A DYNAMIC MODEL FOR PREDICTION OF FOOD INSECURITY

by

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1 INTRODUCTION

1.1 Introduction

The world population experiencing food insecurity ranges from 0.76 to 1 billion people [7] [27] [30] [77]. This is approximately a seventh of the world population. In the report released by Food and Agricultural Organization (FAO) [30], 843 million people were categorized as victims of chronic hunger. It was further established that approximately 805 million people were undernourished. Food insecurity is therefore a formidable challenge affecting the world.

Several factors are said to exacerbate this challenge. According to FAO [26], expanding populations and growth in biofuel practices are exerting high demands on the available food systems. Soil exhaustion, climate changes and environment degradation are on the other hand negatively affecting agricultural yields thus further fueling food insecurity challenge. Poverty has also been cited as yet another catalysit for this challenge: low income populations face financial constrains in acquiring sufficient food for dietary intake [60]. Factors such as these are making it difficulty to realise the first Millennium Development Goal (MDG1) of reducing the victims of hunger world wide [26].

The importance of predicting or monitoring food insecurity has been highlighted by various studies [16] [54]. If this disaster is forecasted early, stakeholders can take necessary steps to prevent it or control its impact. This has proved successful in some parts of the world. For instance, according to the United States Department of Agriculture (USDA), reliable monitoring of food insecurity contributes to the effective operation of Federal programs, food assistance programs, and other government initiatives aimed at reducing food insecurity [71].

Machine Learning (ML) is gaining momentum in the arena of modeling food dynamics. It is an emerging discipline in computational science whose application is also useful in other areas such as disease detection/diagnosis, web search, spam detection, credit scoring, fraud detection, stock trading and drug design [23] [67]. In relation to food security, machine learning techniques are well suited for prediction of risks like famine since they can enhance classification accuracy [54].

The Role of Machine Learning in predicting food insecurity has been exemplified. Contributions to knowledge gaps in areas such as performance improvement, teasing predictions using various data sets, fine tuning parameter selection and exploring the application of Machine Learning have been instrumental in fostering the science of predicting food insecurity. These studies have however given little attention if any on re-usability of machine learning models. In this study we aim at developing a Dynamic Model (DM) to predict food insecurity. The model will use other existing models as a technique to enhance prediction in an environment of limited data sets.

1.2 Background to Study

It is a difficult endeavor to trace the origins of food insecurity. Human beings have lived with this challenge for many generations. This is unappealing. Several sources of information can testify early manifestations of this challenge in humanity. Oral traditional, scholarly work, religious books and story books are examples of these sources. Research carried out by [48] attempts to document incidences of food insecurity that occurred longtime ago. This research reveals that about 43 million people in Europe perished in famines that took place in the years between 1343 and 1345. This must have been a big population given the population status of that period. It is further revealed that between 16 and 64 million people in China perished for the same cause in the period from 1959 to 1961 [48].

The modern society has not completed conquered food insecurity, despite the technological advancements. It is among the seven world concerns in addition to insecurities linked to economy, health, environment, personal life, community and politics UNDP(1994). It has remained a challenge for the last 25 years [14] and unfortunately the signs of spear heading it are still blunt. This is no suprise that researchers such as Rosegrand are speculating that food insecurity will remain a challenge for the next 50 years [64]. The need for combined efforts to circumvent this unfortunate trend is evident.

Human rights community has re-labeled food insecurity as a human right concern [20]. This attracted a legal dimension on food security. More attention would accorded to it. The food crisis of the mid-1970s consequently led to world leaders accepting for the first time the common responsibility of the international community to abolish hunger and malnutrition [20]. This move has nevertheless not been a final solution. According to Clover [20] the right to food is one of those rights most frequently violated in recent times and hence targets set by the World Food Summit in 1996 for the reduction of hunger have largely failed.

What is food insecurity? It is difficult to comprehend this term without seeking the understanding of food security. While there are many definitions of food security, this study adopts a definition proposed by the Food and Agricultural Organization [28] which states that Food Security is a, "situation that exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life". The four dimensions of food security are: availability, accessibility, utilization, and stability [14], [60]. Food access is the ability to either grow or purchase or borrow enough food to maintain a healthy body weight [14]. Availability of adequate food supplies refers to the capacity of an agro-ecological system to meet overall demand for food (including animal products, livelihoods and how producers respond to markets), while utilization of food refers to people's ability to absorb nutrients and is closely linked to health and nutrition factors [25]. According to ASEAN Member States [5], stability means that a population, household or individual must have access to adequate food at all times and they should not risk losing access to food as a consequence of sudden shocks (e.g. an economic or climatic crisis) or cyclical events (e.g. seasonal food insecurity). Now food insecurity is any phenomena that deviates from this ideal situation of food security describe above.

The world populations experiencing food insecurity ranges from 0.76 to 1 billion people [7] [27] [30] [78]. In the recent report released by Food and Agricultural Organization[30] , 843 million people were categorized as victims of chronic hunger. It was established in the same report that approximately 805 million people are undernourished. Of the 840 million people undernourished between 1998-2000, 11 million are in the industrialized countries, 30 million in countries in transition, and 799 million in the developing world [20]. This, therefore, shows that developing countries are bearing the greatest food insecurity burden. Overcoming this challenge as evidenced by these statistics will require special attention or emphasis on the developing world. Intergovernmental Panel on Climate Change [37] has noted Sub-Saharan Africa as likely to surpass Asia as the most food-insecure region and, this is largely independent of climate change but a result of the projected socio-economic developments for the different developing regions. Africa is tending to stand out boldly in the developing world. There are other studies that support this observation. For instance, it has been said that out of the 39 countries worldwide that faced food emergencies at the beginning of 2003, 25 are found in Africa [20]. As the world struggle to spear head the challenge of food insecurity, Africa needs special attention.

Climate changes, social-economic factors, bio-energy practices and rapid population growth are playing a big role in exacerbating the challenge of food insecurity. According to Rosegrant and Cline [64], the strongest impact of climate change on the economic output of agriculture is expected for sub-Saharan Africa, which means that the poorest and already most food-insecure region is also expected to suffer the largest contraction of agricultural incomes. The share of agriculture on total GDP in many developing countries has rapidly declined over the last decades and it is worth noting that in the high-income Organization for Economic Cooperation and Development (OECD) countries today, the share of agriculture on GDP is <2% [64]. However, it is unlikely that this trend is not negatively affecting the food production in Africa.

In addition to socio-economic pressures considered within the IPCC SRES scenarios, food production may increasingly compete with bio-energy in the coming decades; studies addressing possible consequences for world food supply have only started to surface [65]. Food crops that are used for bio-energy production compete (for resources such as land, labor, water and fertilizer) directly with food supplies [25].This researcher predicts that as world commodity markets become more integrated, bio-energy production in one country will have important effects on food security in other countries as changes in food prices on international markets affect domestic markets. He further speculates that artificial price mechanisms may create short and medium term market distortions which may have an upward effect on land and food prices, thereby fuelling concerns about future food supplies as in the case of the 2007 ”tortilla war” in Mexico. The world’s growing population is throwing more complexities to the challenge of food security. According to Poppy *et al*[60], an expanding global population acts in concert to make global food security even more complex and demanding. The world will need to increase food production by 70% in order to catch up with population growth as we get close to year 2050. Food demand has always been driven by population increase, income growth and changing diets [25]. According to USAID [73] (cited in [14]), rapid population growth is one of the many factors that drive food insecurity among households and individuals in the developing world.

1.2.1 Prediction of food insecurity

In an attempt to transmute this food challenge , research on prediction of food insecurity can play a vital role. It is through continuous monitoring of famine indicators that allows for an early preparedness, management procedures and recovery plans to be put in place to avoid famine or manage it [54]. Similarly [16] emphasizes that determining the vulnerability of a population to food insecurity is of interest not only to prevent suffering among the local population due to food shortages, but also, through early intervention, to limit the expense of ameliorating that shortfall. Food security in developing countries could be substantially improved by increased investment and policy reforms [64]. Without reliable information these policy reforms may fail to address pertinent issues. Research on food insecurity, is an attempt to provide an input to these recommended policy reforms. On the other hand, it has been noted that lately, crop yield has decreased in many areas because of declining investments in research apart from infrastructure concerns [64].

Malthus an early scholar investigated the phenomenon of food insecurity. He was a church clergy, economist and a politician. He is known for the Malthusian catastrophe. He predicted that population growth would exceed its capacity to produce adequate food and this is termed as population growth outstripping the food supply [45]. This was based on his assumption that population, when unchecked, increases in a geometrical ratio while on the contrary, the means used to produce food increase in an arithmetical ratio [44]. This incidence would result into rigorous outbreaks of famine and deficiency of other basic needs. It is this anarchy that is termed as Malthusian catastrophe. His model was based on the assumption that technology grew linearly and population increased exponentially. Empirical evidence has proved that technology growth did not remain growing linearly; it shifted for the better. As a result for more than two hundred years the world has been able to survive the Malthusian catastrophe.

Currently Machine Learning (ML) is one of the Computational approaches used in modeling food dynamics. It is an emerging discipline from computational science whose application is not only limited to food modeling but also to other applications such as disease detection/diagnosis, Web search, and spam detection [23]. In relation to food security, ML techniques are well suited for prediction of risks like famine since they can enhance classification accuracy[54].

There are other methods for prediction of food security that exist. For example, to extend short range famine forecasts with those that go out several months, Famine Early Warning System Network (FEWS NET) partners have developed models that use canonical correlation analysis to relate variations in sea surface temperature with rainfall in Africa [14]. Global forecasts from the International Research Institute (IRI) at Columbia University also routinely keep trying to understand future variations in climate through Forecast Interpretation Tool (FIT) that translates forecasts expressed in probabilities into the actual rainfall amounts they represent [14]. Examining and monitoring rainfall can give insights into expected yield outcomes. Other approaches are based on statistical methods (such as linear regression, nonlinear regression, and moving averages) that analyze yield time series [43]. Makowski and Michel emphasize that statistical analysis play a key role in current research studies on food security where yield time series analysis is used to estimate past yield trends and to predict future yield trends. Poor yields forecasted can be a sign of pending food insecurity. Linear regression techniques offer simple methods to estimate yields and it is best for yields that grow at a fairly constant rate. For yields which vary nonlinearly, quadratic and exponential growth methods can provide better approximations [43]. For more complex yield patterns, higher order linear methods are employed. In some cases additional techniques can be integrated in these models to address the complexity of yield patterns.

ML is not entirely a new field; it borrows a number of concepts from some methods described above especially Mathematics and Statistics. It offers a unique approach compared to traditional programming techniques where a computer scientist needs to understand the underlying pattern between variables/datasets. Then the algorithm is built based on the preconceived relationship. With machine learning, focus is on developing algorithms capable of learning and/or adapting their structure such parameters based on a set of observed data; with adaptation done by optimizing over an objective or cost function [67]. ML provides techniques capable of extracting information automatically by computational and statistical methods [54]. It is instrumental in development of sophisticated, automatic, and objective algorithms for analyzing high-dimensional data [67]. Consequently with ML, the developed algorithm can offer better prediction (also called generalization) as it relies heavily on dataset drawn from the problem situation. This study attempts to develop a Dynamic Machine Learning Model (DM) as a means of embracing re-usability.

1.2.2 Challenges/Gaps identified

In the process of reviewing literature, it has been observed that food security prediction is a challenging endeavor. Despite the fact that ML seems to provide a more promising approach to food prediction, still there are some challenges that seek out contribution from the research community. The following challenges/gaps were identified:

1. Monitoring the diversity of agricultural systems can be difficult, as field sizes and

the confounding aspects of native vegetation are a continuing problem [14]. In same research two key proposed elements of a successful early warning system are that the forecasts of the human consequences of an event are accurate in predicting its location, time and severity, and that these warnings are disseminated in time for populations at risk to do something about it.

