et al, 2017). Therefore, the need for a Sustainable urban change and food system framework is indispensable.

However, the major challenge has been the lack of a monitoring system as a result of the inconsistent and essential data (Stein et al, 2001). Addressing the unreliable, analogous and

relevant data combined with the fragile information base therefore represents a prime priority and precondition for future work. Addressing this challenge, the remedying strategy of a Sustainable urban change and food systems is applied consisting of two steps: first, was discovering and prioritizing urban data, and monitoring information needs in an urban food framework (FAO, RAUF and World Bank, 2017); secondly, was determining the multiple, inventive and efficient ways to systematically collect and analyze this data to produce the information required for decision-making by key actors involved in urban food issues. Hence, depictions of these urban areas derived from satellite data principally promised the most congruent measure of defining surface properties (Potere & Schneider, 2007). Accordingly it helped in setting a rudimentary step of assessing the urban change patterns of the district as well as ensuring a quantitative description of the urban space for predictions and framework designs.

Frameworks assists city authorities and other stakeholders to better comprehend issues, distinguish problems, prioritize tasks or programs and facilitate policies. Additionally, it guides policy analysis and contributes to effective policy assessments. For instance, urban changes, food systems and vulnerability analysis among others supports the identification and targeting of urban classes to help in easy intervention and implementation of plans (Hagai, 2014). Geospatial analysis provides a socio-spatial perspective to examine many urban food issues including food accessibility and urban agriculture land uses (Devereux *et al*, 2004). It should be noted that sustainable food frameworks is not intended to be the most comprehensive structure, but rather one most appropriate for contemporary food analysis, considering urban change complexities (FAO, RAUF and World Bank, 2017).

2.8 Urban change and urban food systems modelling

City authorities have conventionally used comprehensive models such as spatial interaction models (Gilbert, and Troitzsch, 2005) for establishing policies and plans for modelling the growth of cities. However, these have several downsides due to their aggregate treatment of individuals and their lack of dynamics and behavioral realism (Heppenstall *et al*, 2016). This has led to an increased attention in using multi-based methodologies from geo-analytical inputs such as cellular automata (Rimal *et al*, 2017) and agent-based modeling (Shoko and Smit, 2013) for enhancing the conception of urban change processes and food dynamics of, and in particular simulating how cities may grow in the future.

2.8.1 Approaches of urban change systems modelling

Generally, the techniques of monitoring urban changes and the reliance on conventional approaches have received varied scholarly perspectives (Reis et al, 2014). For instance, the adoption of land cover data has been widely adopted as a measure for evaluating land change patterns. However, the assessment of aerial photographs and other satellite data is not enough to monitor the complexities of cities. Subsequently, in traditional planning approaches, urban change data (especially, land use and cover) is gathered manually from hard copy maps. Unfortunately, this requires a lot of time to attain complete and accurate information, and as a result of the changing dynamics in Ghana's urban patterns, monitoring outcomes from these approaches have been inefficient.

In fact, this method is timewasting, strenuous, and subject to problems of human errors (Abdou-aziz, 2004). Hence, with the advent of aspatial data sets such as population and housing data acquired from census and city records, property tax estimates among others (Parson *et al*. 1995). The manipulation of data is subject to new approaches and therefore require pragmatic methods. Monitoring urban changes using satellite images and non-spatial datasets provides the opportunity for modelling on a regular basis (Cohen, 2014). This presents timely information that can be combined with ancillary data to monitor urban change and distinguish expansion models (Batty, 2007, Simmonds et al, 2011).

For instance, whereas Yeboah *et al*. (2017) used satellite images and aerial photography to monitor urban patterns and land use change; Addae and Oppelt, (2019) adopted statistical data to create patterns that represented urban growth as well as predict growth scenarios. These approaches determines changing patterns within urban areas such as Adenta municipality and provide planners with a platform for analyzing urban growth dynamics. Additionally, the use of geospatial inputs promises the prediction of change patterns based on models developed.

Urban modelling is usually controlled by static symmetric inventions and has recently seen the development of models openly addressing the dynamics of urban change (Simmonds et al, 2013). In fact, urban modeling systems are anticipated to simplify the complexity of urban systems and make them easier to understand as well as guarantee practical urban policies. Accordingly, remotely sensed data coupled with GIS techniques can be a valuable tool for these applications (Abdou-Azaz, 2004). These change monitoring applications assures one of producing functional information about urban changes and monitoring with food systems modelling for preparing and predicting future solution to urban problems.

Current developments in the incorporation of geospatial systems with planning models, visualization, and cloud hosting have made GIS more useful to urban planning (Zsigmond et al, 2018; Fashal et al, 2019). Scientists have discovered the use of additional data coupled with satellite images to improve change effects and classification of urban areas. A possible source of this secondary data is the multiple data layers stored in GIS databases preserved by users such as the metropolitan planning organizations (Joerin et al, 2001; Coulter *et al*. 1999). Accordingly, urban land data stored in GIS is only a static model of the real world for a specific time period and must be frequently updated. Satellite data are superior in this case because they possess a higher temporal resolution that has the potential of monitoring the dynamic changes within a GIS. An urban information system, therefore, when combined with current remotelysensed data, can greatly improve the efficiency of change discovery, map assembling and revision (Seong 1994).

Compiled geospatial inputs with presents hybrid information that can be used as a base for accountable decisions in urban planning and management. In the same context, GIS offers a platform for this incorporation of spatial data. It presents a strong device for quantitative analysis of urban complexities. The intervention of Geographic information Systems has thus boosted the attention in automating the city through the reliability of geospatial information considering its reliability and repeatability when compared with traditional based methods. The complexity of the urban space in Ghana thus demands a geospatial approach that embraces multi-dimensionality. For that matter, the concept and technique of multi criteria decision analysis was embraced to facilitate this research of monitoring and managing urban communities.

2.9 Concept of Multi-Criteria Decision Analysis and GIS

This research adopts a hybrid of techniques and models with the GIS and multi criteria decision analytics (MCDA) to suit the local context of the Adenta Municipality (Gigović et al, 2017). This methodology adopts the proficiencies of GIS in the administration of geospatial data and the flexibility of the MCDA to associate reliable pieces of data (e.g., land use, population, housing, food access, etc.) with value-based information (e.g., standards, surveys, etc.) (Crush *et al*., 2011).The key benefit of integrating GIS and the MCDA is identified within their specific abilities accompanying each other.

Many local authorities in Ghana need information ahead of time in order to take preemptive and adaptive strategies for human settlement development, particularly in urban communities where trends are complex (Shoko and Smit, 2013). The rapid expansion and integration of spatial technologies such

as Geographic Information Systems (GIS), the Global Positioning System (GPS), remote sensing and drones have led to the creation of an endless range of possibilities for smart urban planning and decision making (Wray and Cheruiyot, 2015). Accordingly, with the advent of geospatial technologies and satellite data operation, experts and governments are shifting their perspective to the wide range of utilizing its potentials for effective spatial management (Crush *et al*., 2011). GIS is a modern day innovation that allows professionals to acquire, store, manipulate, analyze, manage, and present spatial or geographic data in various ways that are applicable for better spatial modelling. One of the key methodologies that has received less popularity in the global south but well known in the global north is the Multi-criteria Decision Analysis (MCDA) model approach.

MCDA methods are adopted to make complex decision within the urban domain (Pavan and Todeschini, 2009). It is often used to highlight the option of analysis and supports local authorities in making the best decision (Bowyer, 2015). However, this in itself cannot make the final decisions but equally depends on a set of variable indicators that guides urban change complexities. In fact, the urban spectrum is characterized with evolving change indicators and for that matter requires a modern and systematic system of measuring its changes (Bowyer, 2015). Consequently, the principal aim of MCDA is to help city authorities and urban policy makers to synthesize information and make well-informed decision. Essentially, Pavan and Todeschini, (2009) describe the MCDA as a prospective tool that integrates spatial measurable dimensions with subjective non-spatial variables to describe urban change complexity patterns.

Indeed, the MCDA allows for flexibility and innovation within the urban framework to effectively predict the implication of change patterns for present and future decision making. Again, urban management decisions do not only demand the selection of best alternative but also considers prioritization of algorithms using MCDAs weights of ranks. This helps to facilitate resource allocations, identify areas of interest for immediate interventions, control haphazard growth among others. Additionally, the system breaks the complex issues of cities into their smaller components (indicators) and institutes a way of weighing and ranking the indicators vis-à-vis available alternatives to arrive at a scientific conclusion. Identifying the array of indicators is however a central task. These urban variations are grouped into explicit and implicit MCDA theories. The explicit indicators are clearly defined and listed called “multi-attributes” whereas those that are implicitly defined are mathematically programmed known as multi-objective optimization theory (Pavan and Todeschini, 2009). In essence, the approach attempts to represent the fix and loose ends of the urban space phenomenon based on individual criterion (Department for Communities and Local Government, 2009).

MCDA - Decision choices are assessed on the basis of a set of indicators, which include attributes and objectives (Karnatak et al, 2007).

- This approach integrates human and natural urban transformation processes, with time patterns that interrelates spatial indicators or criteria observed.
- It allows decision makers to obtain information on the multi-dimensionality of issues in order to make choices among different alternatives.
- It serves as an effective support mechanism for decision-making processes powered by geospatial tools (Mele and Poli, 2017) with functions of storage, manipulation, analysis, and display of large geographically-referenced dataset using analytical modeling operations.

In the area of land use/land cover change detection, research is still needed to find a means to simplify the detection and classification of urban change, as precisions are too low to be useful (Abdou-Azaz, 2004).

There is a need to develop land use/cover models for use in land demand modelling to predict how urban expansion changes affects land use. Furthermore, these approaches are needed to close the loop on the predicting process encouraging the overall modelling process that results in increased accuracy when making predictions (Malczewski and Rinner, 2015)

The application of MCDAs cannot be complete without considering its quantitative analysis through simulation studies. This could be performed through the adoption of weights and ranks as binary elements to facilitate programming.

In fact, the indicators and components of urban change and food systems are well described and assigned weights of prioritization for simulation modelling and decision making.

This study proposed a conceptual model for the application of an empirically informed (predictive) multi-dimensionally based model that can reveal patterns and trends in urban settlement growth and food access in Ghana, considering the Adenta Municipality.
The criteria used was comprehensive and measurable. That is, the set of indicators were holistic (covering main aspects of decision problems), functional (criteria was expressively applied in the analysis), breakable (the set indicators was fragmented into parts to simplify the process), precise (avoided double counting to ensure validity), and sizable (the number of indicators was kept as small as possible) Malczewski, 2018; Malczewski, and Rinner, 2015).

2.9.1 The theory of GIS-based AHP-SA for MCDA modelling

Uniting GIS and MCDA is a prevailing tactic to land management suitability assessments (Chen *et al*, 2009). It includes a set of geographically defined basic units (e.g. polygons in

vectors, or cells in rasters), and a set of evaluation indicators characterized as map layers (Crosetto et al, 2000). The challenge is to unite the indicative maps based on the attribute values and decision maker's objectives with a set of decision rules, or weights. This helps to categorize each unit into a suitability level (Chen *et al*., 2007). To effectively combine spatial and nonspatial indicators for decision making, the modelling demands of scientific instrument helps in weighing and ranking these set of criteria. Therefore, using Analytical Hierarchy Process (AHP), (Saaty, 1977, 1980; Saaty and Vargas, 1991) is among the most standard methods to obtain effective results to help in modelling future outcomes.

The theory of GIS-based AHP-SA tool according to Chen *et al*, (2009) provides extra fast response and feedback to urban modellers. The theory involves the integration of Sensitivity Analysis (SA) with Analytical Hierarchy Process (AHP) using GIS to make predictions of a particular phenomenon in the urban space. This method adopted by Chen *et al*, (2010) augments the conservative AHP module, advances the dependability of MCDA output, as well as extends the existing GIS functionalities. In effect, this theory makes it functional for even non-specialists to understand, and provide a solution to a problem. Furthermore, this system aids in evaluating decision problems whilst identifying how changes in indicator weights affect assessment results spatially and quantitatively (Crosetto, 2001).

The use of a GIS-based AHP and SA will guide decision makers to implement an all-inclusive yet flexible process to observe weight sensitivity ranking in both (urban change and food systems) criteria within a geographic space. Additionally, Joerin *et al*., (2001) reveals that this approach gives a surer way for refining the capabilities of existing GIS-based AHP-MCDM models in order to generate more realistic output scenarios. Nonetheless, continuous progresses in this area of research will permit GIS and MCDA to be effective in practical landmanagement issues with greater success.

2.9.2 Evaluation of Model Accuracies using Sensitivity Analysis

Sensitivity analysis (SA) is essential for modelling since it defines the consistency of the model through assessment of uncertainties in the simulation results. With the budding interest in extending GIS to support multi-criteria decision-making (MCDM) methods, enhancing GISbased MCDA with sensitivity analysis procedures is crucial (Chen *et al*, 2009). Formal approaches of SA are, ranges from physics to economics (Scolo, 2008). Numerous techniques exists, ranging from differentials to Monte Carlo analysis, from methods of importance to sensitivity indices, from regression or correlation methods to variance-based techniques

(Archer *et al*., 1997). An exhaustive review of many techniques can be found in Crosetto *et al*. (2000). However, like Chen *et al*, (2010), the approach where the input factors are varied ‘‘One at a Time’’, better known as the OAT method is considered. The OAT method is easy to implement, computationally cheap, and has been frequently applied in various fields where models are employed (Chen *et al*, 2009. This is also the hypothetical foundation for this methodology.

2.10 Conceptual framework

The future food framework of the Adenta Municipality adopted a conceptual framework which serves also as the model builder. This framework (The FRAME model) describe the relationship of urban change monitoring, food systems and the future prediction model that can facilitate effective decision making in the Assembly. As presented below, this project started with the acquisition of available spatial and non-spatial data from all sources and stakeholders. The data was reviewed to verify its validation and authenticity. Further, a systematic approach of analyzing data of the urban complexities of the district was conducted. Consequently, this allowed for monitoring the logic of urban systems using a scientific computerized model, that is, the MCDA model. This prepares for effective diagnostics of the state or urban change and food patterns in the municipality. Finally, a framework was produced to sustain and predict future descriptive outcomes of the urban municipality of Adenta hence suggesting better measures for a smart urban planning.

Proposed Model for monitoring urban changes and food access dynamics in the district

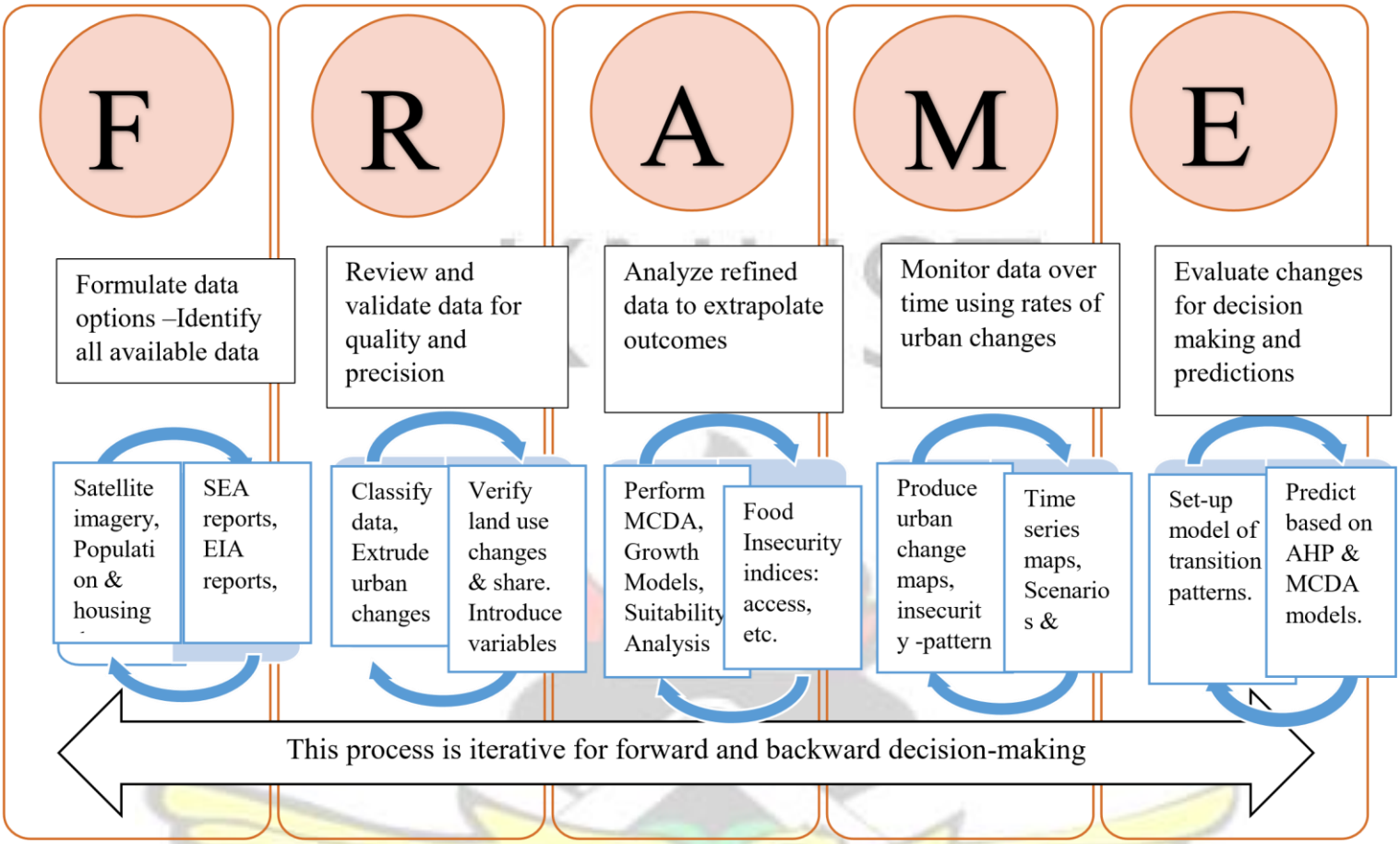

Figure 2.1 Conceptual framework based on Charleston Urban growth model, Allen and Lu, 2003

CHAPTER THREE 3.0 GENERAL SCOPE AND METHODOLOGY

3.1 Introduction

The rationality, consistency and accuracy of every research is highly dependent on the method approach adopted. The methodology provides a roadmap to guide data gathering and analysis of the research. This chapter builds on the previous chapter, where the concepts of urban change and food security was theorized with their crucial indicators for development studied to propose a framework and model for current and future monitoring. This set the basis to leverage these theories within a context and extract practical methods that can facilitate the processes of the research.

