Measuring Food Quality and Safety for Food Security Related Assessments: A Microscopic Review

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Abstract

Food and Agriculture Organization (FAO) and other international organizations have come together to address a public health issue – providing access to adequate amounts of nutritious food for all the nations around the world and raising awareness of food insecurity as a public health concern. The Sustainable Development Goal to "End hunger, achieve food security and improved nutrition" and promote sustainable food systems and agriculture highlighted the necessity of launching reliable food security assessments and strengthening the existing ones. In this spirit, this review presents the current state of research on food quality and safety and food security statistical assessments. The review is split into sections discussing food security indexes that assess food quality and safety, the advantages and disadvantages of the used variable selection techniques, efficiency, and optimizations models of optimizations conducted for ranking and measuring the performance of the countries in terms of food security. It was found that the efforts to provide more reasonable and statistical-based measurement and ranking techniques that consider the concept of food quality and safety have to be intensified to provide resilient integrated measurement methods that sought to be a reference for governments and policymakers.

Keywords
Food Security Assessments, Variable Selection Techniques, Efficiency, Performance Measures, Quality, Safety.

1. Introduction

One of the most important Sustainable Development Goals is achieving food security and appropriate nutrition (Khanam et al. 2020). Sustainability and food security share multiple characteristics. They are both wide and complicated concepts used by various scientific disciplines, governments, and non-governmental organizations, each of which has its own set of definitions SEE (Alsarayreh et al. 2020; Kucukvar et al. 2021; Kutty et al. 2020; Abdella et al. 2020b). Food security occurs when all people, at all times, have physical and economic access to safe, sufficient, and nutritious food that fits their dietary needs and food preferences for an active and healthy life, according to the 1996 World Food Summit, Food, and Agriculture Organization, and to the most frequently recognized definition (Haysom and Tawodzera 2018). Since an undernourished or hungry population hinders economic productivity, food security is a vital concern. The growth of chronic and acute illnesses, endurance, and economic production is affected by malnutrition (Khanam et al., 2020). Measuring food security is both a technical and political concern (Kutty and Abdella 2020; Elhmoud and Kutty 2021). Decisions on what should be measured and how it should be measured are the result of complicated discussions based on resources, time, and capacities, as well as ideological and political viewpoints. Measurement methods that are poorly constructed obscure information can result in negative or wrong food security outcomes (Haysom and Tawodzera 2018; Thomas et al. 2017).

The various conceptual structures of food security, the outcomes and risks of each dimension, and the correlations between them make food insecurity a wicked problem (Ville et al., 2019). There are multiple ways that researchers are splitting the aspects of food security to study and measure them properly (Abdella et al., 2019). The most comprehensive dimensions which are derived from the basis of World Food System (WFS) definition, which are at least partially represented by several existing indicators and which have been considered as lead concerns in many different countries are that each person should be able to access food that is adequate in amount, sufficient in nutritional quality, accepted by the culture, safe, consistent and certain (Coates 2013; Al-Obadi et al. 2021). The conceptual

framework of the Global Food Security Index (GFSI), which has been created to measure food security levels in multiple countries around the world, consists of three aspects 1) affordability, 2) availability, 3) quality and safety where GFSI will be more elaborated on the upcoming sections (Abdella et al. 2021a). Due to the world's growing population, rapid environmental changes, and the significant agriculture's use of pesticides. Thus, various governments and researchers worldwide have shown a keen interest in food safety and quality studies.

However, what is being measured is not the only concern in food security assessments, but how it is measured. Assessments have to be well-grounded and valid to put up knowledge and help result with accurate evaluations. When the appropriate approaches are selected, this will focus more on high-risk populations, proper causes identification, and prevalence estimation. While applying inappropriate measurement methods, unsuitable data generation scales will result in ill-suited policies and strategic responses. Food security is difficult to assess because of the multidimensionality among its different aspects, and creating a single index that encompasses all aspects of the notion is technically challenging. As a result, there is no such thing as a composite measure of food security. However, there is high diversity in the existing measurements with different actors, where each measurements tool depends on the broad purpose of conducting it (Haysom and Tawodzera 2018).