2. Parameter determination for modeling. This comes with two challenges; (1) Conversion of non-numerical variables like politics into their equivalent numerical data. (2) There is need to reduce famine parameters and this can minimize the undesired complexity in developing the model. According to Chung *et al.* 450 are listed as potential variables for prediction of food security. A key issue in many applications is to determine which of the available input features should be used in modeling via feature selection and because this it could improve the classification accuracy and scale down the required classification time [80] (cited in [39]) . According to Kotsiantis [39], presence of irrelevant features can make neural network training very inefficient, even impractical.

3. The research has shown the increased need for improved Machine Learning approaches. Decision trees, neural networks and Support Vector Machines (SVMs) face high-variance challenge resulting into over fitting, a source of poor generalization. As such [81] recommended blending various approaches of MLs in response to this need (cited in [66]). While many methods of ensemble (also called blending options) have been proposed, there is no clear picture of which method is best [75] (cited in [39]). In relation to this need some studies are taking the direction of extending the existingindividual Machine Learning Algorithms (MLAs). Attempts towards this direction are not always successful moreover no single learning algorithm can uniformly outperform other algorithms over all datasets [39].

4. The researcher observed that the unreliability of data sets is also a challenge. In modeling real life situation, data used in training machine learning approach is susceptible to errors. Sometimes the datasets are incomplete. In ML and in other modeling

disciplines, therefore, it is challenging to develop reliable a model with this kind of datasets.

1.3 Problem Statement

Predicting food insecurity is instrumental in guiding stakeholders where to direct early intervention reliefs. In the process, the impact of food insecurity can consequently be controlled or eliminated [54]. In addition, this controls the expense associated in the amelioration [16]. The science of predicting food insecurity has yielded positive results in some parts of the world. For instance, reliable monitoring of food insecurity contributes to the effective operation of Federal programs, food assistance programs, and other government initiatives aimed at reducing food insecurity [71].

Unfortunately, prediction models face challenges such as high time complexity, poor accuracy and limited re-usability. The birth of Machine Learning (ML) was a big leap in addressing these challenges. It offers benefits of high level adaptability as the developed models are capable of learning directly from the data sets. Investigations such as [54] have demonstrated positive results with prediction of food insecurity using Machine Learning. The existing challenges have not been completely addressed, the room for improvement is still open. The concept of blending two or more models as advocated by researchers such as Zadeh [81] (cited by Rudas and Fodor [66]) has been brought forth as a reinforcement. Researchers (such as Okori and Obua [56]; Pai and Lin [57]; Wang and Meng [76]) have demonstrated success with this paradigm. In this study, blending is further promoted but inclined towards developing a dynamic model to re-use existing models as an enhancement strategy. Multi-task learning relates closely to this study. In multi-task learning, the developed model gains from the learning experience of other related models [82] but in a static manner. In this study, dynamism is explored. The notion of a dynamic solution is not new. It is manifested in computing paradigms such as dynamic programming, evolutionary computing, and genetic programming. Dynamic solutions exhibit attributes of high adaptability and improved optimization of resource utilization. This study will explore how these dynamic concepts can be cleverly and dynamically used to foster improved models for predicting food insecurity.

1.4 General objective

To design a dynamic model that integrates existing models for improved prediction of food insecurity.

1.5 Specific Objectives

The specific objectives include:

1. To investigate techniques that will be used in the model selection and integration of existing models in relation to prediction of food insecurity.

2. To design a Dynamic Model that is capable of intelligently selecting suitable models to be used in prediction of food insecurity.

3. To test and validate the proposed model as means of demonstrating the mechanism and viability of this model.

1.6 Research Questions

1. What are the requirements relevant in developing a dynamic model that integrates existing models?

2. How can a dynamic model based on existing models be designed for improved prediction of food insecurity?

3. How can a dynamic model be tested and validated inorder demonstrate its mechanism and viability?

1.7 Conceptual Framework

The goal of this study is to design a dynamic model for prediction of food insecurity with attributes of improved performance and re-usability. The study is envisaged as a four stage process (conceptualization, designing, implementation and validation). Each stage (shown in rectangles) is linked to the specific objectives. Circles represent concepts or theories that will be used to achieve various objectives. Arrows drawn from circles to rectangles signifies the concepts or theories that contribute to the achievement of that target stage. At conceptualization stage, relevant theories and literature will consulted to provide detailed understanding the best option to reach the design stage. Literature on food dynamics, concepts on machine learning, and state of practice will cultivate ground for conceptualization. The design stage is the core of the study. This stage seeks to design a dynamic model that integrates are other models as a technique to enhance prediction food insecurity. Theories and literature such as dynamic programming, optimization techniques and state of practice in this area will provide insights to aid in developing the desired dynamic model. At implementation, using appropriate tools the dynamic model will be deployed in a laboratory test environment. At evaluation, we shall measure the model performance to establish its viability. If the model performance is unsatisfactory, previous stages will be re-examination (as indicated by the double arrow) for improved re-adjustment.

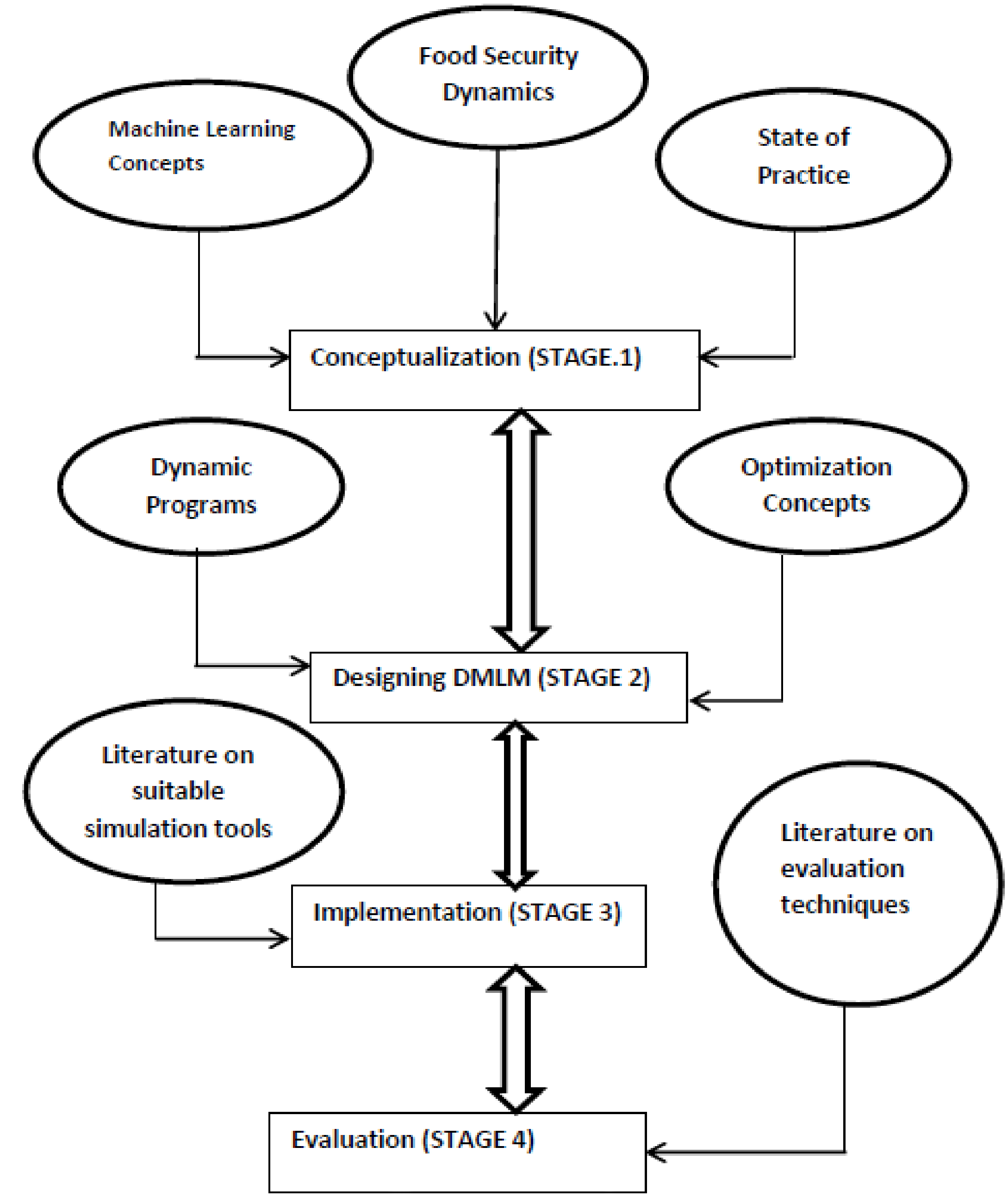

Figure 1: Proposed conceptual framework for the study

1.8 Significance of study

The significance envisaged in this study is as follows:

1. The existing methods for predicting food insecurity face limitations such as low accuracy of prediction model, demand high computation resources, and require high costs to collect prediction records (such household information). Therefore need to address these knowledge gaps is evident. This study aims at designing a noble model to address limitations such as these. The model will integrate existing models with attributes of re-usability and improved performance.

2. The proposed model will be grounded on existing theories/concepts/practices. This will call for extension/modification of these theories/concepts. A new or modified thought line is expected as result and this will potentially impact the direction of future related work.

3. The findings of the study are expected to reveal new insights concerning the relationship between the different variables that cause food insecurity and this can be used by policy makers improve the process of mitigating food insecurity.

1.9 Justification

Food insecurity is a global challenge affecting millions of people especially those from least developed regions such as sub-Saharan African countries who suffer conditions of extreme poverty. Humanity has experienced loss of lives both in past and in recent years due to extreme conditions of food insecurity such as famine and starvation. Food insecurity is responsible for malnourishment in children. This leads has led to distorted growth in infants both mentally and physically. Malnutrition also compromises the body's defense system leading to high prevalence of diseases. Food insecurity is known to cause social disruptions. Therefore big picture of all these side effects of food insecurity is the retarded of societal development. This is intolerable if we are to maintain the objective of promoting of human welfare.

The 1st MDG goal seeks to address the challenge of food insecurity. It aims of reducing number of people suffering from both hunger and extreme poverty. Unfortunately challenge of food insecurity is still persistent. For the last twenty five years, it has remained a big challenge to both local and international governments [14]. The future is not completely free from it. According to Rosegrant *et al* [65] food insecurity is expected to span to the next 50 years. Therefore any innovation that could help to mitigate this challenge is important. This research seeks to contribute to this gap by developing a Dynamic Model to enhance performance and re-usability in the prediction of food insecurity.

1.10 Scope of the study

Food insecurity can manifest at a household level, a village level, a district level, a province level, a state level and many other levels. This study aims at investigating food insecurity at national level. The focus is on pattern extraction of food insecurity in various regions of state. In the context of this study, we are using Uganda as an example of a Nation at in the developing world. The target regions include; northern, north East, central, western and southern regions. To achieve the main objective of proposing DM for prediction of food security, other areas of focus have been identified: (1) Exploring both relevant theories and practices of Machine Learning in relation to prediction of food insecurity; (2) requirement enlisting; (3) Designing DM for food insecurity prediction; (5) laboratory testing of DM; and (4) evaluation of DM. Data will be obtained from databanks as opposed to using questionnaires and interviews. Possible sources include FEWS linked satellite data, National Bureau of Statistics and FEWSNET. Data from these sources include; remote sensed data, house hold information, price trends, audio data and price trends.

1.11 Anticipated contribution

Developing a DM for improved prediction food insecurity based on existing theoretical and empirical frameworks will require a systematic and creative endeavor. Consequently the following contributions are anticipated:

1. Food security dynamics: This study requires establishment of key players in relationship to food security. This involves studying concepts/theories governing food security dynamics. Key players can vary from study to study as food dynamics are not always the same. In some cases the players may remain the same but the inter-linkages may vary. Food security framework for the study will formed as the preliminary stages. This is a one of the study contribution. The developed framework will generate interesting insights for better understanding of both food insecurity and food security dynamics.