This chapter subsequently describes the area of study and the logical data collection thought under which this study was anchored. It capitalizes upon the various variables identified during the review of literature, in order to determine an appropriate research methodology to be adopted. It explains the model design, the data sources or materials as well as the softwares adopted for processing acquired data. The various geospatial techniques utilized as well as the

data processing and analysis methods incorporated to achieve the objectives of this research are explained. It begins with the first stage of the research, the data collection phase, which contains collection, and processing of the different types of data. Data entry and data preprocessing come in the following sections. Data analysis was divided into two parts: spatial analysis, and non-spatial data analysis. Spatial analysis consisted of land use/cover classification (Abdou-aziz, 2004). Non-spatial data analysis includes demographic analysis food access analysis.

3.2 Urban location and profile of study area

The Adenta Municipality was established out of the Tema Metropolitan Assembly in February 2008 by LI 1888 (AdMA report, 2017; PHC, 2010). The municipality has evolved as a popular dormitory town (for most people employed commuters in the service, industrial and civil service from the Tema-Accra metropolitan areas) to a fast-pacing urban municipality (PokuBoansi, and Adarkwa, 2015). According to the PHC report (2010) The Adenta Municipal Assembly (with Adenta as its Central Business District) is located 10 kilometres away from Accra, the capital city. It is specifically located on latitude 5′ 43″ north and longitude 0′ 09″ West. The Municipal has a land area of about 928 sq. km (358.3 sq. mls) (GSS, 2014). It also shares borders with Ashaiman Municipal Assembly and Kpong Akatamanso District Assembly in the east and north, La Nkwantanang Municipal Assembly in the West south, and in the north (GSS, 2014).

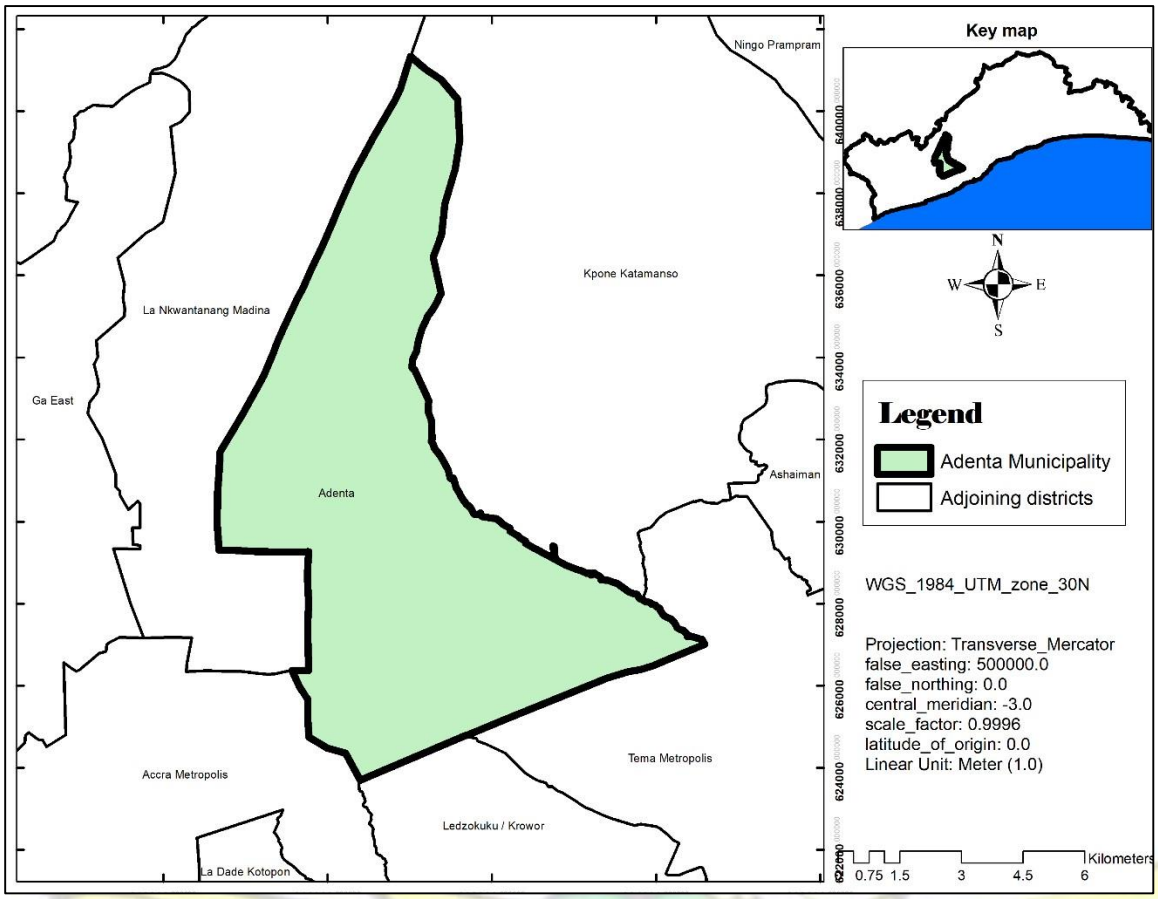

Figure 3: Adenta municipality in scope

Source: Author's construct, 2019

3.3 History and change Structure of Adenta Municipality

Historically, the Adentan district used to be an agrarian community with its inhabitants predominantly famers who cultivated various crops and reared cattle (AdMA web report, 2019). The name Adentan was derived from a Metal Mesh (locally known as DADEI NTANN) which was used to cover weapons during the 1831 war between the Gas and Ashantis (AdMA web report, 2019). Incidentally, the quest for food continually allowed for the district to prioritize food for survival. Utilizing its numerous rivers (popular among them are the Nugbete River in Nmaidjor and the Ogbojo stream, which are all suburbs in the district); the district facilitated farming and agricultural activities, among individuals and institutions over the years through the construction of dams within the Adentan Municipality. This includes Japan Motors Tourist Resort, Faahe Dam at Nmai Djor, Tessa Dam at Adjiringanor, University Farms Dam, and vegetation features at Amrahia and Ashiyie (GSS, 2014).

However, various studies have shown that as a result of urbanization and change, key features of the assembly has been altered if not completely changed over time. For instance, The PHC district report (2010) provides that the Japan Motors Tourist Resort Dam constructed in the 1960's by Japan Motors (an automobile firm) for its cattle ranch has rezoned for the development of residential housing units and hence the facility has been abandoned (PokuBoansi and Adarkwah, 2015; AdMA web report, 2019). Again, The Tessa dam at Adjiringanor built by Dr. Kwame Nkrumah (President of the 1st Republic of Ghana) during the construction of the Accra - Tema Motorway has been extensively encroached upon with just traces of natural areas. Accordingly, the University Farm's dam built by the University of Ghana to encourage practical work of its Faculty of Agriculture has recently become redundant facing constant encroachment by real estate developers (AdMA web report, 2019).

Subsequently, with the overflow of urban sprawl from the capital (Accra) and the increase in housing units, Agricultural areas at Amrahia and Ashiyie have slightly witnessed the reason for which they existed (PHC, 2012). Whilst residents rises alarmingly, land sizes drastically diminishes with land uses frequently altered. This has become a great concern for the future food index of the municipality receiving attention lately.

Demographically, it is among the fastest growing urban districts in the region. With a growth rate of 2.6%, and a regional growth rate of 4.4% it is among the highest in the region and therefore reflects the fast developing nature of the Municipality (MLGRDE, 2014). The swift urban change patterns and local population in-flux has resulted in numerous urban challenges in the district lately. For instance, following a recent collateral damage in 12 communities in the assembly with 552 households and 2,208 persons affected in a rainfall disaster (Composite Budget, AdMA, 2017-2019); Local authorities has made it a priority by to develop practical steps to combat the incidence. Accordingly, food inequality and urban demand is soaring and this can only be collectively monitored and mitigated through scientific approach using Geographic Information systems. Over the years, the manual and poorly monitored urban changes has been a major contributor to poor response of the local authorities and for that matter ineffective decisions (Yeboah et al, 2017). This sets a description for a consistent and replicative method that can holistically advise urban policy makers for pragmatic decisions now and in future.

3.4 Methodology

Many local authorities like the Adenta Municipality, essentially require relevant data to take preemptive and adaptive strategies for human settlement development, particularly in urban

communities where trends are complex (Shoko and Smit, 2013). The rapid development and integration of spatial technologies has opened up endless possibilities for smart urban planning and decision making (Wray et al, 2013).

Accordingly, with the advent of geospatial technologies and satellite data operation, experts and governments are shifting their perspective to the wide range of utilizing its potential for effective spatial management (Crush *et al*., 2011). GIS is a modern day innovation that allow professionals to acquire, store, manipulate, analyze, manage, and present spatial or geographic data in various ways that are applicable for better spatial modelling (Jat et al, 2008). Consequently, the research considered three major approaches – that is, quantitative approach of gathering, processing and analyzing spatial data and qualitative approach of gathering aspatial data and mixed methodology of using multi-criteria to analyze and assess outcomes.

3.4.1 Research design

The research sought to investigate the urban change and food security dynamics in the Adenta municipality, Ghana. Revealing the complex nature of urban changes and the disillusioned food situation in the urban economies of Ghana; it was appropriate to adopt a multi-situational method that suits the conditions of the area of study both contextually and geographically. As a result, the use of GIS, coupled with the case study design and purposive random sampling was adopted due to its suitability and relevance to the subject matter. Also, this approach helps to describe the units of analysis in detail (Yin, 2003).

Again, mixed-approach provided an opportunity for the researcher to gain insight into the character and dynamics of urban change and food systems within the urban setting of Adenta municipality. The intensive analysis, which was characteristic in this research design, led to the detection of the relationships between urban change complexities and food systems. The use of this method settles with the techniques of Ayerakwa, (2017) and Aryee *et al*, (2018) who adopted the case study survey as a comprehensive approach for contextual studies. The levels to which the objectives of the study were reached was underpinned by this approach. Similarly, it sets the pace of evaluating the right results alongside, which promises better outcomes for policy interventions by MMDAs and government on urban management.

3.5 Data, Materials and Methods

This section considers the available research materials and datasets that will allow to shape the research study. It sets the pace of sourcing relevant spatial and non-spatial data required to analyze the research objectives.

3.5.1 Data collection and datasets

3.5.1.1 Spatial data from satellite imagery

In this research study, time periods of cloud free Landsat series images were downloaded through the Earth Explorer, United States Geological Survey (USGS) web portal from 1960, to 2018. Remotely sensed data results obtained was imported to Geographical Information Systems (GIS) and generated a multi-temporal built-up layers, which provided precise urban clusters (Poyil and Misra, 2015). The Landsat 7 ETM+ sensor had a failure of the Scan Line Corrector (SLC) on the 31st of May, 2003 and that resulted in approximately 22% data loss. SLC is a part of the Landsat 7 ETM+ sensor that compensates for the forward motion of Landsat 7 satellite during image acquisition (Huo et al, 2014; Abdou-aziz, 2004). Without the SLC, the images contain black stripes with zero value in all channels. In this study, a gap filling method was used for the image of Dubai in 2010 by mosaicking two images that have been acquired as close in time as possible. The primary image for the gap filling and mosaicking method was acquired on June 16th, and the image used to fill the gap was acquired on July 2nd.The remotely sensed images Landsat-TM 1991; Landsat-ETM+ 2000, Landsat-ETM+ 2005, Landsat-ETM+ 2010, Landsat-ETM+ 2015 and Landsat- ETM+ 2018 was used in the study to derive the built-up area extents in Adenta city using an unsupervised classification method (Rokni et al, 2014). These data were used to generate possible data of urban patterns based on vegetative cover (change detections) and urban expansion. Again, base maps, schemes and planning layouts were obtained from the municipality and other relevant institutions such as the survey and mapping department of Ghana. Again, socioeconomic data such as population and housing census, gender data and other social relevant data was collected from the districts and Ghana Statistical service as well as some semi-structured interviews with selected households was be incorporated.

3.5.1.2 Non-spatial data from multiple sources

These included relevant attribute data and information that contributes significantly towards the objective of the study.

3.5.2. Data processing and adopted softwares

The images acquired, usually come with cloud errors, line errors and in some cases both, it was required to process the data and correct the errors. Using QGIS 2.18, both radiometric and line corrections were executed to correct the errors associated with each image cluster, thus 1991 to 2018. This process improved the interpretability and enhancement of the remotely sensed data. Radiometric calibration and correction facilitates the operation of the data process over multiple time periods.

3.5.2.1 Data Processing with ArcGIS

After correcting the errors associated with each image, the images were loaded into ArcGIS for the individual bands associated with each image to be processed into a composite band. This process is referred to as band stacking where individual bands per each image downloaded were stacked to create a composite Tiff file using the Raster Processing tool under the Arc tool Box. Consequently, this was done for the study area, Adenta Municipality throughout the year periods, i.e, 1991, to 2018. Bands 1, 2 and 3 were stacked in descending order to create a composite band for the year 1991 and 2018 per each of the study area.

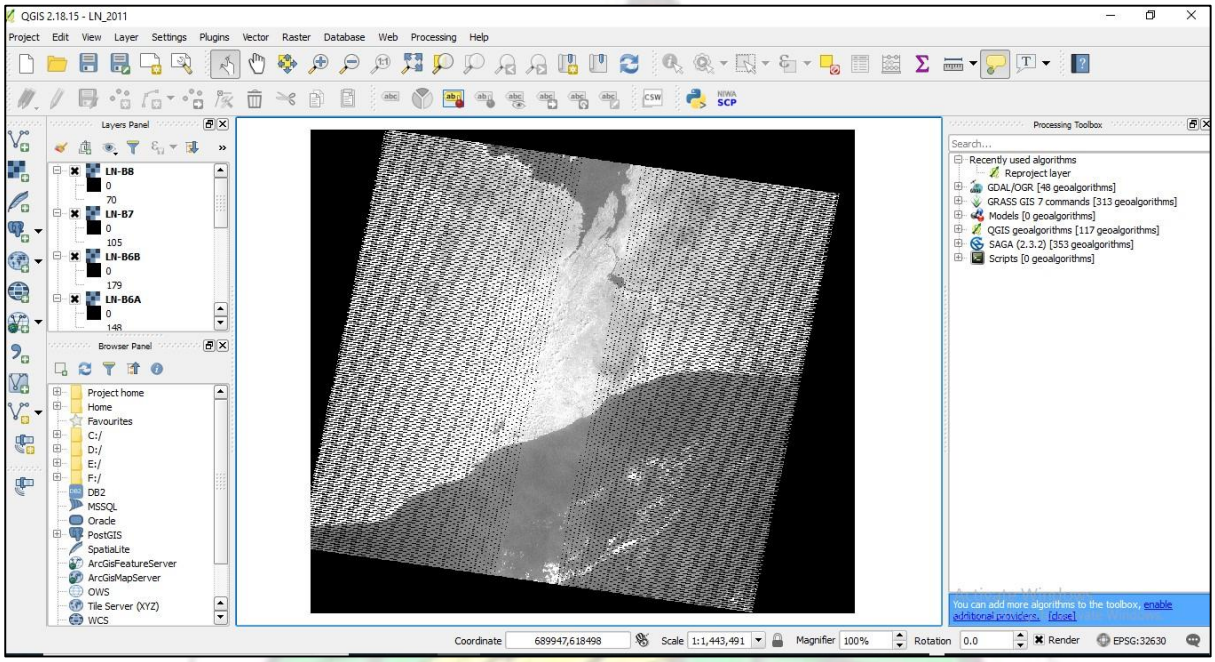

Figure 3.2 Data Processing with Quantum GIS 2.18

3.5.2.2 Data Classification using unsupervised classification tool

An unsupervised classification was done for each composite band using the ISO cluster tool in the Arc Tool Box. Training data of 60 points/ coordinates (20 points per class) were used to process the classes. Three output classes were defined for each of the classification processes. These classes were to represent Vegetation, Built up area and Non-built up. After the classification process for each year (thus 1991, to 2018), the output which was exported as a Tiff file and clipped to the respective boundary of the study areas.