2. Review Method

This paper presents a microscopic review covering studies related to Food security assessments. The review focuses on three aspects related to food security measurements, namely, a) Food security assessments considering food safety measures, b) Food security indicators' selection techniques and methods c) Optimization tools applied on food security for ranking of measuring entities' performance. The stages that this review has gone through are illustrated in Figure 1. At the first stage, the need for this review has been identified by the authors, as mentioned in section 1. The criteria if selecting papers have been listed, where the literature attempted to cover only the publications during the last ten years, starting 2012 until 2022 and focusing only on the English language publications. The search was done in Scopus Online Database by including a combination of the keywords such as: "Food Security Assessments" AND "Food Safety," "Food security" AND "Variable selection approach," "Food security" AND "Optimization Models," then further edits on the keywords were made to filter and exclude the unrelated results. In stage 2, the related studies were selected through reading abstracts and searching the keywords on each publication and the quality of the assessment or publication. After that, the selected papers were read, and the finding and summaries of the papers were highlighted. In the last stage, the review results were organized and reported systematically.

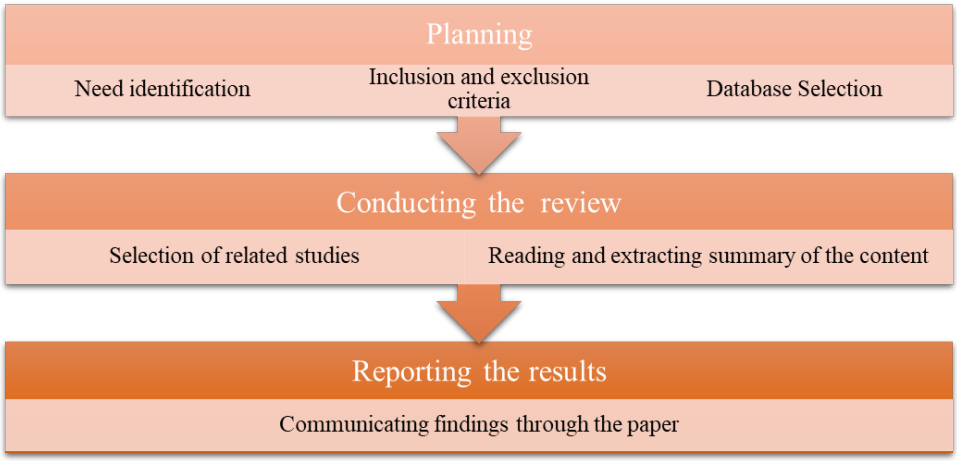

Figure 1. Review Methodology

3. Recent trends on global food security

The International Food Policy Research Institute (IFPRI) conducts the Global Hunger Index (GHI) and publish it annually in line with achieving the United Nations Sustainable Development Goals (UNSDG) – Goal 2 that pertains to food security and aims to reach zero hunger in 2030, increase food security and enhance nutrition status. Moreover, the Global Nutrition Report presents indicators at the country level that may be used to understand food security (Haug 2018) better. GHI consists of three main indicators, and one of the indicators includes two sub- indicators. An assigned

standardized score is given to each indicator. The score assigned is chosen to be somewhat higher than the maximum country-level values reported globally for the one indicator since 1988, so it can measure how the indicator is improving in terms of the highest observed levels. Aggregation is then implemented on the standardized scores to calculate each country's GHI, where each of the three main indicators contributes with equal weight to the GHI score (Grebmer et al., 2017). An index initiated to track the country-level progress toward food security is the Global Food Security Index (GFSI) which is calculated through compiling three dimensions of food security as previously mentioned, GFSI in annually produced since 2012 it measures the index of more than 100 countries, the total number of indicators contributes on the GFSI is 28 distributed over the three dimensions. Affordability is reflected by six indicators, availability by 11 indicators, and quality and safety by 11 indicators (Thomas et al., 2017).

Other papers have also studied and applied different methods of assessing food security nationally or regionally. For example, in Tanzania, a Framework for Participatory Impact Assessment (FoPIA) was used to measure the sustainability effects of implementing agriculture development interventions known as upgrading strategies to improve food security (Schindler et al. 2016). However, the original FoPIA is usually used on a set of indicators to evaluate the impact of policies on them through obtaining and summarizing participants' opinions on the performance of certain sustainability parameters or policies. Thus, it is considered a semi-quantitative technique (Pass et al., 2019). However, it could be highly subjective since this assessment is based on people's opinions away from any related statistical inputs.