2. Parameter selection: It has been argued that parameter selections should be done with great care. Poor choice of parameter can influence the quality of the model. Some studies suggest a change of parameters as an attempt to improve model performance. The study is anticipated to make contribution in highlighting possible prediction parameters which work or don't work and why.

3. -Developing DM: Previous related studies have given little attention on re-usability of existing Models in relation to prediction of food insecurity. This study will contribute to this gap by designing a dynamic model to integrate existing models. This is useful where there is limited dataset for the areas under study. This also promotes software engineering principles which advocate for scalability and re-usability of software solutions as this method builds on existing models.

2 LITERATURE REVIEW

2.1 Theoretical Framework

There is an increasing demand for improved methods to predict future trends. For trends, such market and demographic changes can promote prosperity and provide competitive advantages. Leaders, managers and business people that have accurate forecasts of such trends hold competitive advantage for individual or organization Success. Other category of trends can be life threatening like drought, floods and disease outbreaks. If these disasters are predicted effectively, stakeholders can transmute their negative effects partially or completely. Prediction of food insecurity can help to avoid disasters like famine and at the same time it can provide a competitive advantage to farmers and dealers in crop products to explore ways of maximize resulting profits. Effective prediction of food insecurity requires conceptualization of theories and literature on food security dynamics. This can be gained from studies carried by researchers such as: [14] [16] [48] [55]. Studies such as these will provide basic concepts on food dynamics, the players/determinants of food security. Situations that dictate and demonstrate how food security manifests in relations to variables are contrasted in these studies. The investigations also demonstrate how these situations could be used to predict food security. All this literature and other related investigations will play a vital role in the contextualizing the case study and also guide in the selection of prediction parameters this study.

Several approaches have been proposed for modelling of food security. Research attempts to develop a Model for prediction of food insecurity. Other methods that have been proposed for similar purpose are in fields such statistics, artificial intelligence, data mining and computing. Most of them employ mathematical concepts. According to Mitchell [49], Machine learning draws on concepts from many fields, including statistics, artificial intelligence, philosophy, information theory, biology, cognitive science, computational complexity, and control theory. In the last decade the use of machine learning has spread rapidly throughout computer science and beyond [23]. Established Machine Learning concepts include but not limited to: supervised verses unsupervised, parametric verses non parametric techniques, linear verses nonlinear algorithms. Existing theoretical and practical are demonstrated by various researchers (such as [17] [23] [39] [49] [54]). This will offer foundation concepts in Machine Learning and will also generate useful concepts relevant in development of Dynamic Model as stipulated.

Any study aimed at predicting food security using Machine Learning requires some narrowing. This is ensures that the study is accomplished within the constrained time frame. Even if abundant time was available, scoping is an avoidable. For example Machine learning models appropriate for some phenomenon is not necessarily applicable to some other situation. The need for a narrowed study is evident. The processing of identifying the best Machine Learning approach is envisaged as hypothesis research. According to Mitchell [49], the learner's task is thus to search through this vast space to locate the hypothesis that is most consistent with the available training examples. This is done in the presence of a training data set. During the process searching there is a state for fitting weights by iteratively tuning the weights, adding a correction to each weight [49]. Literature to guide on the available practices for fitting weights is available and will also be used.

ML is a multistage approach and for various authors these stages may vary slights and therefore it is important that phases in this study are identified. Through reviewing literature and more especially the current practice and state of art, gaps can be identified. This study cannot focus on all the gaps identified. There is need to set boundaries on which gaps the study will address in the process of proposing an enhanced approach for food insecurity prediction. Significant contributions are expected along this line.

Developing a Dynamic Model for prediction of food insecurity is main object of this study. Methodological approaches on designing dynamic algorithms have proposed by previous studies on re-usability of models. Some approaches advocate for blending as possible alternative. Others have concentrated on extending some of the existing generic approaches. Existing previous literature such will provide guidance in relation to this main objective.

Evaluation performance will be the final stage in this study. The developed Dynamic Machine Learning Model (DM) will be subjected to critical evaluation. Depending upon its performance its viability will be determined. If performance is unsatisfactory investigations on tuning it will follow after. Literature (for example [33] [39]) on performance evaluation will consulted to guide this phase.

2.2 Classification of famine prediction parameters

Investigations have played a key role in identifying necessary players in an attempt to predict food insecurity with some certainty. There is a strong similarity on these players as suggested by various researchers. In investigations by [16] three key players are identified. These researchers maintains that through monitoring biophysical, economic and political, it is possible predict famine. For [12], famine is the outcome of an interaction between environmental and socioeconomic factors, both in the short and the long terms, and a failure of policy to deal with them. Failure policy in this context is connected to politics. According Bailey [6], the roots of famines lie in complex underlying social, political, economic and environmental factors, but drought usually provides the final push that tips populations over the edge. These payers/factors so far highlighted are too broad to be used for prediction of food security. In the following paragraphs, variables linked to these factors which are more appropriate for model development are examined.

The Biophysical factors focus on the environmental influences on food security and this provides a relevant metric during growing season that can provide insight into prediction of future food supply in the next harvest [16]. Examples of variables linked to biophysical factors include; Normalized Difference Vegetation Index (NDVI), Rain Fall Estimate (RFE) and Water Requirement Satisfaction Index (WRSI). In [14] the biophysical data also called current climatic situation has bigger data list and this includes; precipitation gauges and gridded data from merged satellite models, vegetation data from a variety of sensors, gridded cloudiness products, global climate indicators, precipitation forecasts, modeled soil moisture, gridded fire products, snow extent products, hydrological, models for flood forecasting, and seasonal forecasts. According to this study, these data products were either developed directly by FEWS NET partners for FEWS NET or were adapted to their needs.

According to Okori and Obua [55], social-economic factors are inclined towards supply and demand as seen in many economic goods. In [14] a list of variables for socioeconomic factors is given which include; Agricultural production, Market Prices, Food economy zones, Employment, population, School Attendance, Infrastructure Maps. With socioeconomic data according to Mellor [47], Famine is predicted by successive years of poor crops, a rapid rise in food prices, a decline in the prices of goods that the poor sell (particularly including the livestock of pastoralists), and a decline in employment. By analyzing people's access to food and income as well as their options for coping with adverse events and processes, the livelihoods approach enables FEWS NET to make informed judgments about the resulting likely type and magnitude of the effect on food security of these hazards [11], [46] (cited in [14]). In the small, isolated, and informal markets that are typical of the region, food prices are intimately linked with local food production [16]. Hazard monitoring uses this baseline profile to determine the normal situation from which the impact of both socio-economic and biophysical anomalies can be measured.

Food security dependencies linked or resulting from politics have been also explored by studies. According to United Nations Development Programme (UNDP), technical and political failures such as lack of information to guide farmers in planning their agricultural activities and misguided policies also contribute to famine as cited by [55]. With effective institutions and adequate physical supplies, the occurrence of famine increasingly signals not the lack of food or capacity, but some fundamental political or governance failure [70]. According to Mellor [47], a democratic form of government plays a key role in famine prevention.

2.3 Food Security Frameworks

Food security frameworks provide ways of estimating the amount of food available in a region and the degree of access the population has to that food [14]. In the same study it has been noted that early warning organizations use a particular set of conceptual frameworks to transform all kinds of information, from biophysical information derived from remote sensing to market prices, into actionable food security policy recommendations. The cereal balance approach food security framework by [14] is summarized here. It involves calculating the gross amount of food available in a country through a per capita calculation. National food deficits are considered as food aid needs of the region. Remote sensing of environmental conditions is at the center of this analysis, enabling continental-scale monitoring, where images of vegetation anomalies are transformed into crude percent cereal production deficit across vast areas of a continent. The challenge is that this does not address the differential ability of households to acquire food through the market, or the complexity of stores, stocks and flows of food from one region to another. Secondly, not only excess food aid delivered, but the people who need the aid can fail to receive it because the tools needed to identify and target the neediest were lacking.

A more sophisticated framework than this has been proposed. It incorporates both food access and food availability features and it has been in used by FEWS NET for a period of ten years [14]. As describe by the same study, this frameworks is characterized by vulnerability analysis which allows identification of populations who are likely to face disruptions in their ability to produce or acquire food and who are likely to lack the resources to absorb such shocks. Below is the diagrammatic representation of this framework. There are four dimensions of food security but this study ignores the remaining two dimensions which are stability and utilization.

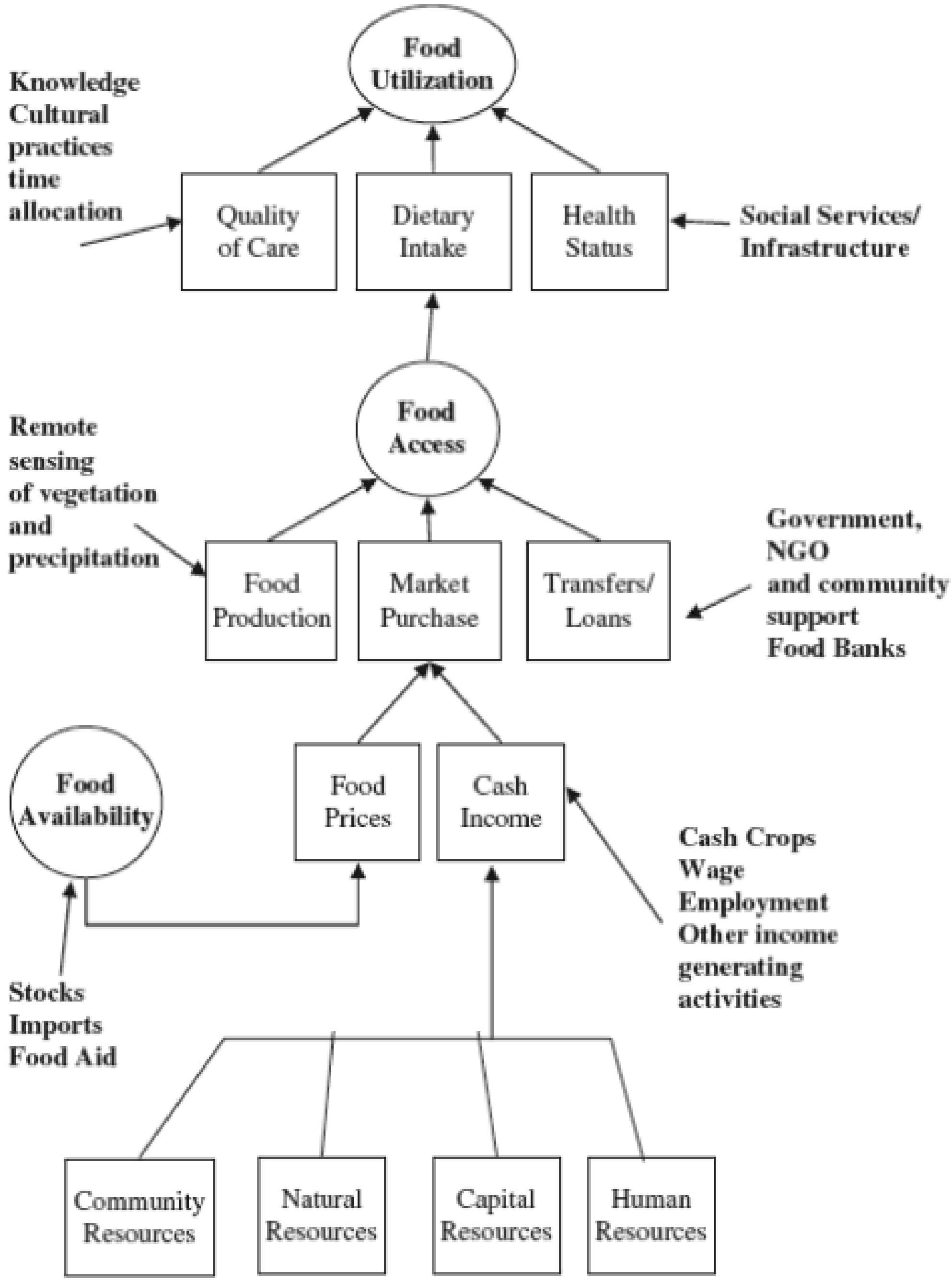

Figure 2: Conceptual diagram showing aspects of food security and monitoring; derived from [73] (cited in [14])