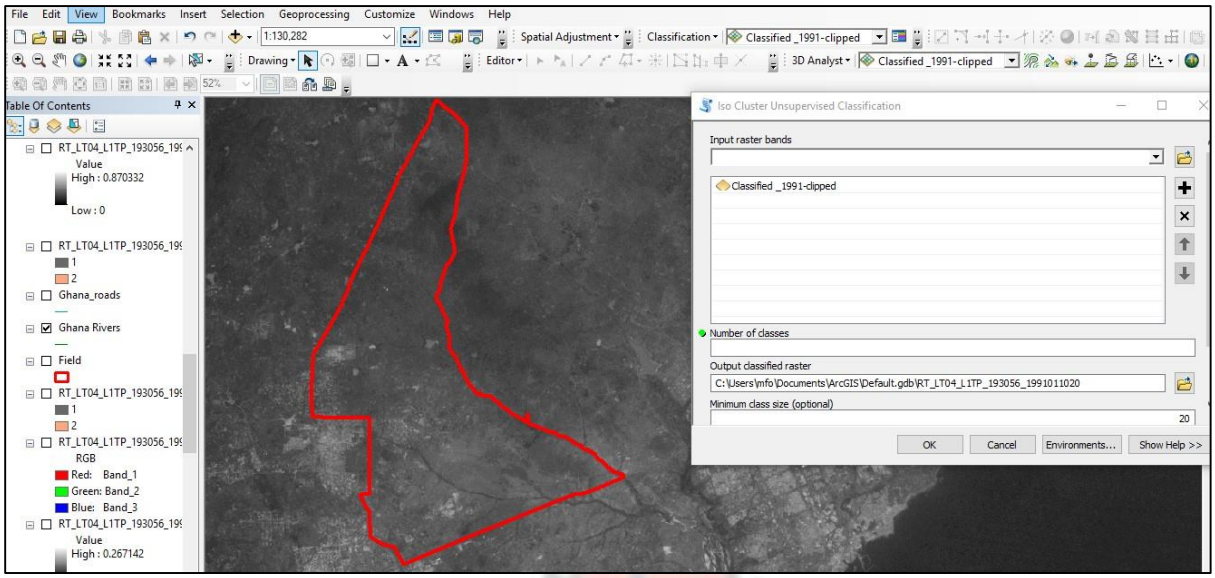

Figure 3.2 Data Classification with ArcGIS

3.5.2.3 Data Visualization

Subsequently, the right colour representation was selected for each of the defined classes, that is, Agriculture, Built Up area and vegetation areas (Neupane et al, 2019). As an unsupervised classification process, the user can specify which algorithm the software used and the required number of output classes which aids in the classification process. However, the user is required to have knowledge of the area being classified when the groupings of pixels with common characteristics produced by the computer have to be related to actual features on the ground (Yeboah et al, 2017).

Hence to ensure that classification matches with what is on the ground, training data from Google earth was used over the specified periods (1991 and 2018) as a guide. To determine the change in land cover over the specified periods, the total pixel count of each class was computed in the attribute table of the classification output. This was then multiplied by the size of a pixel (30m×30m) to ascertain the total area covered by each defined class (Agriculture, Built Up area and water areas). Comparison between the acres covered by land cover across the six periods, therefore, give an indication of the urban change (land use land cover lost or gain) between these periods.

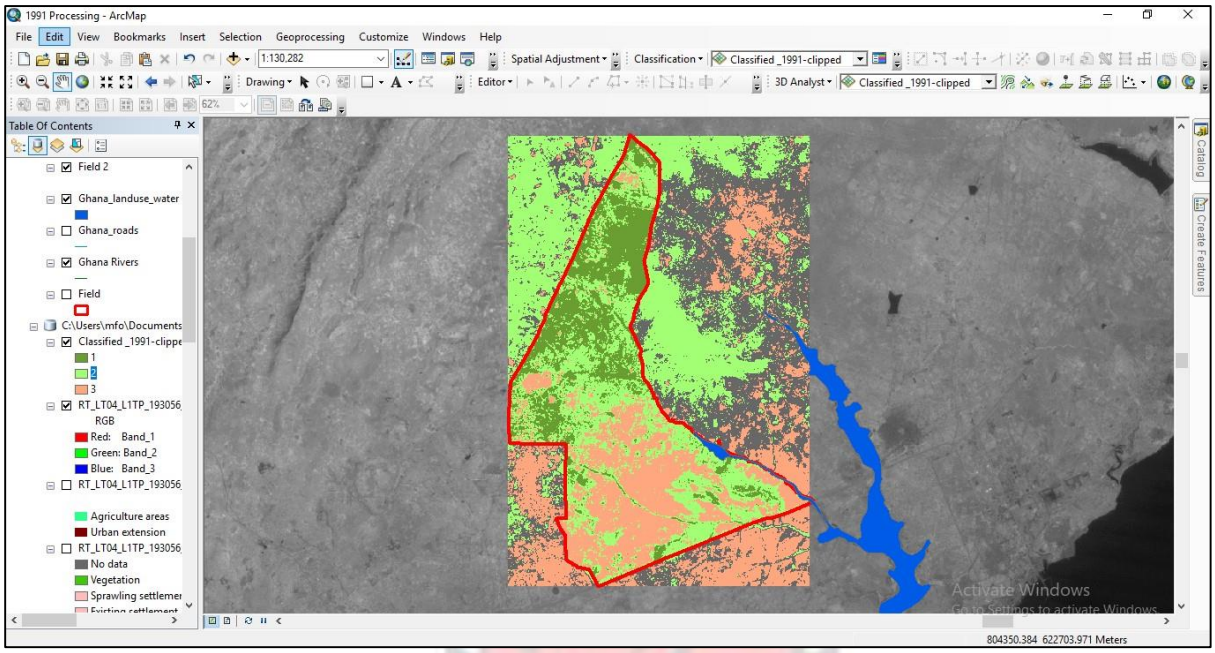

Figure 3.3 Data Visualization with ArcGIS

3.5.3 Ancillary data (Non-spatial data)

In order to practically address urban changes and the level of food security in the municipality auxiliary data [mainly statistical or non-spatial data] were needed. This included municipal reports, statistical data, and all other documents that can be used along with spatial map data to significantly address the dynamism of urban changes and food systems in cities. For instance, the population and housing census results for 1986, 2000 and 2010 (PHC, 1986, 2000, 2010), were used in this study for demographic data. Different data reports such as comprehensive annual municipal reports were also used.

3.5.3.1 Sampling Technique

As part of the extensive research design, a sample of 60 households from purposively sampled areas in the Adenta municipality were assessed and interviewed (Yin, 2003). The aim of the investigation was to identify and interview households in urban and peri-urban areas in the Adenta municipality. Subsequently, the support from the Adenta Planning department was sought to give clear demarcations of the boundaries of the urban spaces. The use of purposive random sampling was used, where the zonal councils of the municipality was used as basis for sampling for data collection.

Table 1: Details on respondents and sampling

MUNICIPAL ZONES	Sample communities	Number of respondents
KOOSE	1. Maledjor 2. Amrahia 3. Amanfro 4. Ashieye 5.AmpomahVillage	15
GBENTANAA	1.Adentan Old Town 2.SSNIT Flats 3.Frafraha 4.Adentan Housing Estate 5.Approtech	15
NII ASHALE	1.Ashale Botwe 2.Ogbojo 3.Sraha 4.Little Roses 5.Japan Motors- Lake side	15
SUTSRUNAA	1.University Farms 2.Nmai Djorn 3.Dzornaaman 4.Otano 5. Adjiringanor	15

Source: Authors construct based on (Adenta MDTP report, 2018)

It was possible to locate the communities since it was sub divided into zones. Therefore, the municipality was put into four quadrants (sub-zones according to the Adenta municipal report, 2016) with the center "Adenta barrier" serving as the epicenter for economic and social activities. The confines of each electoral area was identified with the communities. The objective was to have a relational representation of households throughout the municipality.

Secondly, sub-communities within each zone were identified and randomly selected. Respondents were later selected through purposive random sampling, where respondents were interviewed per their locations.

3.6 The Multi Criteria Decision Analyst tool

Multi-Criteria Analysis (MCA) is becoming increasingly popular in assisting the development of policy strategies. MCA differs from traditional risk management tools (Dunnett et al, 2018). It can maintain competing objectives separately rather than aggregating them into a single, weighted decision metric (Dunnett et al, 2018; Willows and Connell, 2003). It provides a rich collection of techniques and procedures for structuring decision problems, and designing, evaluating and prioritizing alternative decisions. This approach helped to comprehend not only the human and natural urban transformation processes, but also integrate the time patterns that interrelates spatial indicators or criteria observed. Thus, the multi-criteria spatial decision making support system (MC-SDSS) was embraced which allow decision makers to gain more information about the multi-dimensional subjects to choose their preferences among different alternatives (Hagai, 2014). Consequently, as asserted by Chandio *et al*, (2012), the approach powered by geospatial tools serves as an effective support mechanism for decision-making processes; with functions of storage, manipulation, analysis, and display of large geographically-referenced dataset through analytical modeling operations. In effect, the decision alternatives (which in this case were verified indicators of urban change and food systems) were assessed on the basis of a set of indicators, which include attributes and objectives. Multi-criteria assessment in GIS also involves spatial objective on the basis of a variety of attributes that the selected areas should possess. In that sense, the indicators were scientifically acquired from spatial and non-spatial sources, standardized and given weights to aid in its suitability modelling.

3.6.2 Adopting the Analytical Hierarchy Process (AHP)

According to Saaty's (1977 and 1980) Analytical Hierarchy Process, this tool serves as a standard approach to determine the weights (this is one of the standard problems in multicriteria decision analysis). The AHP is a mathematical method of analyzing complex decisions problem with multiple criteria. It is based on three principles: disintegration, relative judgment and synthesis of priorities (Karnatak et al, 2007; Chen *et al*, 2009). The disintegration principle of AHP essentially requires the decision problem to be broken into a hierarchy that attracts the essential element (indicators) of the decision problem (Karnatak et al, 2007). The relative judgment principle of AHP essentially involves pair-wise comparison of the disintegrated elements within a given level of hierarchal structure with respect to the next higher level. Again, the synthesis principle of AHP takes each of the derived scale of priorities in the various levels

of the hierarchy and constructs a composite set of priorities for the indicators at the lowest level of the hierarchy (Karnatak et al, 2007).

3.6.3 Weighting and ranking of data indicators

The validation and normalization of Indicator values were primarily based on other scholarly methods of (Singh *et al*., 2012; Lee *et al*., 2010; Xiao *et al*. 2007). This study thus adopted SPSS and Microsoft Excel to standardize and normalize indicator values as shown in the following steps and formula [in reference to the approach of (Aryee *et al*, 2018)].

a) To normalize all the indicators to matching units and scale, standardized values were calculated using the standard deviation formula as shown in Eq. 1:

Standard Value $Z = (Xi-\mu)/\sigma$ ……. (Equation 1)

Where Z = standardized value, Xi = Indicator value (quantitative data collected on the Urban change and food systems through questionnaires and PHC data), μ = mean value and σ = standard deviation.

b) The next step was to normalize the standardized indicator values such that the values fell within 0 to 1 in order to facilitate the weighting of the indicators. The normalized standardized value as shown in Eq. 2 is defined as

: (Eq. 2) $Y = \frac{Zi - a}{(e-a)}$ ……..(Equation 2)

Where Zi lies between a to e,

Zi = standard score a = minimum value, e = maximum value and Y ranges from 0 and 1.

c) Reverse indicators, such as incidence of vulnerability and gender were further standardized using the formula (1-Y) so that all values nearer or equal to 1 are those approaching food security, while those nearer zero (0) means food insecurity or within the food stress areas.

3.7.2 Weighting and calculating aggregate scores

In this research, equal weight was assigned to each indicator based on the premise that they all possess equal significance to the food sustainability of the city. Aggregate scores for each sustainability dimension, defined as Dimension Sustainability Score, were calculated using

Eq. 3:

$$f(x) = \sum_{i=1}^{n} \left(\frac{\text{YixWi}}{Wi} \right)$$

Where, W = weighting of each indicator, Y = normalized value of each indicator, n = number of indicator and i = year of assessment.

Finally, the overall Urban Food Access Index (UFAI) was calculated by summing the sustainability of each dimension score year by year. Again, equal weight (1/4) was assigned each dimension of Economic Access (E), Social Access (S), and Physical (P) as shown in Eq. 4

$$\text{Urban Food Access Index (UFAI)} = \sum_{i=1}^{n} \left(\frac{(\text{ExW})\ (\text{PxW})\ (\text{SxW})}{\Sigma W} \right) \text{(Eq.4)}$$

3.6.3 Evaluating the FRAME Model Accuracy using Sensitivity Analysis (SA)

An SA tool that is ideal to support MCDA should be capable of taking all forms of uncertainty through the use of standards, GIS and sensitivity analysis. Conversely, there are two aspects of indicator weight sensitivity that are of interest in this study: (1) identifying the indicators that are particularly sensitive to weight changes, and (2) visualizing the spatial change dynamics. Again, the attention is focused on the stability of evaluation rankings relative to standardized changes in the indicator evaluation weights.

Consequently, an arrangement of evaluation maps are simultaneously displayed for related simulations. However, joining the output into a format that is easy to interpret was generally a significant challenge fundamental to SA (Malczewski, 1999).

3.6.1 The FRAME Model flow chart

This research hence sets a direction of flow for the step by step and general logical approach of this study. In fact it gives a road map of the processes involved to achieve the stated objectives.

Below indicates the flow diagram of how this research approach was carried out.