2.4 Machine Learning Process

Process of applying supervised learning ML involves several steps as proposed by [39]

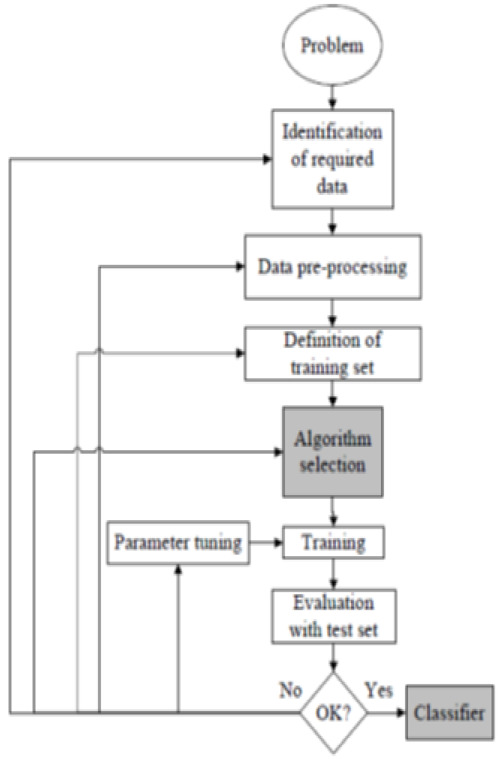

Figure 3: Machine Learning steps as illustrated by [39]

The diagram above illustrates a step by step process for Machine Learning approach. The problem is identified first like need to forecast drought using historical data. Identifying features is the next step. A lot of care is needed at this stage. Poor selection of features leads to poor prediction performance. Kotsiantis [39] also proposes the possibility of using expert guidance in determining the features as an alternative. In the study carried by [52] to identify features, he used his personal experience and literature review to guide his study. The same technique can be applied in other studies.

Pre-processing stage: In the previous stage all possible features where identified. Not all the identified features will automatically be used in the study. Some features could have significant relevance while others could be erroneous and this can impact negative on the performance. At this stage selecting the most appropriate features may be needed. This helps in removal of unnecessary features which would negatively affect the accuracy and performance of the prediction model. On the other hand if there are too few features, performance will be negatively impacted. According to Kotsiantis [39], after using brute force to determine all the possible features, removal inappropriate features can be applied.

Selection of the algorithm: This is a challenging stage. First several classifiers have been proposed and for this stage there need to determine which algorithm (s) will trained with selected data sets. Conditions dictate the choice of algorithms to be applied. If several algorithms are trained on the same dataset, a criterion for determining the best algorithm needs to be established. The commonest approach is to select an algorithm with the lowest training error. Normally 2/3 thirds are used for training the algorithm and the other 1/3 is for estimating the performance of the error of the training algorithm [39]. Cross validation is another technique normally used. The data set is divided into several mutually independent subsets. The classier is the trained on the union of these sets. Performance is the average error on the union of these sub dataset. Some literatures advocate a technique known as leave-one-out which is a special case of cross-validation. In this method the dataset is likewise divided into several mutually exclusive dataset. The classifier is trai ned on n-1 subsets but each time one is retained for estimating the performance. This is repeated with all the possible permutations. Now the training error becomes the average error computed on these permutations.

A situation may arise when error rate evaluation is unsatisfactory. As a result the performance of the classifier is not reliable with its predictions. Fixing this will require revisiting previous stages as shown in the diagram. On the stage of identification of data, inappropriate features could have been used and revision on selection needs to be done. An option of collecting more data set is worthy trying. Too few datasets rarely result into good classifier. It has been found that prediction error decreases with increasing size of dataset. This continues until the error becomes almost constant as shown in the diagram below. After this limit more data would not help to improve the performance of the classifier. This is criteria to guide if more data would improve classifier performanceG

Another important issue to focus on is the dimensionality which can have a big effect

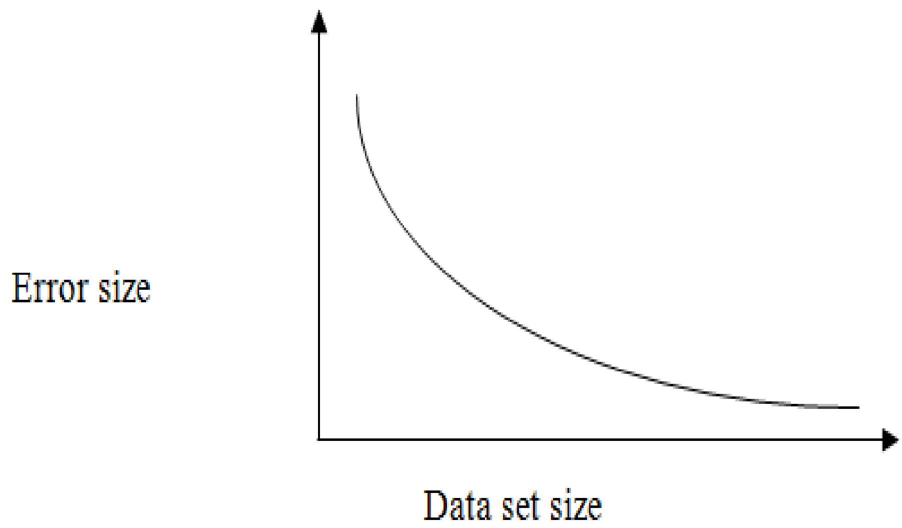

Figure 4: A graph showing how error size should vary with increasig [39]

on performance. More features demand more computational resources. Secondly, if some of these features are irrelevant and others have a lot of noise, both the accuracy and the performance of the outcome will be compromised. On the other hand if features are too few features, this can equally have side effect and the final algorithm will poorly generalize. [39] provides a technique for comparing the performance of two classifiers. The training data is split into N subsets. Each algorithm/classifier is trained separately on these data sets. The average mean of differences in error is measure of the expected difference in the error and their variance is the average of their difference of variance of the data set. This technique is suitable if there suitable large data sets. There is a need to check if the mean difference is zero between these two algorithms. Errors abounds can be Type I or type II. Type I is when the test rejects the null hypothesis incorrectly and Type II error is the probability that the null hypothesis is not rejected, when there actually is a difference [39].

2.5 Supervised versus Unsupervised Learning

Supervised deals with datasets that have both the input features and the output labels. According to Kotsiantis [39], supervised machine learning is the search for algorithms that reason from externally supplied instances to produce general hypotheses, which then make predictions about future instances. Consider a problem of predicting the cost of a plot of land. Sample data of the previous statistics for the purchase of plots can be obtained. The cost y of any plot of land could depend on area x_1 of the plot and its distance x_2 from the main road. Variables x_1 and x_2 are features and y is referred to as label. In many real life situations, features could go high in number like hundreds or even higher. For example as cited by [14] in prediction of famine, process indicators can be extremely complex and involves 450 determinants according Chung *et al.*[19]. In supervised learning, data set is feed into an algorithm to establish the relationship between features (x_1 and x_2) and the label y. The resulting algorithm is able to manipulate features (xs) in order to estimate/predict y label. The estimated function relating features (x's) and the labels (y's) is known as hypothesis h(x). Supervised learning is applied to number of scenarios and these include weather prediction, diagnosis and classification of diseases, model the growth and yield of Eucalyptus, famine prediction, drought prediction, mapping distribution of diseases like malaria ([17] [41] [43] [68]).

On contrast unsupervised learning offers a fairly unique approach. As the societies advance technologically, more data is increasingly being collected and such data is about records such sales, infection outbreaks, human migration patterns, criminology, and domestic bills. This kind of data can be unlabeled however this does not necessarily mean that nothing can be learnt from it. Interesting patterns can be deduced from such data. From online sales, purchase patterns can reveal a decreasing number of customers buying certain commodity or services. This observation can influence service providers to introduce changes to rectify this. It is the work of unsupervised learning algorithms to extract patterns from such data. These algorithms reveal interesting patterns without necessarily associating with an overall label type. Coming to food security; yields for various parts of a region can be available. From this data clusters of food security for given parts can be established. These kind algorithms offer a number of benefits. Their models are less susceptible to over fitting than purely discriminative ones. They behave like large multi-task learning problem in which the model simultaneously predicts many variables (as many as there are inputs), while discriminative learning involves predicting just one [53]. Nair [53] further observes that unsupervised learning puts more constraints on the model parameters, and support more parameters and richer representations without over fitting and this can provide extra training for discriminative models.

2.6 Linear versus Nonlinear regression algorithms

A linear regression algorithm is noncomplex and it establishes relationship between features (say x_1, x_2, x_3, x_n) and the associated label y. This takes form of y=θ_0 + $\theta_1 x_1$ + $\theta_2 x_2$ + $\theta_3 x_3$+ ... +$\theta_n x_n$. It is called a linear regression meaning real valued. θs stand for the parameters or coefficients to be learned by the algorithm. This means the solution is expected to result into continuous range of values ie y $\in$ of R. For some algorithms, the output can be discrete values. If the label y depends on a single feature ie y=θ_0 + $\theta_1 x_1$, we say the hypothesis h(x) is in two dimensions and it can be represented linearly in two dimensions by Cartesian graph. The hypothesis y=θ_0 + $\theta_1 x_1$ + $\theta_2 x_2$ is three dimension and graphically can be plotted into a three dimensional Cartesian graph. It is the job of the learning algorithm to determine/establish coefficients θ_0 ,θ_1,... θ_n. There are tendencies to believe that higher order algorithms (nonlinear) other than linear algorithm are better. A key question is whether proposed algorithm approximately well with data set and can generalize well beyond the training dataset. On contrary, problems that exhibit linear behavior are handy and more appealing. They are easy to understand and normally are less demanding in computation resources like memory and computation power. Because of this, low order algorithms a preferred. Unfortunately most problems in real life do not exhibit linear behavior. The few which manage to do so, it is normally through approximation. This means an approximate linear fit is established.

Nonlinear algorithms exhibit higher order behavior. Here the labels y relate with features x(s) when raised to n where n¿1. Some terms in the nonlinear algorithm can be product of features for example x_1x_2, x_2x_3. Actually there are number of possibilities which can add more complexities. Representing data set exhibiting nonlinear behavior results into or approximates to curve. It is the job of the learning algorithm to estimate/establish the best curve that describes the relationship between labels y and the features x and the corresponding coefficients θs. As noted in above section, most problems in nature exhibit nonlinear behavior. Unfortunately nonlinear algorithms are unfriendly as they are complex to comprehend and highly resource hungry. Techniques have been devised to deal with these complexities. One of the techniques is to approximate to the lower order algorithms which are capable of performing fairly well. Secondly is to make transformations on the data sets into another dimensional which could approximate the algorithm into linear mapping between the transformed data set and the labels. Attempts have been made to determine which transformation functions can aid in this kind of transformation and unfortunately this process is to try and error.

2.7 Booting Machine learning algorithm (Meta learning techniques)

It is sometimes necessary to improve performance of a machine learning algorithm. This is especially important if the obtained algorithm is performing poorly. [42] proposes two reasons for this poor performance: (1) the sample (training data) available for algorithmic training is very small; and (2) better results require excessive running times. A small size of data set does not give an algorithm adequate data set for an algorithm to extract meaningful patterns. If there are limited resources, the learning algorithm will fail to perform to the desired level required for meaningful pattern extraction. Two techniques that can help to improve the performance of an algorithm are described.

Bagging: Bagging is an ensemble technique used in breeding high performing machine learning algorithms. Ensemble allows aggregating more than one algorithm into one which is better than either of the constituent algorithms. Bagging is an acronym for bootstrap aggregating [13]. In bagging, several algorithms are created from the subset of the original dataset. The subsets are uniformly distributed and randomly selected. For some cases replicate subset can re-occur and this is allowed. The obtained hypotheses are now aggregated by either averaging for regression problem or voted for logistic problem. This procedure as describe by [42] is summarized below:

1. For s = 1, . . . ,b do:
2. construct a bootstrap sample Xs
3. train the base learner on the sample space Xs
4. Let the resulting hypothesis (concept) be hs(x): X !{-1,+1}.
5. Output as 'aggregated' classifier:
6. hA(x) = the majority vote of the hs(x) for s = 1. . .b.

Boosting Weak PAC Learners: This technique assumes that a weak algorithm obtained on the initial training on the data set is better than random guesses. With boosting, the same data is used to retrain more weak algorithms. For each re-train, a sub set of the training data set is used. Each subset, bigger weights are assigned to dataset on which the algorithm performed poorly. This means in the subsequent retrain, the algorithm focuses more on the dataset on which the previous algorithm performed poorly. This process continues until many weak algorithms are progressively obtained. Now these algorithms are submerged into one algorithm which is believed better than each of the weak algorithm

2.8 Concept of blending

No single learning algorithm can uniformly outperform other algorithms over all datasets [39]. This observation is independent how best an algorithm has been improved to address its limitations. With [39] Blending is now seen as a technique to achieve performance improved by integrating more than one algorithm. The objective is to utilize the strengths of one method to complement the weaknesses of another. According to Kotsiantis [39], Mechanisms that are used to build ensemble of classifiers include: i) using different subsets of training data with a single learning method, ii) using different training parameters with a single training method (e.g., using different initial weights for each neural network in an ensemble) and iii) using different learning methods. Increased storage required to accommodate the combined method is one of the challenges of combining more than learning methods. Secondly, there is an increased demand on computation resources because in order to classify an input query, all component classifiers (instead of a single classifier) must be processed and lastly decrease comprehensibility.

2.9 Machine Learning Algorithms

2.9.1 Neural Networks

Neural Networks provide a unique method to train Machine Learning. They mimic how a human brain operates. Through ages there has been considerable efforts to understand how the brain/nervous functions. Brain and the nervous system as a whole, is said to be a complex network of interconnected neurons. The human brain is estimated to contain a densely interconnected network of approximately 1011 neurons, each connected, on average, to l04 others [49]. Electrical signals trigger a section of interconnected neurons. The resulting response is forwarded to the brain for interpretation so that an appropriate action is taken. Through this process, the brain and the nervous system as a whole is capable of accomplishing very many tasks. Amazingly some tasks which look simple to humans like face recognition are complex for automation in Computers. Emulating the functioning the nervous, is an attempt automate task such as these that are difficult to program using traditional programming techniques.

In 1980 neural networks have gained prominence in the research community. Unfortunately in late 1990's the research community seem to have lost interest in neural networks. The major reason to explain this setback was due to high demand for computational resources by neural networks. Currently due to technological advancement, scarcity of computational resources is not a big problem. As a result neural networks are regaining prominence in the research community again. According to Khan *et al.*[38] Artificial Neural Networks certainly have the potential to distinguish unknown and hidden patterns in data. Neural networks are better suited for achieving human-like performance in the fields such as speech processing, image recognition, machine vision, robotic control [41]. Their use in investigations related to food security has been common. For example Okori and Obua [54] experimented on the use neural network to predict famine used household information as features.

Back-propagation is one of the techniques used in training artificial neural networks. According to Lee *et al* [41], back-propagation is necessary because the hidden units have no target values which can be used, so these units must be trained based on errors from the previous layers and as the errors are back-propagated through the nodes, the connection weights are continuously updated until the errors in the weights are adequately small to be accepted. Back-propagation is as follows [41].

1. Step 1: Feed the normalized input data sample, compute the corresponding output;
2. Step 2: Compute the error between the output(s) and the actual target(s);
3. Step 3: The connection weights and membership functions are adjusted;
4. Step 4: IF Error ¿ Tolerance THEN go to Step 1 ELSE
5. Step 5: Stop.

The architecture of an artificial neural network refers to how neurons are organized and they comprise three layers: an input layer where variables are introduced to the network, a hidden or intermediate layer where most of the signal processing occurs, and an output layer where the end result is completed and presented [17].Neural networks can be classified according to the layers in a given architecture. They can be single and multilayer neural networks. Below is an illustration of a single layer networks.

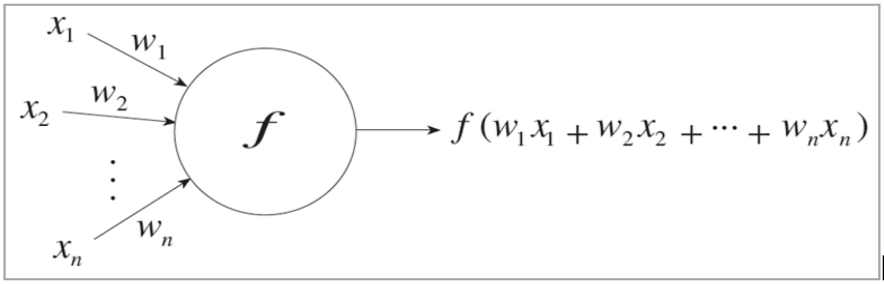

Figure 5: Single layer neural network as adapted from [63]

For a single layer, the output is function of the input variables (xs) each with a weight (w) to predict function h(x) is the form question 1. The output could be discrete value or a continuous. Discrete values are for classification problems while real values are reserved for regression problem.

y= w_0x_0 + w_1x_1 + w_2x_2 + ... + w_nx_n

Neural networks can be multilayer as illustrated in figure below. According to Rojas [63], multilayered networks are capable of computing a wider range of Boolean functions than networks with a single layer of computing units. [63] also notices that the computational effort needed for finding the correct combination of weights increases substantially when more parameters and more complicated topologies are considered.

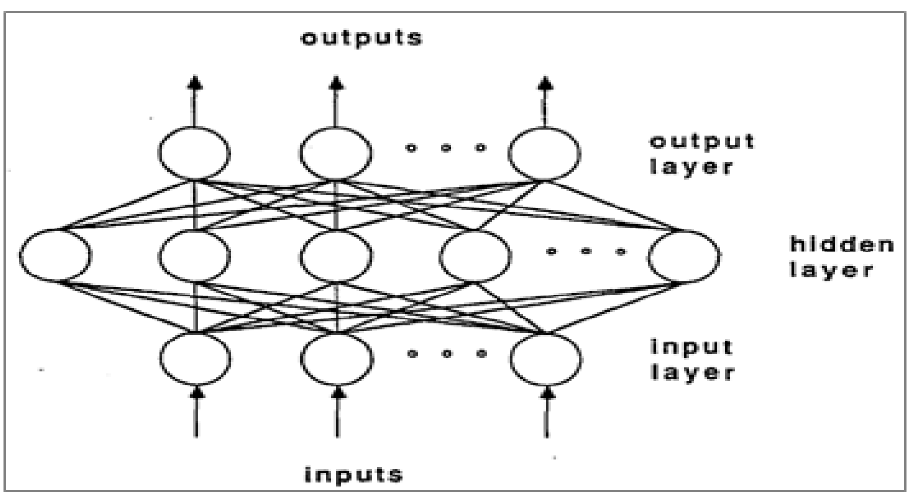

Figure 6: A sample for feed-forward multi-layer neural network [41]

In a feed-forward procedure, the data flow algorithm moves in only one, noncyclical direction, to initially determine the synapse weights and the back-propagation algorithm corrects the initial synapse weights so as to minimize prediction error [17]. Performance evaluation: The selection of best network for each output variable can be based on: (a) coefficient of correlation between observed and estimated values (ryy), (b) coefficient of variation (CV %), (c) root mean square error (RMSE), (d) bias, (e) bias %, (f) absolute mean differences (AMD), and (g) graphic analysis of observed versus estimated values [51] (cited in [17]).

2.10 Dynamic Modeling

2.10.1 Contextualizing the notion of a dynamic model

The primary role of a model is to mimic a working system. According to Shannon (1998), a model is representation of an object, a system, or an idea in some form other than that of the entity itself. With a similar idea, Maria (1997) defines a model as a representation of the construction and working of some system of interest. A model can be in a form of a prototype, a mathematical representation, a description of a phenomena or any other form. In this research, focus is on mathematical models. Mathematical models use mathematical language to describe the behavior of a system. A Mathematical model can be static or dynamic. Static models can also represent systems that do not vary their state variable with time. In these models, time element not included either directly or indirectly. Some static models represent systems that are in a state of equilibrium. Dynamic models are for phenomena that vary their state variables. Time is included in the model either directly or indirectly. A dynamic model reveals the relationship among various variables in a system/phenomena and this is instrumental in understanding the mechanism of a system studied. In this way users are empowered in tuning and optimizing systems performance in fields such as manufacturing systems. On the other hand, this can power users to predict the future state of the system studied. Our study focuses on developing models that can predict the future behavior of a system which employs dynamism as an enhancement technique.

Most of the models developed mimic dynamic systems, systems that change their state. However with the current trends in modeling, the adjective "*dynamic*" is assuming a new meaning. Many systems modeled portray some level of uncertainty. This creates a compromise in the model performance. The available models approximate the behavior of system. Recent developments have revealed new techniques that allow models to adapt their behavior in response to erratic changes in the system. It is this context that this study is using the term dynamic to describe models with the capability of adapting their behavior to cater for unpredictable changes in the systems. Imbedding these adaptive capabilities in the models have revealed performance improved. In this research focus is on developing a blended model with capability to adaptively select appropriate models for use in prediction of food insecurity.

This adaptability or dynamism in modeling is a not a new concept. It has been used mainly in formation of individual models. Now attention is also shifting in aggregating two or more models. The following subsections review the concepts of dynamism/adaption either at model aggregation or at formation of individual models. Effort has made to demonstrate how these concepts would help or not help in the formation of the desired model.

2.10.2 Dynamic programming:

This is recursive problem solving technique for optimizing a problem that can be solved into stages. At each an optimal solution can be found. The challenge of dynamic programming is that the solution is not a simple search and a combination of optimal solution at each stage. Greedy algorithms can be used to find the optimal solution in a dynamic programming. Greedy algorithm is linear combination of optimal solutions at each stage. Studies show that greedy algorithms do not always result into optimal solution. For example finding an optimal path for heavy traffic roads cannot be solved by greedy algorithm. An optimal local path can lead into a route that will end up being most difficult. Therefore finding an optimal solution therefore requires careful decision making. Dynamic programming is a three stage process: (1) Obtain an optimal solution for a small a small stage; (2) Enlarge the previous scope to and obtain the optimal solution; and (3) Continue enlarging and finding optimal solution until a fully solution is obtained. Dynamic programming is suited for a problem that can be decomposed into stages. If this is to work with formulation of a dynamic model for predicting food insecurity, some restructuring of the problem is needed. A possible method is to restructure a solution as a layered combination of various possible models. Relevant theories or techniques will be is required structured the problem a hand accordingly.

2.10.3 Probability as a tool for dynamic modeling:

Systems that portray randomness or stochastic behavior are studied using probability theories. Various concepts in probability theory have been proposed and their applications have led to formation of viable models. Great contribution has occurred in formation single tasks model for predictive purpose. In context of our study we stipulate that models to participate in model aggregation portray some uncertainty. We need to develop a technique to favor performance improvement while selecting certain models to participate in formation of a required dynamically model. This will involve exploiting probability theory concepts such a maximum likelihood probability to determine which model are most appropriate given a certain situation.

2.10.4 Modularity in dynamic integrated systems:

It can be argued that a model is a group of modules that work together to produce a desired behavior. In designing an integrated dynamic model as decision support for disaster management, modularity has proved helpful. According to Asghar et al, [4] the participating models are decomposed into their constituent modules. These modules are then held at a collection center some sort of a database. A solution is dependent on the nature of the task. An intelligent algorithm captures requirements from the user and it appropriately selects which modules are suitable to model formulation. Using this strategy Asghar et al. [4], have developed a technique to design a dynamic Integrated Model for Disaster Management Decision Support Systems. Decomposing each model into its constituent modules can be challenging. Depending on the development technique used, some models are not easily decomposed into thier consituent modules. Exploring this approach in the context of a dynamic model for predicting food insecurity, the assumption is that each participating model can be decomposed into modules. This is not apparent in our case.