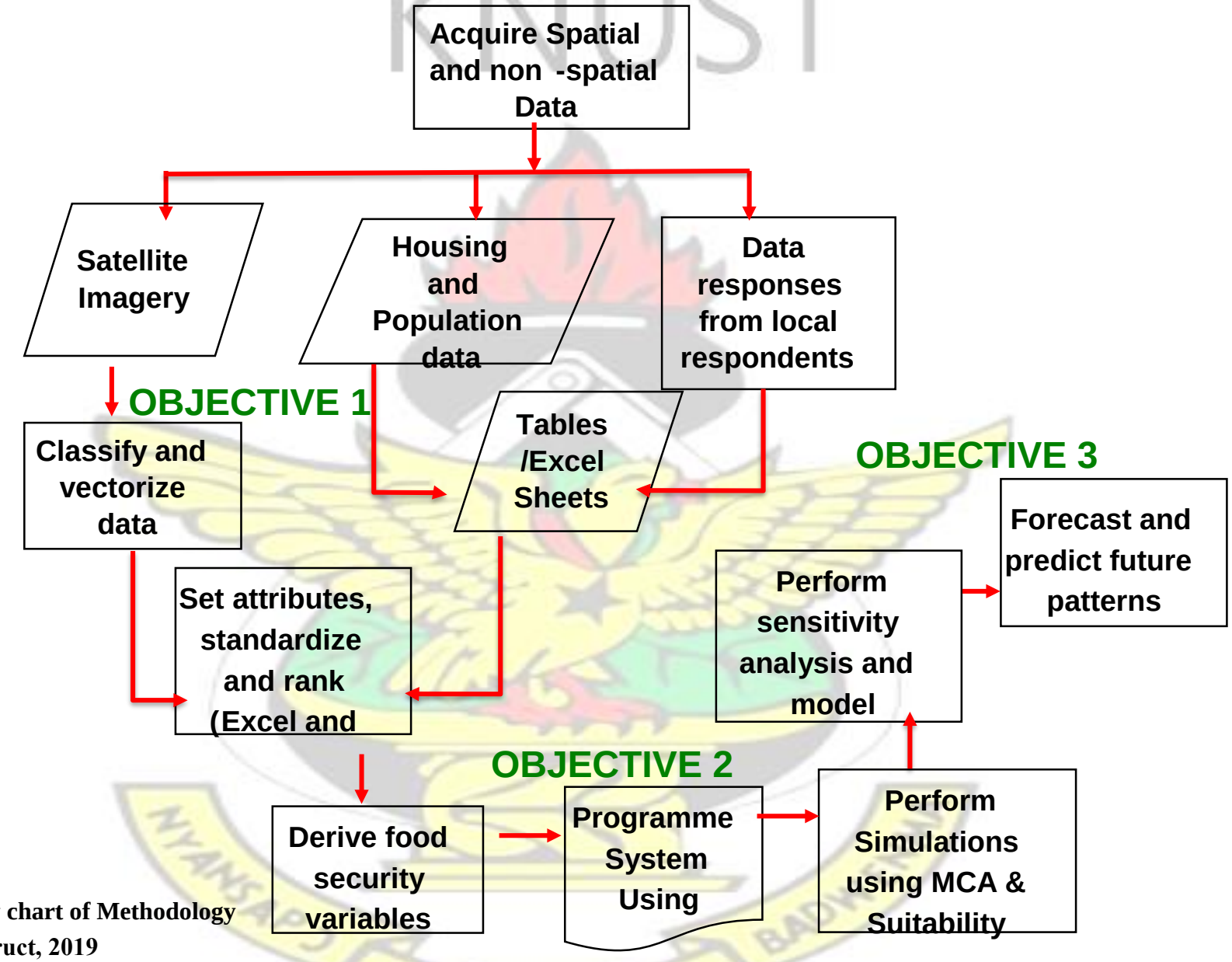

Figure 3.4 Flow chart of Methodology
Author's construct, 2019

CHAPTER FOUR DATA PRESENTATION, RESULTS AND DISCUSSION

4.1 Introduction

In this chapter, the results of data obtained in the study are presented and analyzed. The presentation is in line with key objectives of the research. This includes; assessing the rate of urban change and their variable indicators, food systems dynamics and their variable indicators, as well as the modelling outcomes out of these relationships for future predictions. Additionally, these results will be analyzed and discussed to tease out major findings that can inform decision making.

4.2 Monitoring and evaluating the urban change patterns of Adenta municipality

Urban communities are experiencing responsive change. The urban change pattern in the Adenta municipality is described as a complex one in some case characterized as a sub-urban district. This chapter is dedicated to comparatively diagnose the urban dynamics and varied food security situation in the municipality. Classified images of Adenta municipality was combined with population and housing data for the study years and presented (Higgins, 2011).

4.2.1 The extent of urban change (land use land cover)

The Adenta municipality continue to experience a phenomenal shift from its periurban state to a highly dense and populous municipality within the Greater Accra region. The Municipal has a land size of about 928 sq. km (358.3 sq. mls) (GSS, 2014). Figure 4.11 represents the land use land cover changes of the municipality from 1991 to 2018. With concentration on the intensity of development and urbanization, the built up areas as observed has radically increased from 245.85 sq.km (representing 26.48 %) to 416.94 sq.km (representing 44.91 %). Incidentally, the non-built environment which consists of non-impervious areas (such as open spaces, areas acquired but haven't witness any building development yet) among others had also increased. Especially between 2000 and 2010. This was basically as a result of the rapid rate of land acquisition and population in flux within this time period.

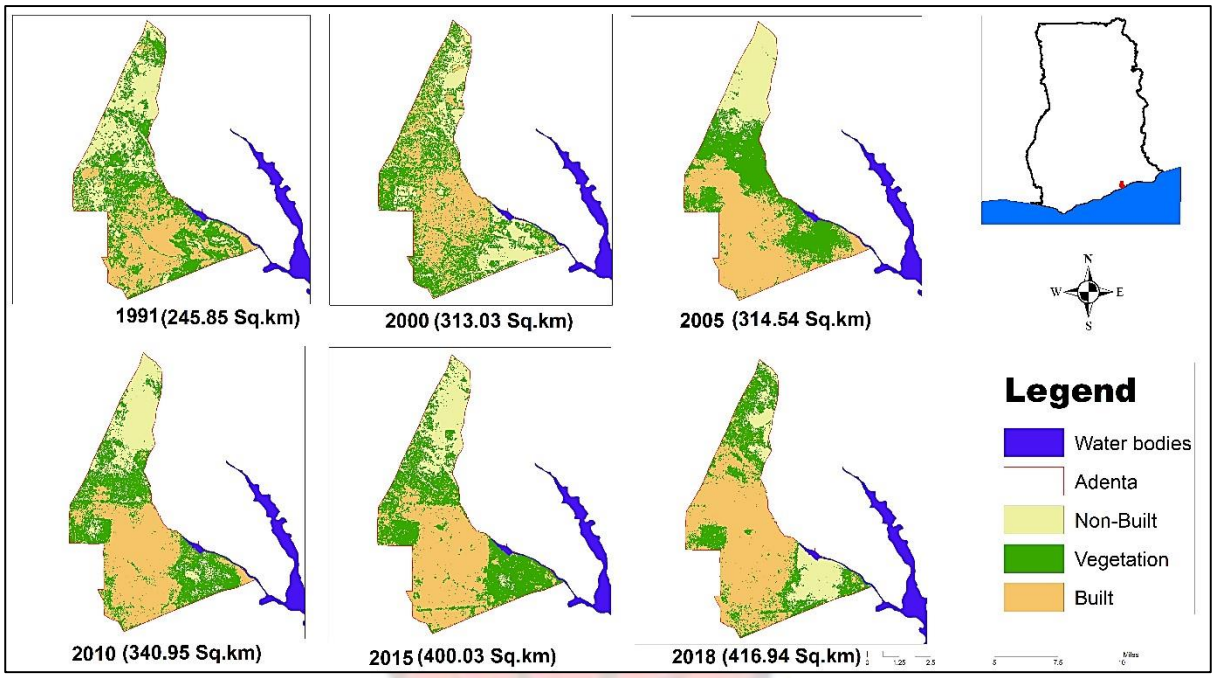

Figure 4.11 Land use land cover changes from 1991 to 2018

From figure 4.12 the graph shows the change pattern between the various LULC classes. It could be seen that the built and non-built areas are negatively correlated. That is, an increase in the built area result in the reduction of the non-built areas significantly. This explains the rapid growth of physical structures and impervious surfaces. The municipality for instance in their 2010 report recorded over 13600 building permits with over 50 % being completed buildings.

Like Cheng (2003) describes; Land use is an estimation of complex socio-economic interactions on the urban land system. In their report, the Adenta municipality has witnessed an exponential growth of transportation, educational, commercial and industrial land uses in the last few years. The land use land cover of the Adenta municipality illustrates a growing structural and functional shift from a low density district to a mounting high density of land use - reflecting the outcomes of its socioeconomic processes.

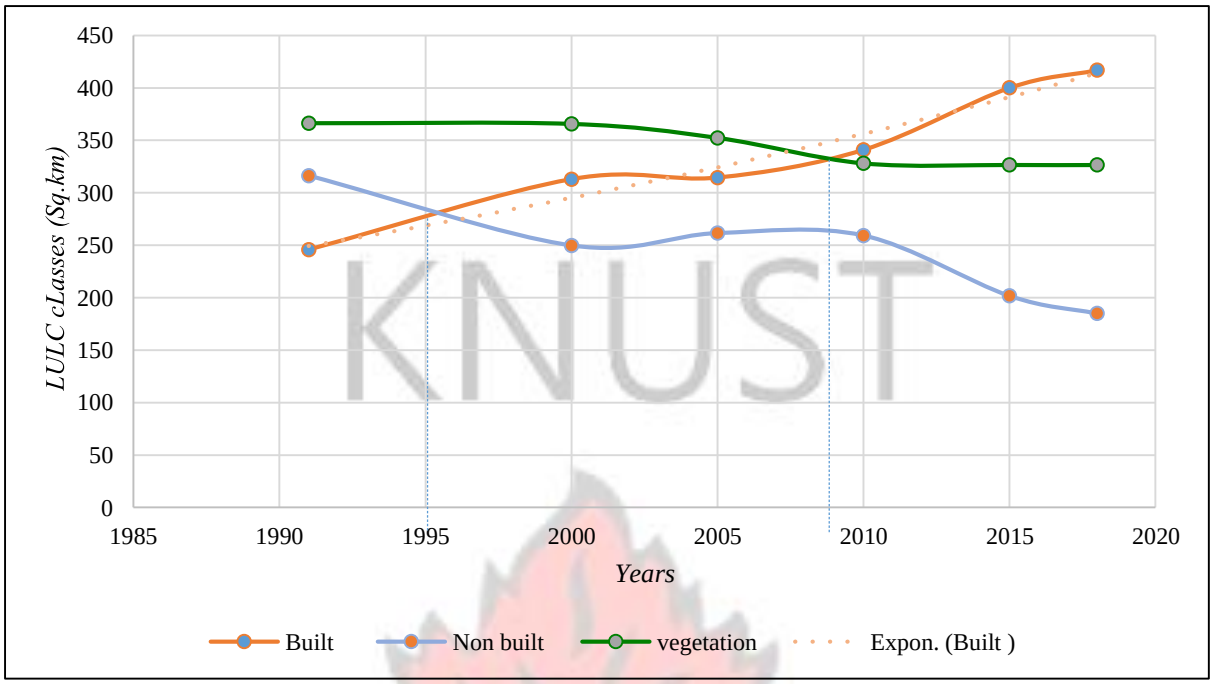

Figure 4.12 Land use land cover changes graph from 1991 to 2018

Land use land cover (LULC) metrics as an indicator of urban change can be defined as a measureable guide to define the structural arrangement and pattern of an urban space through GIS based (Chen, 2003). It is an effective mechanism for monitoring and computing the degree of urban morphology of a geographic area (Kronert *et al*., 2001). However, based on the complexity theory, the multidimensional features of urban settlements require other indicators to measure and monitor change.

4.2.2 Urban growth and footprints

One of the urban indicators of notable discussion is the population distribution and spatial emphasis of the municipality. This helps in monitoring and tracking the urban spills, population increase and deficiencies of the geographic scope. This study was equally interested in this urban indicator as it serves as a key actor in monitoring urban growth and change. The population of the municipality reckons to be increasing at a significant rate with a sporadic urban growth of 4.87 currently. This growth correlates to the sporadic regional urban growth of 4.4.

Additionally, it must be recognized that the urban population growth distribution will further rise in the next 7 to 10 years considering the rate of growth. This calls for pragmatic attention to be given to urban change monitoring and food access within the municipality.

Table 4.1 Population and growth rates of Adenta Municipality 1991 to 2025

Years	Growth rate	Population
1991	2.69	31357
2000	5.1	49,070
2005	5.52	64,194
2010	4.36	78215
2015	3.58	93264
2018	4.87	111105
2025	5.32	159702

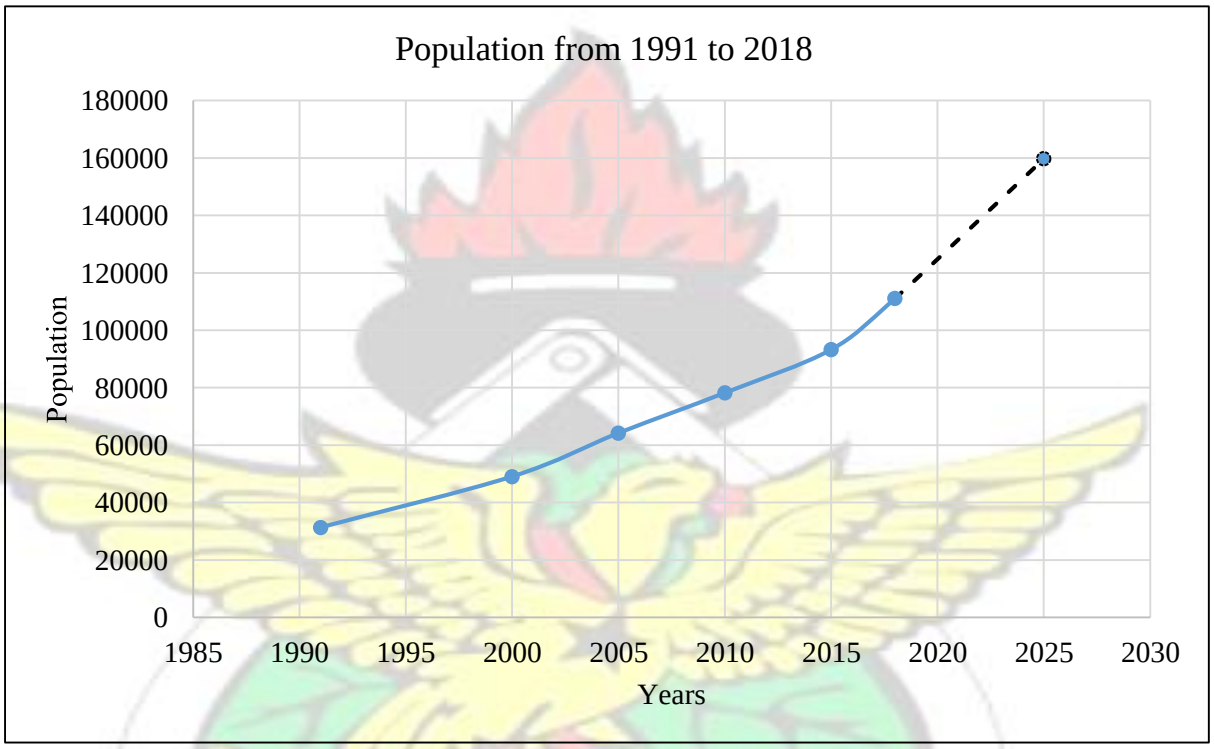

Figure 4.13 Population distribution of Adenta municipality from 1991 to 2025

Again, the Fig.4.13 and Table 4.1 as a determinant for urban growth and change, the population of the municipality "intends" to rise swiftly more than the usual in the next 5 to 10 years. The results gathered also revealed that whereas rate of urbanization in the Accra city [(1.97 %), (World Population review, 2019) gradually reduces, that of the municipality is skyrocketing (4.87 %). In fact, it is expected to experience even more growth in the next years (Raut, 2011).

This is as a result of the presence of sprawl and urban migration from the "choking" city centre to the "free peri-urban" areas. Adenta municipality is one of the key population absorbers from the Accra central city of the Greater Accra region. This urban character has positioned the Adenta municipality in a critical view that requires a consistent approach to salvage its

associated urban problems. For instance, the municipality records annual floods, uncontrolled physical growth, congestion, pollution among others. In addition to control this change, the internal system of the municipality was considered.