2.10.5 Agent Technology:

Agent technology is a more advanced method for modeling systems as opposed to using modular programming. The system is modeled in terms of autonomous entities said to be intelligent. These entities play various roles such as providing services requested. This study can exploit this technology if a solution can be envisaged as collection center for several models. Agents can play a role select of dynamically selecting appropriate models participate in model formulation depending on defined criteria. The challenge with this approach is designing the appropriate agents which are aware of availability of several models and can integrate models to suit a given situation is a complex exercise [1]

2.10.6 Evolutionary programming:

This is computing technique borrows concepts from Darwin's evolution theory. The evolution theory attempts explain how species manage to survive. Species adapt to suit the changing conditions in the environment. Species that are not able to adjust to unfavorable conditions are susceptible to extinct. The Science of evolution is now inspiring the development of applications that highly adapt to the changing circumstances. According to Engelbrecht [24], evolutionary programming is derived from the simulation of adaptive behavior in evolution (phenotypic evolution). Machine Learning is playing a leading role in exploring this possibility. Techniques adopted from evolution programming can be exploited to formulate a dynamic model for that integrated existing models [24].

2.10.7 A Model of Inductive Bias Learning:

Early works by VC-dimension had provided theory to guide and guarantee learning in single task learning. This was a corner stone to foster the field of Machine Learning. VC dimension provides bounds to provide a set of hypothesis that will ensure learning. Many of the Machine Learning works are based on this theory. Multi-task necessitated new approach to ensure inductive learning among many tasks. According to Baxter [9], inductive bias is instrumental in enhancing performance in multi-task learning environment. It had been observed that inductive bias was always supplied by experts and this is challenge in an environment of limited experts. In response to this challenge Baxter [9] proposed an automated technique to discover a bias that encourages formation of novel tasks. The proposed technique samples the tasks and discovers the bias that will promote learning novel tasks. Contribution to the knowledge is the automatic discovery the appropriate set of hypothesis the will promote multi-task learning. Baxter [9] provides a high level bias, our focus on a dynamic technique to aid in selection of models participate in model aggregation on a problem at hand.

2.10.8 Boosting with Decision Trees:

According to Chapelle et al [18], boosting had proved a successful technique in single task learning. The strategy is to train several weak learners with and aggregate them to form a superior model. This technique had not explored rigorous exploration in the field of a multi-task learning. Chapelle et al [18] acknowledges the previous work which combined probabilistic technique and boosting to promote multi-task learning. He however observes that little attention if any had been given to explore boosting with decision tree in multi-task learning. In this technique several learning tasks are learnt with a joint model, explicitly addressing their communalities through shared parameters and their difference with task specific ones. The algorithm is derived using the relationship between l1-regulation and boosting. This technique was found to produce comparable results with other multi-task models. The limitation is in failure to determine which groups will yield the optimal results. There is need for a systematic technique to guide on how to create there grouping to promote performance enhancements in learning individual tasks. Our study will make a contribution towards this need as it aims at a dynamic technique to select models are appropriate to participate in the model aggregation

2.10.9 Convex Multitask Learning with Flexible Task Clusters:

There had been a tendency to model multitask learning according to cluster relatedness. According to Zhong and Kwok [82], there other forms of relatedness which had received ignored such as relatedness at a feature level. Their study explored this relatedness and combined it with cluster relatedness. In this innovation, there is no need to predetermine clusters. The variations and similarities among tasks were exploited to generate clusters during multi-task learning. Their proposed solution is convex and this means the challenge of local mina has been addressed. Positive results have been reported. Has interesting attributes that relate to objective of this work.

2.10.10 A Framework for Learning Predictive Structures from Multiple Tasks and Unlabeled Data:

Ando and Zhang [2] raised a concern about the limitation in exploring the structural patterns in multi-tasking learning. Their study exploits relatedness at structural level in both supervised and unsupervised learning to promote multi-task learning. Their study reveals a set of hypothesis which is most likely to contain relevant model. An exploration of their techniques can be instrumental in designing a dynamic model which is the major focus of this study.

3 METHODOLOGY

In chapter one, research objectives were formulated to define target areas for this study. Well-formulated study objectives are not enough for the success of any investigation. Strategies to achieve them are equally important and this is the major focus of this chapter. This chapter is hinged on four concepts: research philosophy, research approach, research design and methods. These aspects are not distinctly independent, they are linked to each.

3.1 Research philosophy

Philosophy is derived from two Greek words meaning love of knowledge. Philosophy is for people interested in pursuing the truth for its own seek. Throughout ages philosophers have been critical on the how to reach the truth. On the other hand research is a vehicle for a logical and systematic search for new and useful information on a particular topic [61]. Philosophy is said to be rigorous in its attempts and it is worthwhile to use its concepts to streamline any research investigation process. Ssemalulu [69] emphasizes the need for a research philosophy that can unravel the complexity to enable us understand the whole process yet every philosophy has a distinct way of explaining the nature of reality (ontology), knowledge (epistemology) and values (axiology). Several philosophical paradigms have been proposed that could be useful in such undertaking and these are not limited to positivism, anti-positivism, critical theory, functionalism and pragmatism. The major emphasis of such debates lies in the epistemologies of research and is critically linked on the underlying assumptions [10]. In the context of this research, positivism, anti-positivism and critical theories were found to be most relevant.

Positivism strives for objectivity, measurability, predictability, controllability, patterning and the construction [22]. With objectivity, it believed truth (knowledge) can be generated without the investigator's influence on research results. The external influences due to researcher, subjects, and environmental factors are controlled and consequently do not affect the final outputs of the study. Quantitative methods are the major techniques for collecting and analyzing data. In positivist approach the size and nature of the samples used is key to quality research out comes. If the size and nature of the samples are appropriately selected, dependable results can be relied on for generalization. Hence prediction, controllability and patterning become possible. Positivism suffers from problems of observer bias and structural limitations in inquiry [10]. There are convictions that it is hard to control human influence on the research results [40].

In the early 20th century, strong accounts of positivism were rejected by interpretive sociologists (ant positivists) belonging to the German idealism school of thought [10]. Ant-positivism offers quite a unique approach. It is believed that reality can be obtained by interpretation of social setting subjected to research. Researcher's and subjects' influences cannot be completely controlled. They have influence on the research findings. In response to this, anti-positivists are expected to interpret the observations other than treating them as mare facts. In the process such influences are controlled. Ant-positivist also focus on the interpreting their results with aim of providing explanations. The main method for data acquisition and analysis is mainly by qualitative techniques. Anti-positivists emphasize that social actions must be studied though interpretive means based upon an understanding the meaning and purpose that individuals attach to their personal actions [10].While understanding the social aspect of people in the context of this research, the major focus on artfact development.

In our study the phenomena investigated is towards making a contribution in computational models for predicting food insecurity. Social interactions that could effect the final outputs will be minimal in this study. The study shall identify data banks to provide suitable data sets to evaluate the proposed model. This calls for positivist approach as a dominant research philosophy.

3.2 Research approach

A research approach provides a framework for guiding and conducting research as a whole. Two contrasting research approaches are studied in relation to guiding this research. These are; Behavioral Science and Design Science approaches [34]. According to Hevner et al. [34], behavioral science paradigm seeks to develop and verify theories that explain or predict human or organizational behavior. It is more focussed in Social Science research. It is a suitable paradigm where there is a need to comprehend human behavior with aim of stimulating greater productivity with the use of various motivational tools. [36]. The potential danger of behavioral-science is over emphasis on contextual theories and failure to adequately identify and anticipate technogical capabilities. Behavioral science is an inappropriate for this study. Our study mainly focuses on formulation of an artfact; designing a dynamic model for predicting food insecurity.

Design Science has been proposed for adoption as a research approach. This is also called improve science approach [74]. The general goal of design science research is to create or contribute to new and interesting design science knowledge in the area. The creation of new knowledge should be through design of novel or innovative artefacts such as algorithms, human/computer interfaces and system design methodologies [74]. In the context of this research, focus on designing a dynamic approach based on exisisting models, making Design Science approach appropriate to this study. In design science, computational and mathematical methods are primarily used to evaluate the quality and effectiveness of artefacts; however, empirical techniques may also be employed. Design science approach is characterized five outputs instantiations, methods, theory, constructs, models [74]. The key differentiator between routine design and design research is the clear identification of a contribution to the archival knowledge base of foundations and methodologies [35]. Design Science involve building and evaluation of artifacts designed to meet the identified business needs. According to Hevner *et al.* [35], routine design is the application of existing knowledge to organizational problems, such as constructing a financial or marketing information system using best practice artifacts (constructs, models, methods, and instantiations) existing in the knowledge base. The diagram below illustrates the various components of Design Science approach.

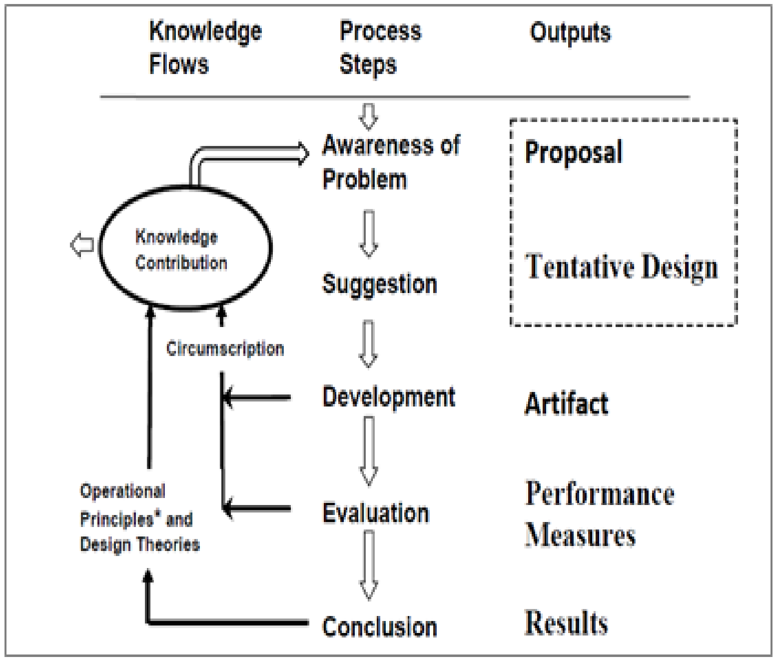

Figure 7: An illustration of Design Science approach: Adopted from [74]

The five stages involved in this approach describe below:

1. Awareness of the problem: At this stage an interesting challenge or a problem is identified. According to Ardakan and Mohajeri [3], awareness of an interesting problem can come from multiple sources such as new developments in industry or in a reference discipline.In context of this study, the problem statement describes the challenge invisaged. The possibility of contributing towards the formation of better models to predict food insecurity has been identified. The aim is design a model that will integrate the existing models as means to enhance re-usability. To achieve this, state-of-practice and relevant literature will provide the building blocks for formulating of the desired model. This was expounded in conceptual framework. In this way objective one will be achieved.

2. Suggestion: A noble solution / approach to address the challenge/problem observed is formulated. In reference to design science approach the solution is expected be a contribution to knowledge area. According to Gregor and Hevner [32] (cited in [74]), research contribution comes from three areas: Improvement (New solutions for known problems), Invention (new solutions for new problems) and Exaptation (non-trivial extension of known solutions for new problems). In our study improvement is applicable: a new solution (by designing a dynamic model) is desired. The literature and experience gained in the previous stage will be harnessed to formulate the desired model. Consequently, objective two will be achieved.