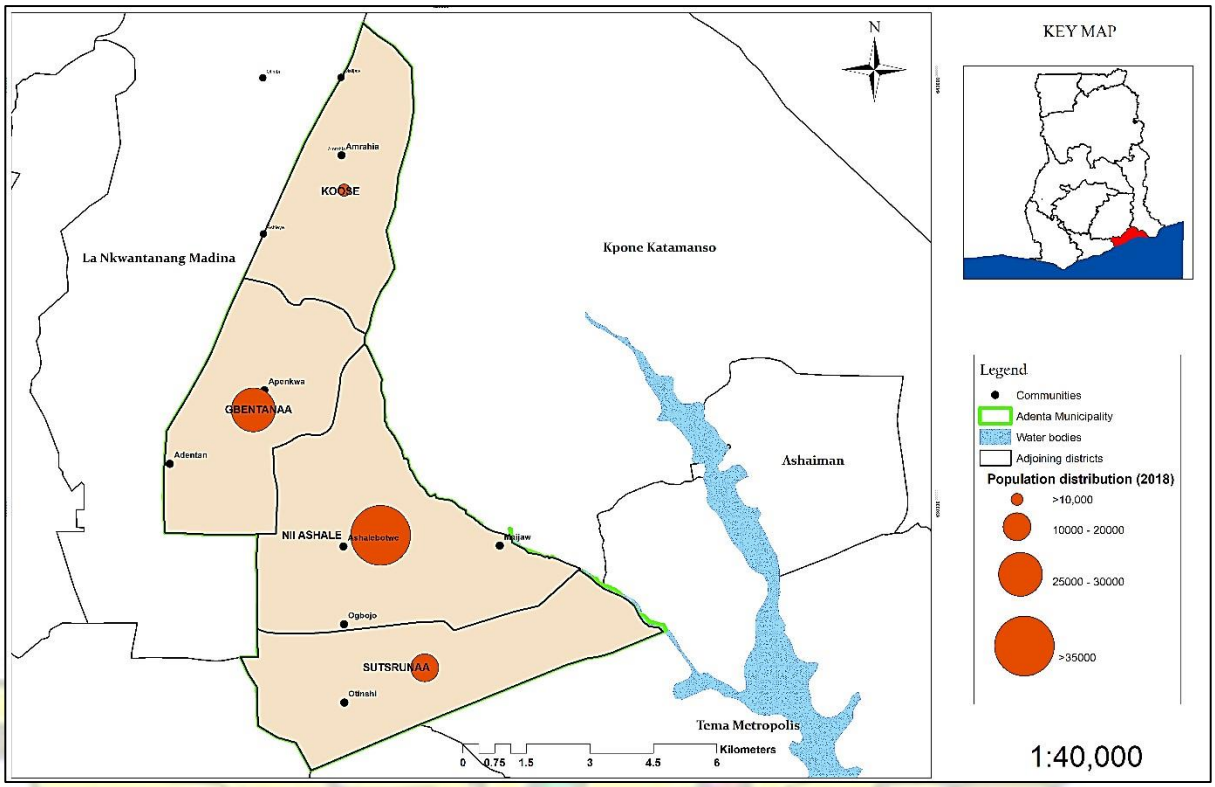

Figure 4.14 Population distribution of Adenta municipality in 2018 shown in zones

Table 4.2: Population distribution of Adenta municipality represented in their zones

MUNICIPAL ZONES	1991	2000	2005	2010	2015	2018
KOOSE	2686	4282	5511	6995	27436	33631
GBENTANAA	9274	14432	18974	23009	8341	9938
NII ASHALE	9898	15414	20198	24535	29256	34852
SUTSURUNAA	9499	14942	19511	23676	28231	32684
Total	31357	49,070	64,194	78215	93264	111105

Source: AdMA Medium Term Development report, (2008 to 2018)

The population change with respect to their zones showcased the internal change distribution of the municipality. As indicated above, despite the gross change of population rise within the municipality, its level and rate of change varies from location to location. In other words the population and growth pattern within the municipality is unevenly distributed. This is

particularly due to the functional differences and socio-economic evolutions that characterizes each zone.

4.2.3 Monitoring urban densities in the Adenta municipality

One of the critical determinants or indication of urban change is the density of the urban area. It is determined by the total population (inhabitants) or houses per the land area. This indicator helps in describing and monitoring the extent of urban change according to the level of concentration of the urban space.

The classified land use land cover images of Adenta municipality were been combined with population and housing data so that population densities and housing development trends for the areas or zones could be observed. Their respective urban densities were displayed in residents per km^2 and was calculated by dividing the population with its corresponding area. Figure 4.14 displays the population density in Adenta for the years 1991, 2000, 2010, 2015 and 2018 computed according to Table 4.3.

Table 4.3 shows that in 1990 almost the entire population of around thirty thousand people living along the main transport routes (a characteristic of urban sprawl) close to the central parts of Accra. This also reveals that the city both grew in population and expanded in areas significantly between the years 2010 to 2018. The urban density rose from 331 inhabitants per land area to 470 inhabitants per unit area over the time period, giving an annual population increase of over 4100 inhabitants. The average density over the urban area was 132 individuals/ km^2. Additionally, the city was condensed and the areas with the highest density levels were found at the central part of the city (Gbentanaa zone), North-western parts of the municipality. Similarly the level of growth keeps extending to the northern parts of the municipality especially.

Table 4.3: Population distribution of Adenta municipality represented in their zone

MUNICIPAL ZONES	1991	2000	2005	2010	2015	2018
KOOSE	14.69	23.43	30.15	38.27	45.64	54.38

GBENTANAA	44.89	69.86	91.84	111.38	132.80	162.79
NII ASHALE	32.95	51.32	67.24	81.68	97.39	116.03
SUTSURUNAA	39.79	62.61	81.74	99.199	118.28	136.94
Total	132.34	207	271	330.53	394.12	470.14

Correspondingly with the built-up areas, concentration of urban activities population densities occur around existing urban areas of Gbentanaa and Nii Ashale. However, prior to this, Sutsurunaa had receive much attention due to the proximity to the Motorway and Accra city centre. These areas tend to grow linearly along major road network. Currently, urban development seems to move towards the North particular to Koose zonal areas. This has been largely due to the high rental values within the other zonal areas. For instance rental values in Gbentanaa is priced at a minimum of Ghc 500 per month or Ghc 12000 per year. The economic restriction imposed on these developing areas in the municipality, has affected urban growth. For instance, the fringe areas towards the North where land and rental values are relatively cheaper is now rushed for. The density and level of concentration is now pushing for development towards Koose sub areas (shown in Fig. 4.15). This has significantly affected farming lands and vegetation, thereby contributing to the rise of food limitations within the municipality.

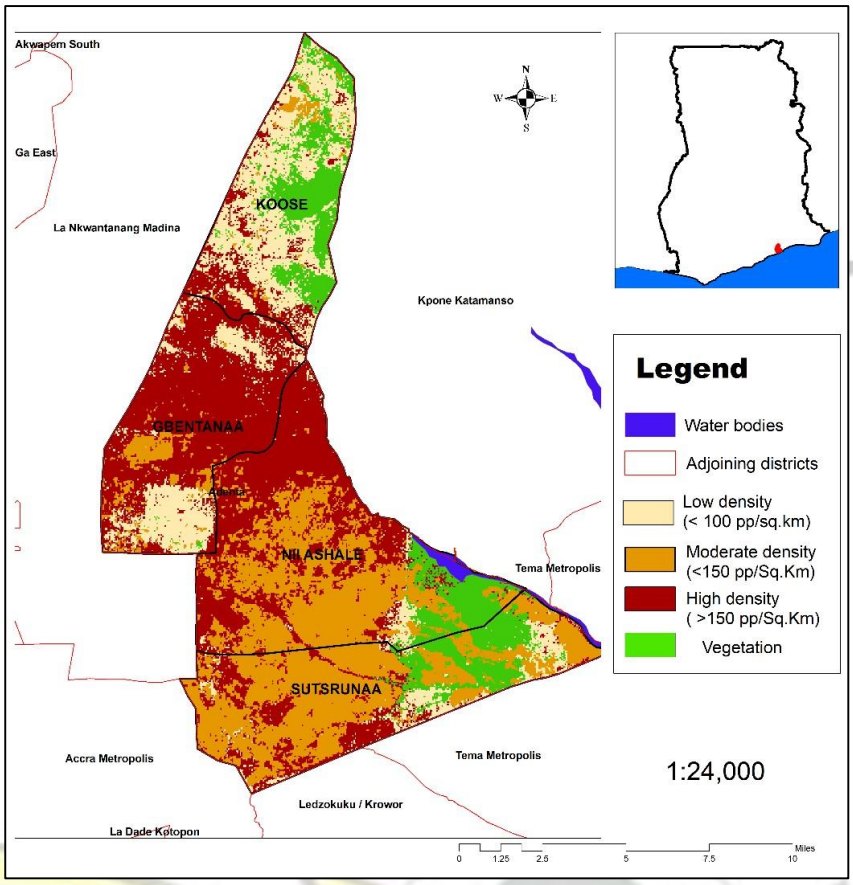

Figure 4.15 Urban density distribution of Adenta municipality shown in zones

4.3.1 Monitoring the urban food dynamics of Adenta Municipality

The continuous expansion of physical developments with its direct effect on the socioeconomic landscape of cities constantly affects its food systems. The phenomenon of urban change has altered the food accessibility trend of the municipality. The study explored according to the literature review, indicators to check the level of access. The urban food systems indicators used to assess the food in accessibilities were physical access, economic access and social access. These parameters were adopted from Aryee *et al*. (2018), as a metric system for evaluating the food access situation of Adenta municipality.

4.3.2 Food systems (physical access)

Food access as a component of food security is an essential constituent for the development of every nation. Countries that do not monitor its level of urban change and corresponding food supply and access stand high risks of experiencing food crises in future. Therefore in this study, the first indicator for measuring food access was physical access (travel time and distance it takes people to access food).

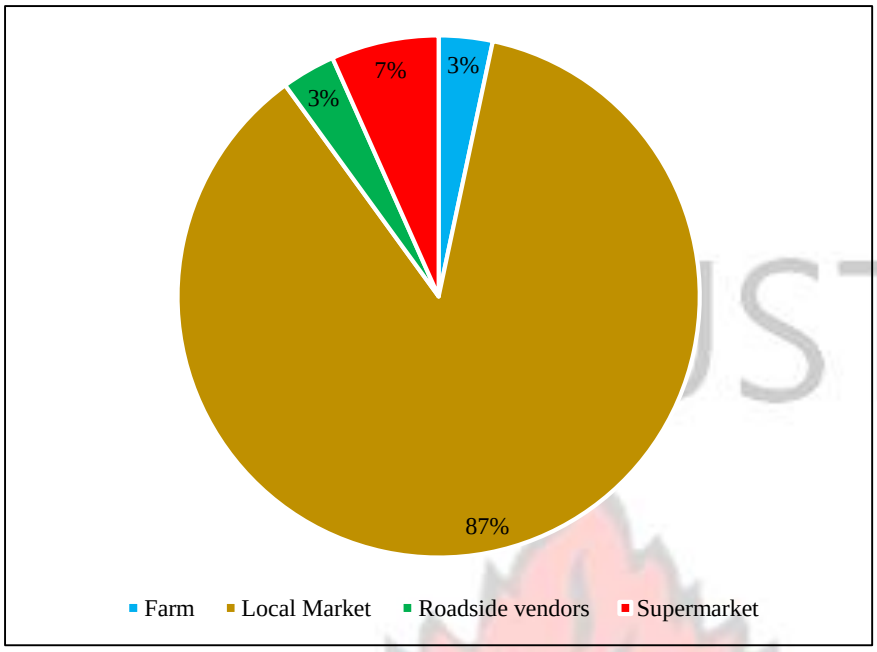

Figure 4.16 Sources of food for local inhabitants

The results in Fig. 4.16 shows that a little over 10 % varied their source of food inputs from farm and local vendors. The remaining local respondents in the municipality solely depend on the local market for their food stuffs. The local market is the main hub for food access indicating significant dependency on food imports from other sources into the Greater Accra region. The market plays an important role in the food dynamics of the municipality. To access food in these markets largely depends on the distance travelled to access food. Respondents revealed that they travel the distance to three main markets, Madina market, Makola and Adenta market.

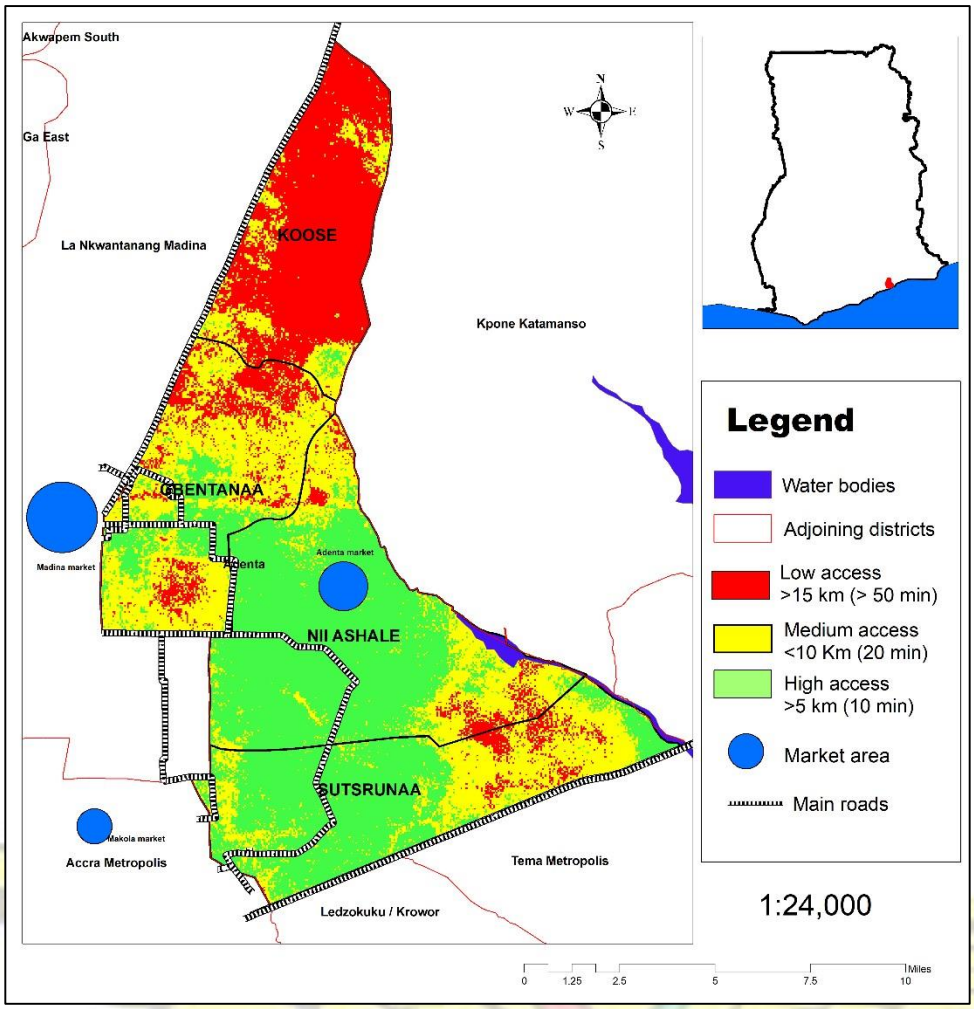

Figure 4.17 Physical access to food

Again, Fig. 4.17 indicates the pattern or distribution of access to food supply joints within and outside the municipality. Accordingly, despite the presence of Adenta market within the municipality, only 30 % patronize it. The remaining 70 % rely on the Madina market (50 %) and the Makola market (20%) despite the distance. This is obviously due to other indicators other than physical access, particularly economic access. Food items within these markets are relatively cheaper as they serve as dormitory market hubs for adjoining communities to trade. The madina market for instance, enjoy this "economies of scale" as well as has a relatively less travelling time (10 km) than Makola market (more than 15km). It therefore receives more visits and is the most preferred market by many in the municipality.

4.3.3 Food systems (Economic access)

The economic component of the food system discussed considers the income levels (demand) and food expenses (supply) made by inhabitants. Although the Adenta municipality is

perceived as middle class city, the terrain has expressively transformed due to urban changes. Currently, the informal sector is catching up with almost 40 % of the working class moving into the informal sector (Table 4.4). Again, a significant portion (12.7%) of the population do not work and therefore depend on their working relatives for food access. This represents a typical characteristic of urban sprawl, as the city keeps experiencing massive urban change.

Table 4.4: Occupation status of the municipality

Occupation		
Both Formal and Informal	5	7.3
Formal	32	43.6
Informal	16	36.4
Not working	8	12.7

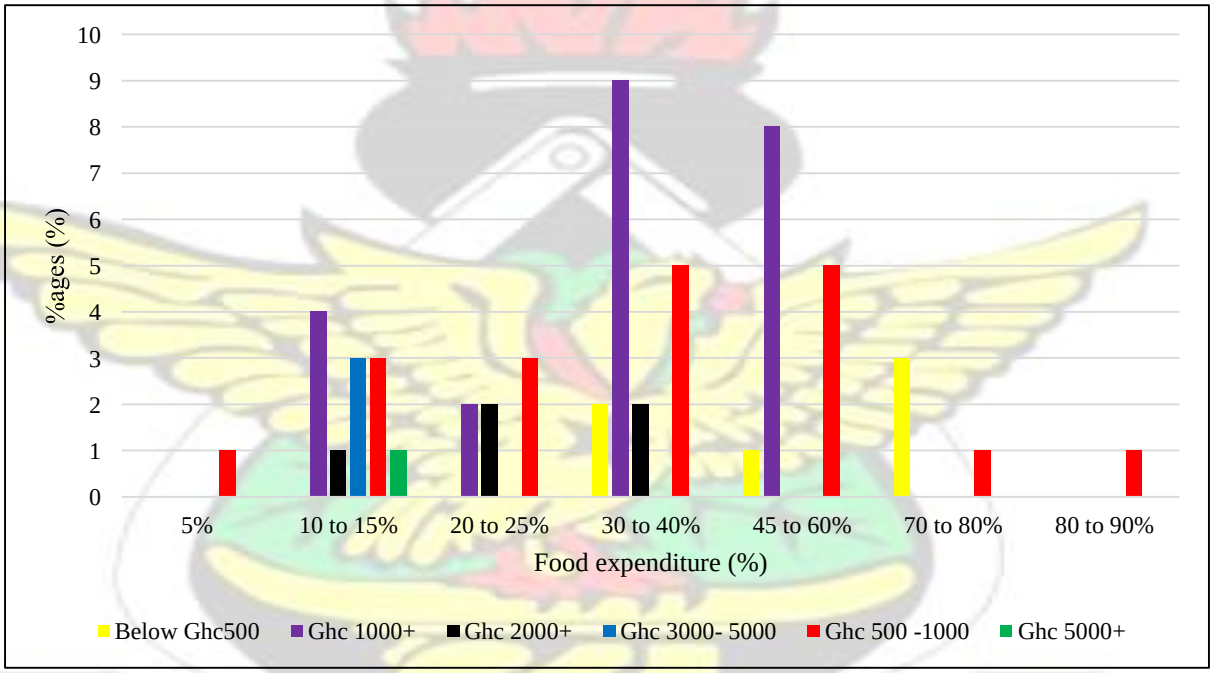

Figure 4.18 Food expenditure and income levels of inhabitants in Adenta municipality In effect, the urban economy of the Adenta municipality has been polarized, with an average income of Ghc1200. Additionally, the economic access to food has become a great concern to both the formal and informal income groups. For instance, over 50 % of the population spend close to 40 % of their net income on food. This situation is worsened in the case of low income earners. For example, from Fig. 4.18, it noticed that residents with low income spend a high %age of their income on food. Whilst some spend 70 %, others spend 80 and close to 90 % of their residual income on food alone. This implies an alarming rate of food insecurities that exist within such a so-called middle class city. Furthermore, this questions the food security identity

of the country, that is, we are not fully "secured" as far as economic food access in the Adenta municipality is concerned.

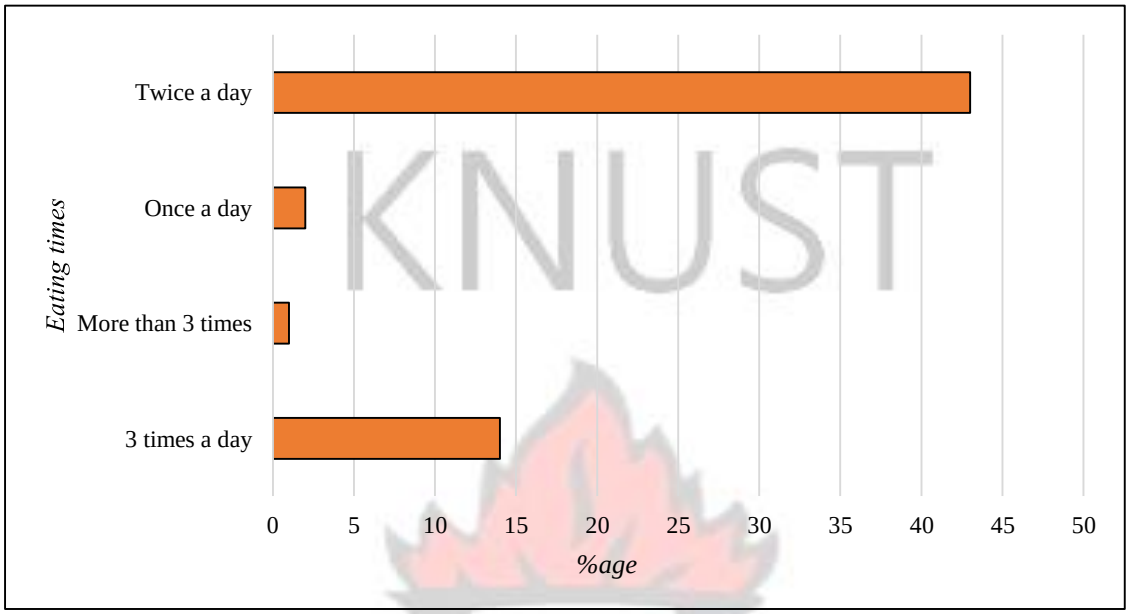

Figure 4.19 Eating times for people in Adenta municipality

Another revealing story was the eating times that of the urban dwellers. According to the definition for food security, one must be able to afford food in their required nutritional proportion at all times. The situation is somewhat different in the municipality, almost 50 % indicated that they only eat twice a day, whilst only close to 15 % eat three times a day. It was recorded that some even eat once a day. This implies that despite the income levels and social status of the urban residents, food insecurity is evident. In fact, it must be recognized that this indicates traces of urban marginalization, inequality and poverty. This is because, the major reason for their eating times was due to high costs of food for the majority and the high rental values on the part of others. Represented also in fig. 4.19 indicates the notable areas that this urban phenomenon occurred.

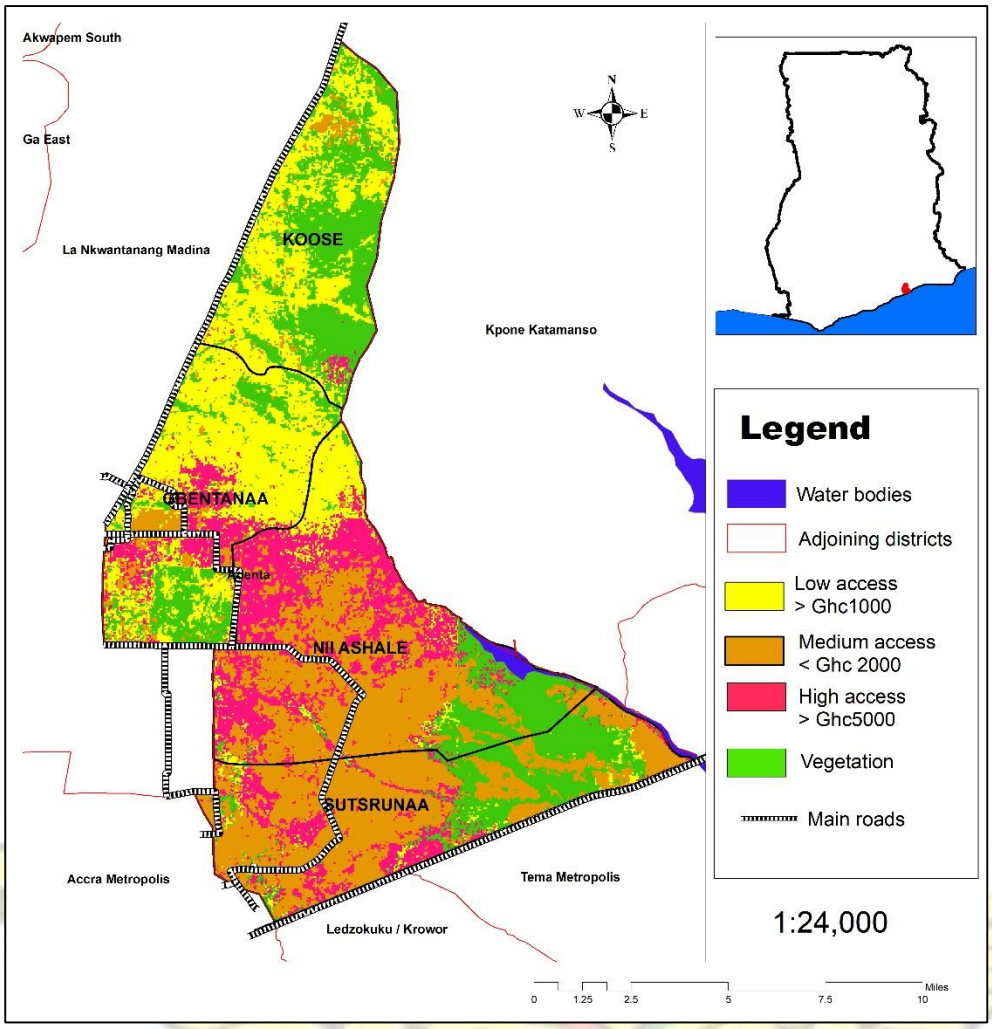

Figure 4.20 Economic access to food shown in zones

The nature of urban change complexities breeds sensitive areas of vulnerability and insecurity traces that emerges in the urban food spectrum. Discovered by Darfour and Rosentrater, (2016) about 2 million people are prone to food insecurities and are normally urban vulnerable groups, this suggests an unanticipated natural or human-induced shocks that can greatly affect the chain of food consumption in the district. From the Fig. 4.20, it can be observed that although traces of low access cuts across the municipality, urban residents in Koose and Gbentanaa records severe vulnerabilities with low access to food. This is largely due to the rate of urbanization, since many of these occupants were farmers and depended on their farms for survival. Unfortunately, all these areas keeps experiencing conversions from its agricultural areas into commercial and residential areas.

Food is arguably available in the country (MOFA, 2016), but it is not accessible to all sections of the population, especially the vulnerable (FOA, 2015). In Ghana, 1.2 million people suffer acute food insecurity and a further 2.07 million are vulnerable to poor diets in the country

(WFP, 2009). Incidentally, food insecurities are traced within rural and urban areas that are lowly measured due to inadequate household food supplies. Subsequently, informal areas which are characterized with significantly less food production for home consumption, heavily depend on food imports and others. Notably, (73.3%) of the employed urban inhabitants in Greater Accra fall within the informal sector of employment. Arguably, it is expensive to afford food at all times with the right nutrients by these urbanites since most resort to street foods or already processed food. According to the food prices as at February, 2019 for instance, a bag of maize was sold at Ghc 146.26 in Accra with 2.49% increment whilst it was sold at Ghc 115 in Bawku. Likewise, a bag of local rice gained 1.24% increment from Ghc 326.71 to Ghc 400 in Accra whilst it was recorded at Ghc274 at Tamale (Fugar, 2019).

4.3.2 Food systems (Social access)

Figure 4.21 indicates the social dimension of food access in the municipality. With an increasing growth in the informal sector, the economic groups of the urban food system confirms that despite the variations of income, over 50% of net income is spent on food (Fig. 4.18). Tentatively, it could be concluded that despite the presence of food, its access and utilization is somewhat delusional. In fact, it is observed that the poor and marginalized who represent the low income groups rather stand higher risks of food insecurity. Unfortunately, this segment of the urban class is dominated by women.

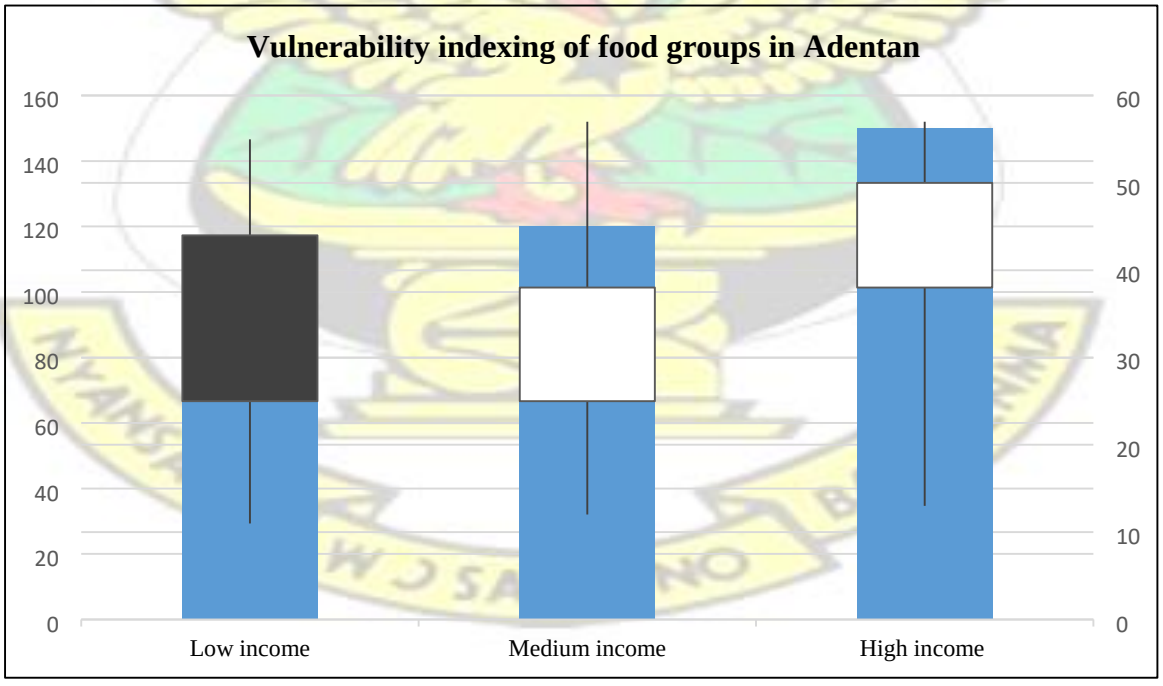

Figure 4.21: Vulnerability indexing of food groups in Adentan municipality

Source: Adenta Municipality medium term report, 2017

Economic speaking, the women of Adentan Municipality progressively dominates the informal sector (MLGRDE, 2013). Most household heads in the Adentan Municipality are women particularly as a result of the high rate of single parenthood. Besides, these women are forced to raise their children single-handedly. Hence, they constitute a majority of household leaders who ensure food security at home levels. This leaves a heavy burden of urban survival on the women and children despite all the developments to make their lives better in the municipality (GOG, 2015). Additionally, most resort to informal job opportunities particularly in the food sector, an area that seems to be of great priority to the survival index of the Adenta Municipality and Ghana.

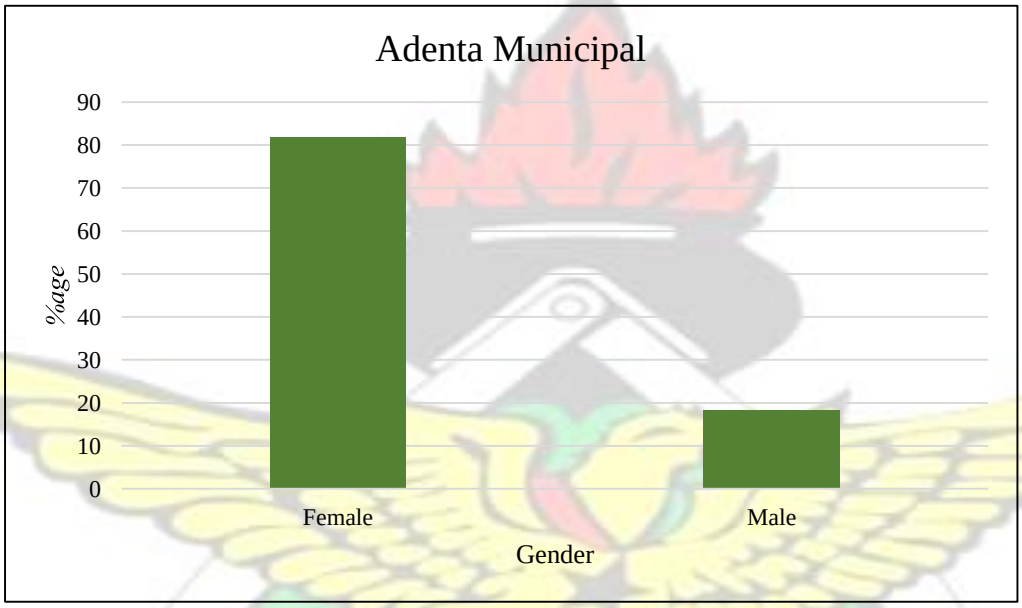

Figure 4.22: Gender distribution of informal income groups in Adentan municipality Source: Adenta Municipality medium term report, 2016

According to the Adenta medium term report, (2016), the agriculture sector employs a lot of women in the municipality with 80 % involved in food production. Nonetheless, with the recent urban changes (i.e the farming land conversion to residential areas) the food vulnerability situation in the district has escalated. Thus the women who used to farm on these lands for commercial purposes have resorted to subsistence farming, induced labour and other means of survival so that they can earn a living. Likewise, these women lack the necessary support such as access to and control over land which remains one of the fundamental sources of power defining women's status, identity and opportunity in many communities in Adenta municipality.

4.4 Evaluating indicators with multi criteria analysis

The multi-dimensional approach to monitor and model urban change complexities and food dynamics is addressed using the multi-criteria analysis method. Based on the indicators mentioned above.The multi-criteria analysis positions the urban space in a consistent way of viewing its multifaceted problems. In fact, it addresses the decision-making difficulty of combining spatial and non-spatial indicators, by decomposing the urban challenge into more organized pieces (indicators) to allow data and intuitions to be applied on these indicators. This follows a process using the Analytical Hierarchy Process (AHP) proposed by Saaty, (1977) to congregate these indicators in order to present a comprehensible and inclusive representation to decision makers. The purpose of multi-criteria decision making is to serve as a tool for guiding decision making, but not to take the decision.