3. Development: At this stage the proposed solution (the dynamic model) will be implemented in a laboratory environment. This is to demonstrate the mechanism of this model. Partially, the validation and the testing objective will be fulfilled.

4. Evaluation: Data will be split into training and testing data sets. Specificity, performance errors, sensitiviy and area under the curve of the output shall be used as evaluation attributes to determine the viability of the solution. This will be the last stage in fulfilling the testing and validation objective.

5. Conclusion: Conclusion will be drawn from the evaluation based on experimental results obtained.

3.3 Research design

Research method describes the specific techniques used in a given study and there is typically a one-to-many relationship between a given research approach and method [31]. The research design refers to the overall strategy that you choose to integrate the different components of the study in a coherent and logical way, thereby, ensuring you will effectively address the research problem; it constitutes the blueprint for the collection, measurement, and analysis of data [72]. It is a challenging exercise to categorize research designs and according to Mohammad [50] this is due lack of consistency in classification of different types of research designs. He observes that some classify these types based on research questions being addressed while others focus on the data collection tools. Existing research designs include but not limited to : laboratory experiments (using human subjects), field studies, case studies, action based design, cross section, mathematical proof, ethnographic, explorative, and field experiment [31] [50].

3.3.1 Proposed design

Research design is governed by the notion of 'fitness for purpose' [21]. Given the nature of this study, mixed research design is proposed which cuts across; case study, longitudinal and cross-section designs. Partial attributes of each of these design will be applied. The attributes included will be selected on their relevance to study objectives.

The aim of longitudinal design is to track observational changes over a given period. Pattern for predictive purpose can be extracted as a result. Time series studies leading of longitudinal prediction are best for this design. This being predictive study, the need capture observations in a longitudinal trend design is evident. In longitudinal design observations can be obtained by questionnaires, interviews and other data collection techniques. In this study relevant data archived/collected by data banks like national bureau of statistics and Famine Early Warning System (FEWS) will be used. For details about data to be collected see see subsection 3.3.2 data generation.

A case study: This is one the commonest research design applied to most of the studies. An instance(s) of some phenomena/phenomena are selected. Case study is appropriate if it is required to investigate a situation of interest without disrupting its natural setting like in experimental environment. Not all situations are suited for this design. According to Yin [79], a case study design should be considered when: (a) the focus of the study is to answer "how" and "why" questions; (b) you cannot manipulate the behavior of those involved in the study; (c) you want to cover contextual conditions because you believe they are relevant to the phenomenon under study; or (d) the boundaries are not clear between the phenomenon and context as cited in [8]. In this study contextual conditions are important because they have role to play in understanding food dynamics. This can influence independencies of prediction parameters. This study is a bout prediction of food insecurity with in country or a state. There is a need to understand the situation in relation to study objectives which will require questions of why and how. These can be answered best in a case study.

Cross section design: This is appropriate if there is a need to compare observations over multiple cases at a given time. In this study predictions will based on sub regions of a country like its districts or provinces. Dynamic techniques to predict food insecurity rests at the core of this research. Re-usability will be based on cross section models of various regions in a country.

3.3.2 Data acquisition

Data will be obtained from databanks as opposed to using questionnaire, interviews or any other type of data collection method. Possible sources include FEWS linked satellite data, National Bureau of Statistics and FEWSNET. Data from these sources include; remote sensed data, house hold information, price trends, audio data and price trends. The table enlists possible databanks and the associated data.

Table 1: The table showing data sources for the study

Data Source	Data description	Studies that have used similar data
National Bureau of Statistics	House hold information such as	[54]
FEWSNET-Uganda	Price trends	[16]
FEWS	Weather patterns such precipitation, vegetation indices like Normalized Vegetation Index (NDVI), Ratio Vegetation Index (RVI), Soil Adjusted Vegetation Index (SAVI), and Difference Vegetation Index (DVI).	[15]
Web	Message postings in the web, blogs, facebook	Not established yet

References

1. Akbari O. Z., (2010), A survey of agent-oriented software engineering paradigm: Towards its industrial acceptance. *Journal of Computer Engineering Research* **1**(2):14-28. Retrieved from http://www.academicjournals.org/article/article1379926489_Akbari.pdf [Accessed on 2nd June 2015]

2. Ando, R.K., and Zhang, T. (2005). A framework for learning predictive structures from multiple tasks and unlabeled data. *Journal of Machine Learning Research* **6**: 1817-1853

3. Ardakan, M. A., and Mohajeri, K. (2009). *Applying Design Research Method to IT Performance Management: Forming a New Solution*. Journal of Applied Sciences, **9** : 1227-1237. Retrieved from http://scialert.net/fulltext/?doi=jas.2009.1227.1237 [Accessed on 3rd Feb 2015]

4. Asghar S., Alahakoon D., and Churilov L. (2005).*A Dynamic Integrated Model for Disaster Management Decision Support Systems*. Retrieved from https://www.researchgate.net/pro [Accessed on 12 May 2015]

5. Association of Southeast Asian Nations (ASEAN) Member States [AMSs]. (2013). *ASEAN Integrated Food Security (AIFS) Framework and Strategic Plan of Action on Food Security in the ASEAN Region (SPA-FS).* Retrieved from http://www.gafspfund.org/sites/gafspfund.org/files/Documents/Cambodia_11_of_16_REGIONAL_STRATEGY_ASEAN_Integrated_Food_Security_Framework.pdf [Accessed on 6th June 2014].

6. Bailey, R. (2013). *Managing Famine Risk Linking Early Warning to Early Action.* 10 St James's Square London SW1Y 4LE: A Chatham House (The Royal Institute of International Affairs). Retrieved from http://www.chathamhouse.org/sites/files/chathamhouse/publi [Accessed on 3rd Aug 2014].

7. Barrett, C. B. (2010). Measuring Food Insecurity. *Science*, 825-828. Retrieved from www.researchgate.net/publication/41424901_Measuring_food_insecurity/file/d912f50e6512036c9e.pdf [Accessed on 20th Aug 2014].

8. Baxter, P., & Jack, S. (2008). Qualitative Case Study Methodology: Study Design and Implementation for Novice Researchers. *The Qualitative Report*, **13**(4), 544-559. Retrieved from http://www.nova.edu/ssss/QR/QR13-4/baxter.pdf [Accessed on 2nd Aug 2014].

9. Baxter J. (2000). A Model of Inductive Bias Learning. *Journal of Artificial Intelligence Research.* **12** (2000): 149-198

10. Bhattacherjee, A. (2012). *Social Science Research: Principles, Methods, and Practices.* Global Text Project. Retrieved from http://scholarcommons.usf.edu/oa_textbooks/3 [Accessed on 21st Aug 2014].

11. Boudreau, T.E. (1998).*The Food Economy Approach: A Framework For Understanding Rural Livelihoods.* RRN Network Paper 26, Relief and Rehabilitation Network/Overseas Development Institute, London.

12. Braun, J. V. (1991). *A Policy Agenda for Famine. Prevention in Africa,Food Policy Report.* Washington, D.C.: International Food Policy Research Institute. Retrieved

from http://www.ifpri.org/sites/default/files/publications/pr1.pdf [Accessed on 3rd Aug 2014].

13. Breiman, L. (1996). Bagging Predictors. Machine Learning, 24, 123-140. Retrieved from http://www.machine-learning.martinsewell.com/ensembles/bagging/Breiman1996.pdf [Accessed on 2nd Aug 2014].

14. Brown, M. E. (2008). *Famine Early Warning Systems and Remote Sensing Data.* Berlin Heidelberg: Springer-Verlag.

15. Brown, M. E. (2009). Biophysical Remote Sensing and Climate Data in Famine Early Warning Systems. *Geography Compass*, **3**, 1381-1407. Retrieved from http:// onlinelibrary.wiley.com/doi/10.1111/j.1749-8198.2009.00244.x/pdf [Accessed on 3rd Aug 2014].

16. Brown, M. E., Pinzon, J. E., & Prince, S. D. (2008, May 1). Using Satellite Remote Sensing Data in a Spatially Explicit Price Model: Vegetation Dynamics and Millet Prices. *Land Economics*, **84**(2), 340-357. Retrieved from http://le.uwpress.org/content /84/2/340.refs [Accessed on 3rd Aug 2014].

17. Castro, R. V. O., Soares, C. P. B., Leite, H. C., Souza, A. L., Nogueira, G. S., and Martin, F. B. (2013). *Individual Growth Model for Eucalyptus Stands in Brazil UsingArtificial Neural Network.* Hindawi Publishing Corporation ISRN Forestry. Available at http://dx.doi.org/10.1155/2013/196832 [Accessed on 18th June 2014]

18. Chapelle O., Vadrevu S., and Tseng B. (2011). Boosted multi-task learning. *Mach Learn* **85**:149-173, DOI:10.1007/s10994-010-5231-6

19. Chung, K., Haddad, L., Ramakrishna, J. and Riely, F. (1997). *Identifying the Food Insecure: The Application of Mixed-Method Approaches in India.* International Food Policy Research Institute, Washington DC.

20. Clover,J.(2003). Food Security in Sub-Saharan Africa. *African Security Review*, **12**(1), 5-15 Retrieved from http://www.issafrica.org/pubs/ASR/12No1/Clover.pdf [Accessed on 25th Jan. 2015]

21. Cohen, L., Manion, L., and Marrison, K.(2007) *Research Methods in Education, Sixth Edition*. Routledge Taylor & Francis Group, London and New York. Retrieved from www.ed.ac.uk/polopoly_fs/1.88259!/fileManager/RESEARCH-METHODS-3.pdf

22. Cohen, L., Manion, L., and Morrison, K. (2007). *Research Methods in Education (Sixth edition)*. Routledge 270 Madison Avenue, New York, NY 10016

23. Domingos, P. (2012). *A Few Useful Things to Know about Machine Learning*. Retrieved from

24. Engelbrecht A. P. (2007). *An Introduction Computational Intelligence, 2nd Edition*. The Atrium, Southern Gate, Chichester, West Sussex PO19 8SQ, England: John Wiley & Sons Ltd.

25. Faaij, A.(2008).*Bioenergy and global food security*.Retrieved from http://www.wbgu.de /wbgu_jg2008_ex03.pdf [Accessed on August 2014]

26. Food and Agricultural Organisation (FAO). (2011). *The State of Food Insecurity in the World*. Retrieved from http://www.fao.org/docrep/014/i2330e/i2330e.pdf [Accessed on 18th Aug 2014].

27. Food and Agricultural Organization (FAO). (2002). *The State of Food Insecurity in the World*. ftp://ftp.fao.org/docrep/fao/005/y7352e/y7352e00.pdf [Accessed on 4th July 2014].

28. Food and Agriculture Organation (FAO), World Food Summit Rome. (1996). *Rome Declaration on World Food Security and World Food Summit Plan of Action*. Retrieved from http://www.fao.org/ag/againfo/programmes/en/lead/toolbox/indust/romedec.pdf [Accessed on 19 th Aug 2014].

29. Food and Agriculture Organisation (FAO). (2013). *The State of Food Insecurity in the World*. Retrieved from http://www.fao.org/docrep/018/i3434e/i3434e.pdf [Accessed on 19th Aug 2014].

30. Food and Agriculture Organisation (FAO). (2013). The State of Food Insecurity in the World. Retrieved from http://www.fao.org/docrep/018/i3434e/i3434e.pdf [Accessed on 19th Aug 2014].

31. Glass, R., Ramesh, V., and Vessey, I.(2004). Research in Computer Science: an emprical study. *The Journal of Systems and Software* **70** ,165-176. Retrieved fromRetrieved from : http://sprouts.aisnet.org/177/1/tr112-2.pdf [Accessed on 14th Jul 2014]

32. Gregor, S. and Hevner, A. (2013). "Positioning and Presenting Design Science Research for Maximum Impact. MIS Quartely 37(2): 337-355

33. Hansen, K., Montavon, G., Biegler, F., Rupp, M., Scheffler, M., Lilienfeld, O. A. V., Tkatchenko, A. and Mu?ller, K. (2013). 'Assessment and Validation of Machine Learning Methods for Predicting Molecular Atomization Energies.'*Journal of Chemical Theory and Computing*, **9** (8), 3404-3419 available at DOI: 10.1021/ct400195d

34. Hevner A. R., March S. T., Park J., and Ram S. (2004). Design Science in Information Systems Research, MIS Quarterly 28 (1):75-105.