4.4.1 Using Analytical Hierarchy Process for multi-criteria simulations

The maps for the known indicators were derived from their various measurements, and was connected to the findings of the AHP, based on the relative importance of every indicator that was evaluated. Sarath et al, (2018) categorizes AHP into three stages: I) Disintegration – where the urban situation are identified and structured into indicators II) Relative judgment – this done through pair wise comparison III) Aggregating the priorities - Calculate suitability index. Structuring of the indicators is fairly a subjective activity and somewhat relies on decision maker's expertise and experience. The indicators were therefore considered based on the importance of the field data acquired (Explained above)

Table 4.5 presents the pair-wise conditions developed in AHP for each adopted standard. Eigenvalues were used to designate the relative importance weight of each indicator according to the parameters of Saaty (1980).

Table 4.5 A pair-wise comparison matrix for calculation of criteria weights and ranking of indicators.

Pairwise comparison - Criteria Comparison Matrix ©							
	LULC	growth	density	economic access	physical access	social access	Total
LULC (Built)	1.000	3.000	5.000	0.110	0.140	3.000	12.250
growth	3.000	1.000	0.330	0.140	0.330	3.000	7.800
density	5.000	3.000	1.000	0.200	0.200	3.000	12.400
economic access	9.000	7.000	5.000	1.000	3.000	5.000	30.000
physical access	7.000	3.000	5.000	0.330	1.000	7.000	23.330
social access	0.330	0.330	0.330	0.140	0.110	1.000	2.240
Sum columns	25.330	17.330	16.660	1.920	4.780	22.000	

Table 4.6 Variable description based on Saaty's AHP

Variables	Description
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance
2,4,6,8	Intermediate values between adjacent scale values

After the pairwise comparison was done, the standardized weights from all the indicators were then normalized in order to adjust their weights in a relative common scale. This allowed for the Indicator weights to be acquired.

Table 4.7 Normalized results of indicators

Normalized (C) Matrix						
	urban land use	**growth**	**density**	**economic access**	**physical access**	**social access**
LULC (Built)	0.039	0.023	0.017	0.057	0.029	0.136
growth	0.118	0.068	0.028	0.073	0.069	0.136
density	0.197	0.205	0.084	0.104	0.042	0.136
economic access	0.355	0.477	0.422	0.521	0.628	0.227
physical access	0.276	0.205	0.422	0.172	0.209	0.318
social access	0.013	0.023	0.028	0.073	0.023	0.045
Sum	1.000	1.000	1.000	1.000	1.000	1.000

4.4.2 Performing Sensitivity Analysis on urban indicators

Sensitivity analysis is a technique adopted for assessing how the spatial multi-criteria model outcomes is sensitive to small changes in the input values (Sarath et al, 2018). This approach helped to check the consistency of the indicator values to show the effects of introduced findings in the input values on the output (indicator outcomes).

The two most important essentials to consider in sensitivity analysis are criterion weights and attribute values (Satty, 1980; Ghamgosar et al, 2011). Out of these, sensitivity to indicator weights was possibly ranked. For example assessment grade was connoted in 5 levels = {the most strongly sensitive, strongly sensitive, sensitive, low-sensitive, not sensitive}. Then for each single factor, establish the thematic layers that reflect the different attribute

	Criteria Weights (W)	Consistency measure
LULC (Built)	0.050	0.866370552
Urban growth	0.082	0.85447467
Urban density	0.128	0.772997949
Economic food access	0.438	1.174275049
Physical food access	0.267	0.849487371
Social food access	0.034	1.340029637
	1.000	0.976

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Satty, 1980

Stress Index	Description
0.019-0.049	Less stress (not sensitive)
0.05 – 0.19	Stressed (Sensitive)
0.19 – 0.29	Strongly stressed (sensitive)
0.3 – 0.39	Very strongly stressed (sensitive)
0.4 – 0.49	Most stressed (sensitive)

Where n = the number of indicators or criteria paired, RI = Random consistency Index

Additionally, the consistency values were computed.

Consistency Index (CI) = 0.97627, Random Index (RI) = 1.24 therefore

Therefore the Consistency ratio C.R = C.I/ R.I, = 0.787

Where RI is the random consistency index obtained from a randomly generated pair wise comparison matrix Table 2 shows the value of the RI from matrices of order 1 to 10 as suggested by Satty. If CR 0.1 <, then the comparisons are acceptable. If, however, CR 0.1 ≥, then the values of the ratio are indicative of inconsistent judgments

4.4.3 Performing Stress Index Analysis with indicators

After the indicators were operationally analyzed with the multi-criteria approach, decision making outcomes were derived based on the weighted sensitivity results (Table .

Indicators	Urban Food Stress Index (UFSI)
LULC (Built)	0.050
Urban growth	0.082
Urban density	0.128
Economic food access	0.438
Physical food access	0.267
Social food access	0.034
	1.000

4.5 Predicting urban change and food system dynamics

A regression formula was adopted for the predictions of scenarios for the frame model.

P (Y) = f (0.047x + 0.1325)

A prediction was therefore made based on the indicators and consistency index derived from the multi-criteria analysis. Figure 4.23 shows the pattern of change for the municipality as at from 1991 to 2025.

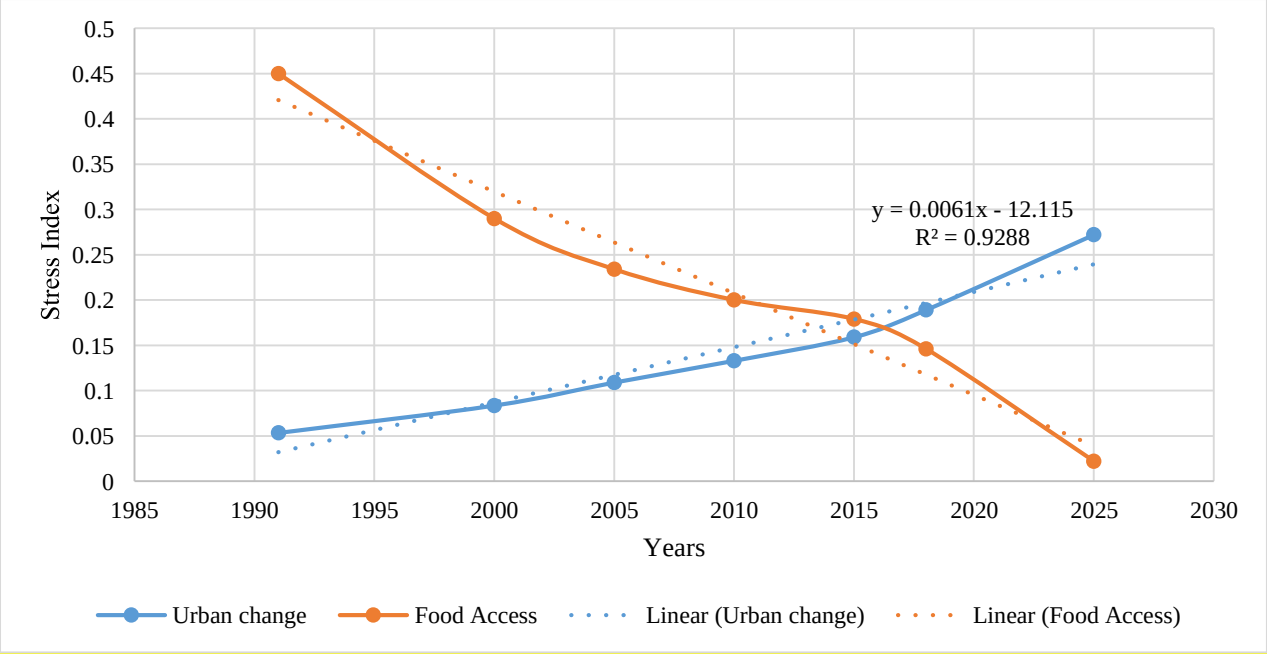

Figure 4.23 Urban change and Food access from 1991 to 2019

The figure 4.23 confirms that whereas urban change is alarmingly rising, the capacities to access food within the urban space reduces. This reflects the theory of food insecurities within the municipality where inhabitants are gradually experiencing a constant decline in socioeconomic access to food. In fact, with further, discussion made earlier urban complexity needs to be considered on a multi-dimensional scale to help critically diagnose its issues. For instance, the same approach was applied to the various zonal areas of the municipality for effective evaluation. From figure 4.24, it is realized that the urban stream is dynamically affecting certain areas of the municipality more than others. Whereas residents in Nii Ashale faces less food stress, Sutsurunaa, Gbentanaa and Koose are faced with high risks of food insecurities particularly as a result of the food expenditure component of the indices. Food expenditure within the municipality is rapidly increasing as a result of the growing urban change and annual decline of crop production.

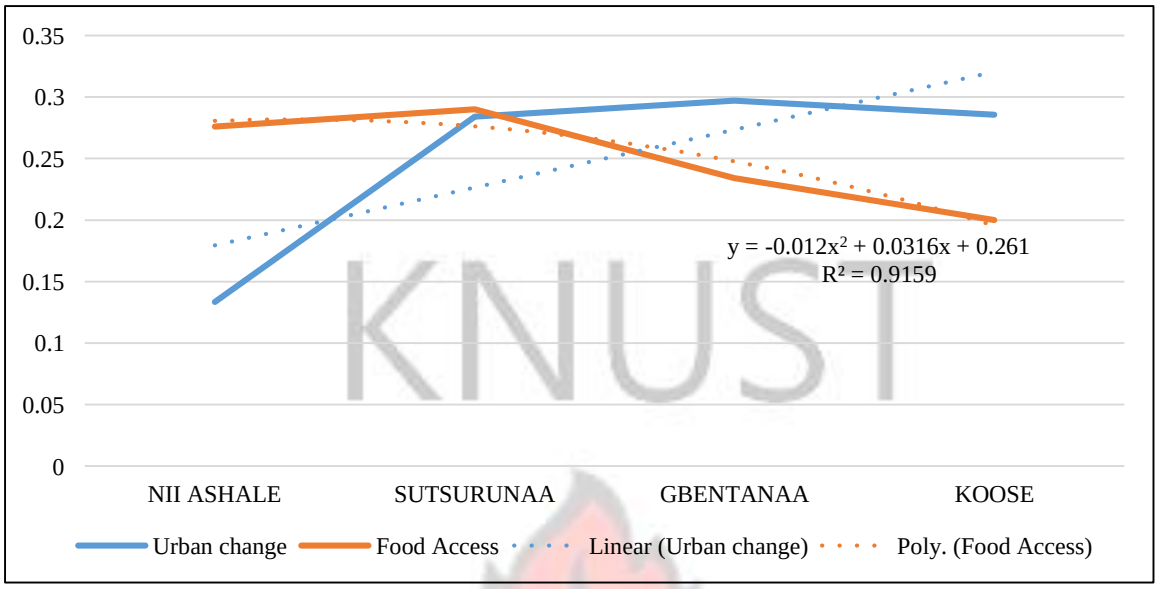

Figure 4.24 Urban change and Food access of Adenta municipality as 2019

For instance, Figure 4.25 identifies a shocking revelation of drastic reduction of urban food supply (crop production) within the district. This is largely due to the inconsistent urban change monitoring and the massive land use changes occurring within the urban periphery especially.

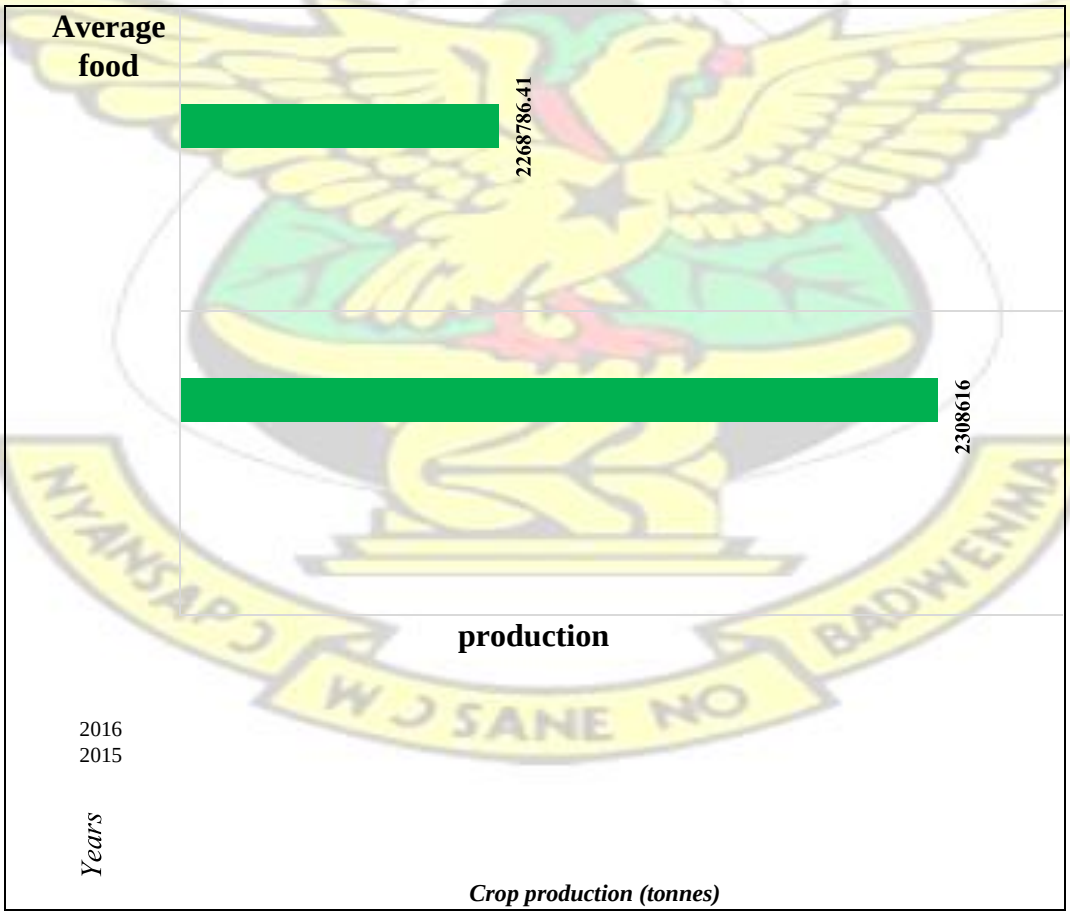

Figure 4.25: Food production in the Adentan municipality

Source: Adenta Municipality medium term report, 2017

According to the Adenta Municipal report, (2016) Agriculture production in the Municipality has largely reduced with farming done on subsistent basis shown in *figure 1 and 2*. Presently, the average land holding per farmer in Adentan is estimated at two (2) acres with most farmlands lost to construction of residential facilities due to significant urban changes from Accra. However, for the first time in decades, developing urban areas are taking steps in food policy initiatives (such as the PFFJ-indicated earlier) to re-focus food as an urban system where sustainability is tightly knotted with other urban sub-structural components—considering all aspects, such as economic, social and physical access to food (Ilieva, 2017).

Applauding the attempts of the Adenta Municipality to facilitate food accessibility in their locality, it is essential to note the unfortunate circumstance where the food subsystems within the context of rapid changes has been relegated and ill focused.

Furthermore, the Food and Agriculture Organization (FAO, 2017) in their urban food analysis for Ghana indicated high food stress index within the Greater Accra region and predictively within the Northern surroundings of the region which included the Adenta municipality.