35. Hevner, A. R., Ram, S. and March, S. T. (2004). Design Science in IS Research. *MIS Quarterly* **28**(1), pp. 75-105. Retrieved from http://www.brian-fitzgerald.com/wp-content/uploads/2014/05/Hevner-et-al-2004-misq-des-sci.pdf [Accessed on 28th July 2014]

36. Indabawa S. L., and Uba Z. (2014). Human Relations and Behavioral Science Approach to Motivation in Selected Business Organizations in Kano Metropolis Nigeria. European Journal of Business and Management, 6(25):168-175

37. Intergovernmental Panel on Climate Change (IPCC).(2007).*Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp. Retrieved from http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_full_report.pdf [Accessed on 25th Jan 2015]

38. Khan, Z. H., Alin, T.S., and Hussain, M. K.(2011). Price Prediction of Share Market using Artificial Neural Network (ANN). *International Journal of Computer Applications* **22**(2):42_47.

Kotsian

39. Kotsiantis, S. B. (2007). Supervised Machine Learning: A Review of Classification Techniques. *Informatica* **31**:249-268. Retrieved from http://www.informatica.si/PDF/31-3/11_Kotsiantis%20-%20Supervised%20Machine%20Learning%20-%20A%20Review%20of...pdf

40. Kura, Y. S. (2012). Qualitative and Quantitative Approaches to the Study of Poverty: Taming the Tensions and Appreciating the Complementarities. The Qualitative Report, 1-19.

41. Lee, K. Y., Y. T. Cha, Y. T., and Park, J. H. (1992). Short-Term Load Forecasting Using An Artificial Neural Network. *Transaction on Powere System*, **7**(1) Retrieved from: http://web.ecs.baylor.edu/faculty/lee/papers/journal/1992/199202.pdf [Accessed on 15th June 2014]

42. Leeuwen, J. v. (2004). Approaches in Machine Learning. *Research, Algorithms in Ambient Intelligence* **2**:151-166. Springer. Retrieved from http://www.staff.science.uu.nl/˜ leeuw112/soiaML.pdf [Accessed on 20th Aug 2014].

43. Makowski, D., & Michel, L. (2013). Use of dynamic linear model for predicting crop yield trends in foresight studies on food Security. *Sixth International Conference*

on Agricultural Statics. Thiverval-Grignon, France: UMR 211 INRA AgroParisTech BP01.

44. Malthus (1798). *An Essay on the Principle of Population.* London. Printed for J. Johnson, in St. Paul's Church-Yard. Electronic Scholarly Publishing Project. Retrieved from

45. Malthus, T.(1803). *An Essay on the Principle of Population (14th edition:1826).*London: J.M. Dent, pp. 1-24 passim. Retrieved from

46. Mathys, E., (2005).*Fews net's Approach to Livelihoods-based food Security Analysis*, FEWS NET USAID, Washington DC.

47. Mellor, J. W. (1986). Prediction and prevention of famine. *Fed Proc*, 2427-31.

48. Mellor, J. W., & Gavian, S. (1987, January 30). Famine: Causes, Prevention, and Relief. *Science*, 235, 539-545. Retrieved from http://www.ifpri.org/sites/default/files/publications/Mellor87_01.pdf [Accessed on 3rd Aug 2014].

49. Mitchell, T. M. (1997). *Product Details MACHINE LEARNING.* McGraw-Hill. New York, NY Columbus.

50. Mohammad, M. J. (2013), *Practical Guidelines for conducting research. Summarising good research practice in line with the DCED Standard.* Retrieved from http://www.enterprise-development.org/page/download?id=2133 [Accessed on 23rd Jul. 2014]

51. Monty, A., Lejeune, P., and Rondeux, J. (2008). Individual distanceindependent girth incrementmodel forDouglas-fir in southern Belgium. *Ecological Modelling* **212** (3-4): 472_479

52. Mwebaze, E., Okori, W. and Quinn, J. (2010). Causal Structure Learning for Famine Prediction. *In Proc. of the Association for the Advancement Artificial Intelligence*

(AAAI) Spring Symposium on Artificial Intelligence for Development, Technical Report SS-10-01. Retrieved from http://ai-d.org/pdfs/Mwebaze.pdf [Accessed on 5th Feb. 2015]

53. Nair, V. (2010).*VISUAL OBJECT RECOGNITION USING GENERATIVE MODELS OF IMAGES* (Doctoral dissertation).University of Toronto. Retrieved from http://www.cs.toronto.edu/ṽnair/thesis.pdf [Accessed on 5th Feb 2015]

54. Okori, W., & Obua, J. (2011). Machine Learning Classification Technique for Famine Prediction. *Proceedings of the World Congress on Engineering, 2*, pp. 991-996. London, U.K. Retrieved from http://www.iaeng.org/publication/WCE2011/WCE2011_pp991-996.pdf [Accessed on 3rd Aug 2014]

55. Okori, W., Obua, J., & Baryamureema, V. (2009). Famine Disaster Causes and Management Based on Local Community's Perception in Northern Uganda. *Journal of Social Sciences*, **4**(2), 21-32. Retrieved from http://docs.mak.ac.ug/sites/default/files/21-32.pdf [Accessed on 3rd Aug 2014].

56. Okori W., and Obua J. (2014). Computational Learning in Climate Change Adaptation Support. Journal of Computational Intelligence and Electronic Systems, 3(3):220-224

57. Pai P. F., and Lin C. (2005). A hybride ARIMA and support vector machines model in stock price forecasting. Omega-Elsevier, 33, 497-505.

58. Panda, S. S., Ames, D. P., and Panigrahi, S. (2010). Application of Vegetation Indices for Agricultural Crop Yield Prediction Using Neural Network Techniques. *Remote Sensing 2010*, **2**, 673-696. Retrieved from http://www.mdpi.com/2072-4292/2/3/673 [Accessed on 28th Jan 2015]

59. Panda, S. S., Hoogenboom, G., and Paz, J. O. (2010). Remote Sensing and Geospatial Technological Applications for Site-specific Management of Fruit and Nut Crops: A

Review. *Remote Sens*, **2**(8), 1973-1997. Retrieved from http://www.mdpi.com/2072-4292/2/8/1973 [Accessed on 28th Jan 2015]

60. Poppy, G. M., Chiotha, S., Eigenbrod, F., Harvey, C. A., Honza, M., Hudson, M. D.(2014). Food security in a perfect storm: using the ecosystem services framework to increase. *Philosophical Transactions of the Royal Society B (Phil. Trans. R. Soc. B)*, **369**:20120288 Retrieved from http://rstb.royalsocietypublishing.org/content/369/1639/20120288.full.pdf [Accessed on 20th Aug 2014].

61. Rajasekar, S., Philominathan, P., and Chinnathambi.,V. (2013). *RESEARCH METHODOLOGY*. Retrieved from http://arxiv.org/pdf/physics/0601009.pdf [Accessed ib 29th July 2014]

62. Reblic of Uganda (Directorate of Relief, Disaster Preparedness and Refugees Office of the Prime Minister). (2010). The National Policy for Disaster Preparedness and Management. Retrieved from http://www.preventionweb.net/files/21032_ugandanational policyfordisasterprep.pdf [Accessed on 3rd Aug 2014].

63. Rojas, R. (1996). Neural Networks:*A systematic Introduction*. Berlin,Springer-Verlag. Retrieved from http://www.inf.fu-berlin.de/inst/ag-ki/rojas_home/documents/1996/NeuralNetworks/neuron.pdf [Accessed on 3rd Aug 2014]

64. Rosegrant , M. W., and Cline, S. A.(2003). Global Food Security: Challenges and Policies. *Science*, **302**(5652) pp. 1917-1919. Retrieved from http://www.sciencemag.org /content/302/5652/1917 [Accessed on 25th Jan 2015]

65. Rosegrant, M., Ringler, C., & Msangi, S. (2007). Agriculture and Food Security in Asia: The Role of Agricultural Research and Knowledge in a Changing Environment. *Open Access Journal* , **4**(1), 600-610. Retrieved from http://www.icrisat.org/journal/SpecialProject/sp6.pdf [Accessed on 1st April 2014].

66. Rudas, I. J., and Fodor, J. (2008). Intelligent System. *Int. J. of Computers, Communications and Control*. **III**: 132-138

67. Sajda, P. (2006). Machine Learning for Detection and Diagnosis of Disease. *Annual Review of Biomedical Engineering*, **8**, 8.1-8.29. Retrieved from http://liinc.bme.columbia .edu/publications/SajdaAnnRevBME.pdf [Accessed on 3rd Agust 2014].

68. Shen, S., Jiang, H., and Zhang, T. (2012). Stock Market Forecasting Using Machine Learning Algorithms. Stanford University. Retrieved from: http://cs229.stanford.edu/ proj2012/ShenJiangZhang-StockMarketForecastingusingMachineLearningAlgorithms.pdf [Accessed on 18th May 2014]

69. Ssemalulu, P. M. (2012). *An Instrument to Assess Information Systems Success in Developing Countries.* (Doctoral dissertation) University of Groningen, The Netherlands.

70. U.S. Committee for Human Rights in North Korea. (2005). *Hunger and Human Rights: The Politics of Famine in Northern Korea.* 1101 15th Street, NW, Suit 800, Washington, DC 20005 USA. Retrieved http://www.hrnk.org/uploads/pdfs/Hunger_and_Human _Rights.pdf [Accessed on 5th Feb 2015]

71. United State Department of Agriculture (USDA). (2013). *Household Food Security in the United States in 2012, ERR-155.* Retrieved from http://www.ers.usda.gov/media /1183208/err-155.pdf [Accessed on 18th 2014].

72. University of Southern California Library. (2014). *Organizing Your Social Sciences Research Paper.* Retrieved from http://libguides.usc.edu: http://libguides.usc.edu /print_content.php?pid=83009&sid=818072 [Accessed on 2nd Aug 2014]

73. USAID, 1995. *Food Aid and Food Security Policy Paper*, USAID, Washington, DC.

74. Vaishnavi, V. and Kuechler, W. (2004). Design Science Research in Information Systems. Last updated: October 23rd 2013. Retrieved from http://www.desrist.org/design-research-in-information-systems [Accessed on 3rd Feb. 2015]

75. Villada, R. & Drissi, Y. (2002). A Perspective View and Survey of Meta-Learning. *Artificial Intelligence Review* **18**: 77-95.

76. Wang X., and Meng M. (2012). A hybride Neural Network and ARIMA Model for Energy Consumption Forecasting, Journal of Computers, 7(5):1184 1190

77. WFP and FAO (2010).*The State of Food Insecurity in the World.* Retrieved from http://www.fao.org/3/a-i1683e/ [Accessed on 7th Jan. 2015]

78. World Food Programme (WFP) and Food and Agrictultural Organization (FAO) (2010).*The State of Food Insecurity in the World.* Retrieved from http://www.fao.org/3/a-i1683e/ [Accessed on 7th Jan. 2015]

79. Yin, R. K. (2003). *Case study research: Design and methods* (3rd ed.). Thousand Oaks, CA: Sage.

80. Yu, L., Liu, H. (2004).Efficient Feature Selection via Analysis of Relevance and Redundancy, *JMLR,* **5**(Oct):1205-1224.

81. Zadeh, L. A. (1994). Fuzzy Logic, Neural Networks, and Soft Computing, *Communications of the ACM* . **37**: 77-84.

82. Zhong L. W., and Kwok T. J. (2012). Convex Multitask Learning with Flexible Task Clusters. *Appearing in Proceedings of the 29 th International Conference on Machine Learning*, Edinburgh, Scotland, UK, 2012