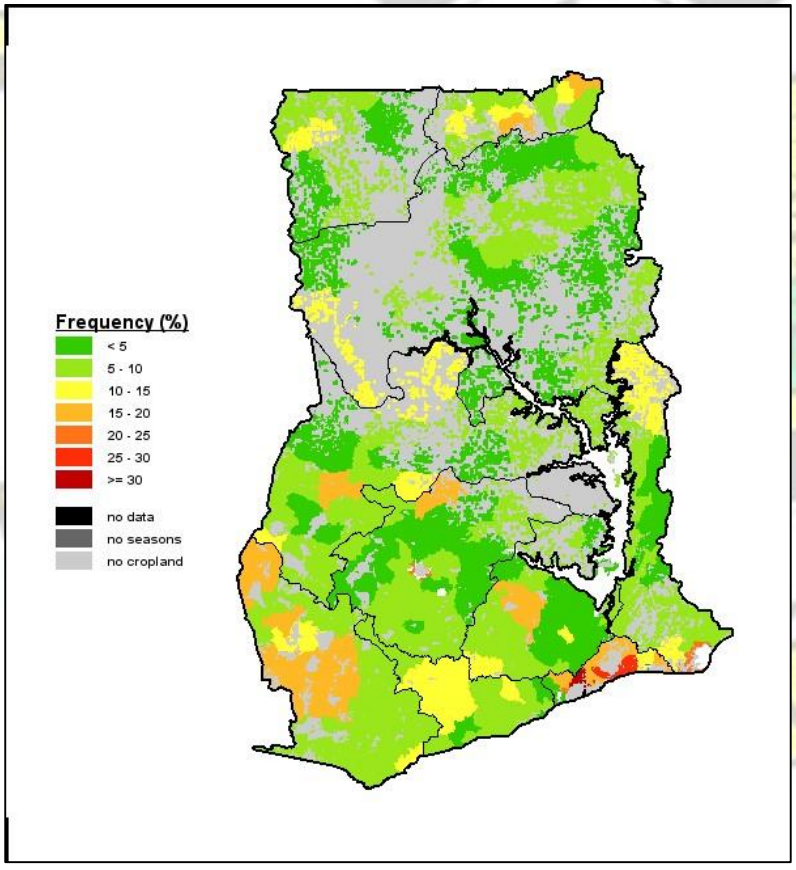

Figure 4.26 Agricultural Stress Index analysis for Ghana (1984 to 2017)
FAO-UN, Global Information and Early Warning System (GEWS), 2018

Subsequently, analysis made indicated a similar trend within the Adenta municipality. For instance, based on the prediction model identified, the urban food stress index (UFSI) was determined for the municipality. As indicated in Figure 4.26, it is discovered that the municipality despite its rigorous urban change, stand high risks of urban food insecurities.

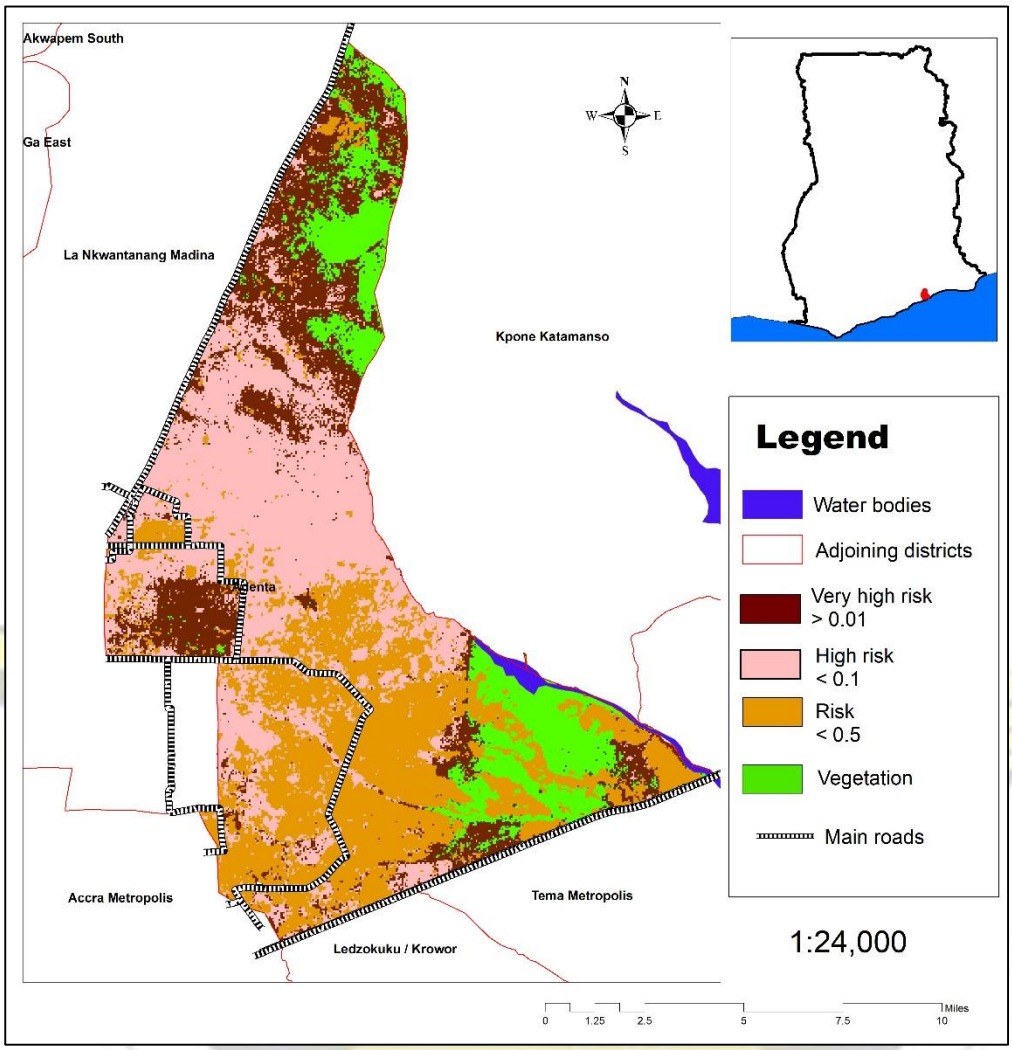

Figure 4.27 Food risk areas for Adenta municipality based on indicator Stress Index (SI) for 2019.

The risk of food is directly associated with forms of vulnerability and at some point poverty. The Adenta municipality was known to be a medium income level district upon its creation. However, the change pattern of its urban domain has embraced various levels of income groups and therefore reflects different forms of food risks, vulnerability and inequality. In fact, the rate of urbanization is rapidly altering our so-called food secured state and if the steps of multidiagnostics and criteria based decision-making is not embraced in addition with the right technology of GIS, the country could be in food crisis in the coming years.

Therefore, it is necessary for steps to be taken to rein enforce the Agricultural and food subsector for pragmatic decisions to be made now and in future.

CHAPTER FIVE FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 The sub urban nature of the Adenta Municipality

The speed of population growth on the fringes of Accra has resulted in an equivalent surge in demand for land to reside, infrastructure and commercial centres to trade, as well as food to satisfy-causing a profound swelling of the sub-urban populace. This has successively influenced the urban change pattern of Ghana's capital, which is overwhelmingly moving towards previously peri-urban districts (such as Adenta), that surrounds the Accra city. In effect, the express changes and condensations has altered the physical and socio-economic features of these sub-urban communities (Yankson, et al, 2004; (Oduro et al, 2015). A key component of this change is the urban food dynamics that follows up. For instance, before the recent re-demarcation of districts, the official boundaries of Accra covered only 300 sq. km, or 7.4% of Greater Accra Region's total land area with the rest possessing agricultural dominance (Twum-Baah, 2000). However, due to the limited capacity to contain the rapidly growing urban population and economic activities, Accra's massive spill over into peri-urban settlements has reduced drastically their vegetative presence and affected farmlands.

This change unfortunately has been limited to certain indicators only (especially Land use land cover changes) neglecting the other urban indicators that equally affect the change and complex pattern of urban spaces. Therefore, these indicators revealed a profound hint of the level and character of the municipality. The urban growth rates implied a sporadic trend of population in-flux and socio-economic advancement of the areas within the municipality. Again, the land use and cover changes showed the extent of sprawl and vegetative destruction of the municipality. Additionally, the urban density pointed out the level of concentration with respect to the people and activities per unit area. These indicators could serve as strategic benchmarks for the municipal assembly to adequately track the rates and levels of urban change to facilitate decision making.

5.1.2 Food system dynamics in the Adentan sub-city

Food is increasingly an urban issue in urban and sub-urban areas (Dubbeling, et al, 2015) for that matter the concept of urban food systems is gaining considerable popularity among local, and inter-regional levels. The food system of the growing sub city are prone to a range of socioeconomic and agro-climatic shocks and this could aggravate if food systems measurements are trivially recognized.

Subsequently, the interaction between urban changes and globalization with their joint effect on urban food systems is vital to better comprehend urban food security. For instance, cities like Adenta in the Greater Accra region will always be dependent on cross food systems; that is, they will continue to outsource food, from further locations and global food chains as well as from nearby rural, peri urban and urban producers. Although its urban residents are entitled to various food options, (such as

processed foods, street foods, fresh foods, imports, etc.) its over dependence on global food supply and systems, has increased vulnerabilities and risk with a rippling effect on local economies. The narrative surrounding its constituents contributes to the dynamic nature of food systems in the municipality and has of late affected the social and economic landscape (as indicated in Fig. 4.20 and 2.1 above). For example, compared to rural food systems in Ghana, sub-urban food systems are have more stress index in the urban communities than the rural. Particularly within the economic and social dimensions, many urban groups within the country are at risk when it comes to food.

For instance, 50 % of the urban groups were willing to give up their organic foods to go for genetically modified (GM) foods during interviews. Although 50 % were not willing, over 20 % were willing to patronize genetically modified foods, whilst almost 30 % greatly considered it. Many attributed this condition to their economic standings.

"I feed 7 children every day, we sometimes eat once a day, because we cannot afford all food ingredients"

Street hawker and Single mother, Adenta Commandos

This alarming finding indicates the likelihood on the rush for GM foods over organic foods due to economic limitations

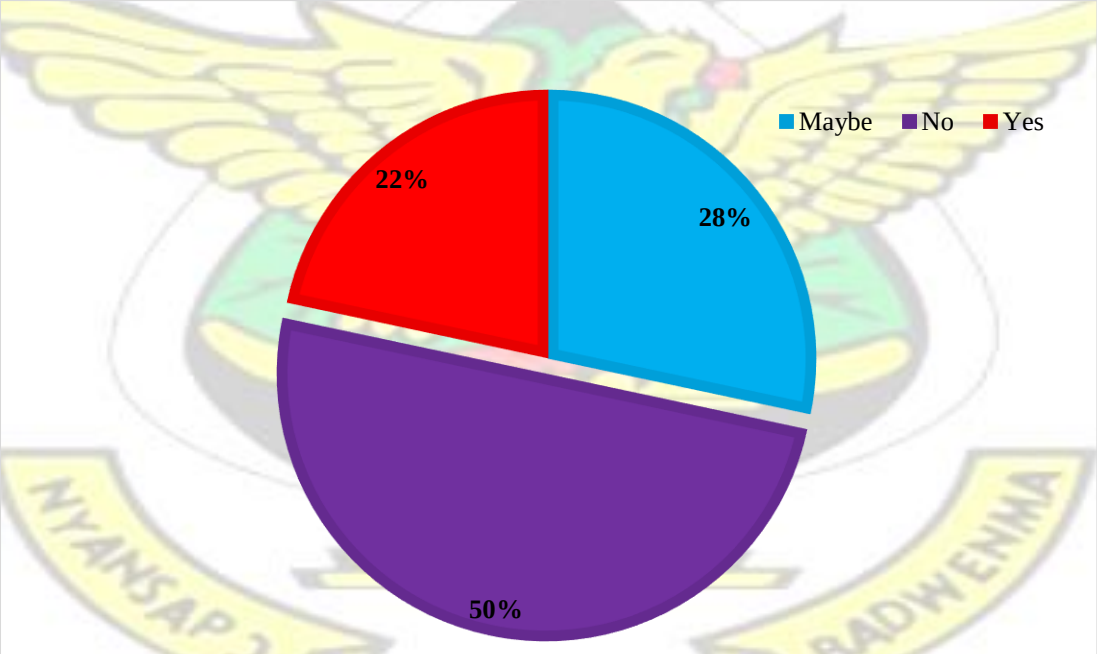

Figure 5.1 Preference for Genetically modified foods.

5.1.3 The relevance of GIS based- Multi-criteria analysis

Many local authorities require information ahead of time in order to take preemptive and adaptive strategies for human settlement development, particularly in urban communities where trends are

complex (Shoko and Smit, 2013). The rapid development and integration of spatial technologies such as Geographic Information Systems (GIS), the Global Positioning System (GPS), remote sensing the advent of geospatial technologies and satellite data operation, experts and governments are shifting their perspective to the wide range of utilizing their potentials for effective spatial management (Crush et al., 2011). GIS is a modern day innovation that allows professionals to acquire, store, manipulate, analyze, manage, and present spatial or geographic data in various ways that are applicable for better spatial modelling. One of the key methodologies that has received less popularity in developing countries is the Multi-criteria Decision Analysis (MCDA) model approach.

The urban spectrum characterized with evolving change indicators and for that matter requires a modern and systematic system of measuring its changes (Bowyer, 2015). Consequently, the principal aim of MCDA is to help City authorities and urban policy makers to synthesize information and make wellinformed decision. Essentially, Pavan and Todeschini, (2009) describes the MCDA as a prospective tool that integrates spatial measurable dimensions with subjective non-spatial variables to describe urban change complexity patterns. Whereas Youssef et al. (2016) recommends, Chandio et al, (2012) confirms that the GIS-based multi-criterion analysis approach is the best way of assessing land suitability of urban development in different environments.

Indeed, the MCDA allows for flexibility and innovation within the urban framework to effectively predict the implication of change patterns for present and future decision making. It is worth noting that urban management decisions does not only demand the selection of best alternatives but also considers prioritization of algorithms using MCDAs to facilitate resource allocations, identify areas of interest for immediate interventions, control haphazard growth among others. The Analytical Hierarchy process (AHP) system broke the complex issues of cities into its smaller components (indicators) and instituted a way of weighing and ranking the indicators using available alternatives to arrive at a scientific conclusion. Identifying the array of indicators was however a central task. Accordingly, the urban disparities were grouped showed the multi-disciplines of the urban challenge. The explicit indicators clearly defined were listed as “multi-attributes” whereas those that are implicitly defined were mathematically programmed known as multi-objective optimization theory (Pavan and Todeschini, 2009). In essence, the approach attempted to represent the fix and loose ends of the urban space phenomenon based on individual criterion (Department for Communities and Local Government, 2009). The use of multi-criteria decision making and Geographic Information systems (GIS) enabled this study to diagnose the complexity of urban changes and food system dynamics.

5.2 Conclusion

Ghanaian urban districts need to embrace the package of tools and methodologies in numerical modelling and simulation capacities to study cities and municipalities as complex, socioecological system that has an evolving character.

Although changes in the complex system of urban communities reflects challenging ways of monitoring for its spatial units (especially due to its multiplicity), GIS-based urban growth modeling can provide measurable and visualized methods for determining spatial and nonspatial information. It provides the leveraging tool of importing indicators for systematic monitoring and predictions of cities.

This study identified the plurality of urban complexities and food systems in urban districts.

It followed on the impact of urban changes on food demand and accessibility in the urban regions of Ghana where agriculture or food access could be a luxury. It concluded on the importance of modeling food Security assessment using GIS techniques since they promise a relatively faster and convenient approach. Again, it marked the need towards effective and rational predictions through GIS modeling which is highly scalable guaranteeing its potential for integration of other related datasets e.g. from emerging satellite images. Consequently, this approach connected all urban indicative phenomena such as population, housing, income among others to make a significant contribution towards the literature of urban development and food systems. The study further assessed the food stress performance of Adenta municipality based on verifiable indicators which were categorized under economic, physical, and social dimensions. The data analyzed revealed the high and low stress extents and indicators of the city. The urban change of Adenta characterized by high population growth, destruction of vegetative and agricultural lands with the city's development. Exploring these urban pointers were systematically seamlessly allowed for ranking and prioritization of the urban components that needed more attention. Whilst urban growth, density and land use land cover changes were factor that impact on urban food insecurity, the economic access indicator had highest weights. This shows that despite development in the municipality, there exist food access constraints per their economic status.

5.3 Recommendation

For a sustainable and secured urban food system, city authorities needs to channel its fastgrowing economy to a greener growth development paths by addressing the city's major challenges cohesively. The study recommends economic initiatives to be well considered; this should include employment opportunities for the youth and women especially, localizing the

Planting for food and jobs (PFFJ) policy within municipalities. This will facilitate socioeconomic innovations to bridge the inequality gap within the municipality. The provision of consistent spatial and non-spatial data is essentially required to help monitor the development of urban outcomes in the municipality. Since urban change has an inverse relationship with food access, more options must explored to supplement the net food supply within the municipality to promote economic sustainability of Adenta. Urban change monitoring should be improved through constant observations with the appropriate technology. The adoption of geospatial inputs and GIS methods will help address the consistency of acquiring and effectively analyzing data. Researchers and policy makers should embrace this new and innovative approach of applying multi-criteria analysis with GIS technology to solve urban problems. This can ensure a more definitive, practical universal and effective system of decision making for local, regional and cross-national governance.

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