4. Variable selection for food security assessments

Assessing food security has been an interesting, controversial topic that gained the attention of many researchers internationally. However, food security is a theoretical construct that can only be measured indirectly (Vaitla et al., 2017). In the last decade, different organizations have been using, merging, and implementing multiple techniques for assessing food security. Therefore, longstanding debates were driven to discuss the best measurement technique used in the food security assessments (Barrett 2010; Carletto et al. 2013). Doreswamy & Nigus (2020) have proposed filter-based feature selection techniques to reveal the best feature selection method according to their correlations with the target variable. Correlation matrix, machine learning, deep learning, and intersection method are food security prediction practices and variable-based selection approaches (Headey and Ecker 2012; Westerveld et al. 2021). The correlation matrix is a table illustrating each food security-related variable (Vaitla et al., 2017). The correlation coefficient mainly ranges between +1, a perfect positive correlation, and -1. Combining machine and deep learning methods is useful for comprehending food security and its complexity (Deléglise et al., 2022). The intersection method is a filter-based selection approach that functions similar to feature importance and univariate method for selecting the best feature technique to achieve a secured food system (Doreswamy and Nigus 2020).

Several interventions have been established to quantify food quality and measure food security safety in the agricultural system. Recent publications have reviewed the variable/feature selection techniques that have been used in food security assessments. To ensure the accuracy of the variable/feature selection technique, Doreswamy & Nigus (2020) suggested using multiple machine learning algorithms, including K-Nearest Neighbors (KNN), Random Forest (RF), Logistic Regression (LR), and Support Vector Machine (SVM). Kerner et al. (2020) employed K-Nearest Neighbors (KNN) to collect and cluster crop types data to ensure food security in Kenya. Babu & Gajanan (2022) have classified household groups based on certain socioeconomic characteristics to assess food security using K-mean cluster analysis. Egbunu et al. (2021) used Random Forest (RF) to predict climatic changes, helping farmers prepare in advance to avoid the influence of the climate variations; therefore, the yield of crops would certainly be boosted. A binary Logistic Regression (LR) model built by Omotesho et al. (2016) was established to identify factors affecting Nigeria's household food security. Barbosa & Nelson (2016) successfully classified household food security by applying a novel use of Support Vector Machine (SVM) in Brazil.

Variable selection techniques are practical for measuring food quality and ensuring food security safety. However, considering all food security variables might not be a convenient option causing over-fitting and reducing the validity of the results (Wang et al. 2020). A plethora of techniques adopted by multiple studies have been used to assess food security. Statistical variable selection methods, including Least Absolute Shrinkage and Selection Operator (LASSO), Ridge and Elastic-Net regression, have been used extensively for selecting food security-related variables (Abbas et al. 2020; Abdella and Shabaan 2020; Kutty 2020a). A regression model using the L1 regularization technique is known as "Lasso Regression" compared to L2 regularization, which is known as "Ridge Regression" (Ogutu et al., 2012; Abdella et al. 2019). The feature selection procedure can be employed using additional techniques such as Difference of Convex functions Algorithm (DCA) and Variable Importance Projections (VIP). However, these techniques all

have the typical objective of decreasing model complexity and vary in what is considered complex (Wang et al. 2020). Each variable/feature selection method is associated with its corresponding advantages and drawbacks. Table 1 summarizes the main selection techniques related to the assessment of food security aligned with the advantages and disadvantages (drawbacks) for each selected method.

Table 1 Summary of the main variable selection techniques for food security assessments.

Variable selection technique	Advantages	Drawbacks	Reference
Difference of Convex functions Algorithm (DCA)	a. The ability to solve a class of optimization problems where the objective function is a large sum of non-convex features and a regularization term. b. Do not generate infeasible solutions while searching for an optimum variable.	a. Expensive except when proposing an effective DC decomposition for which the stochastic program has a reasonable price.	(Thi et al. 2017)
Variable Importance Projections (VIP)	a. Allows the user evaluating the importance of individual variables from the predictors. b. Results were easier to interpret compared with the Selectivity Ratio (SR) method.	a. Less reliable for prediction purposes.	(Zakharov et al. 2019). (Farrés et al. 2015)
L1 regularization (LASSO regression)	a. Provides the summation of the absolute value of weights of food security-related variables. b. Displays sparse solution. c. The output provides multiple solutions, allowing the user to compare the results. d. Allows built-in feature selection. e. Robust/resistance to outliers. f. Facilitates interpretation of the resulting parameters.	a. The cost of possibly discarding variables that still may be relevant. b. Sometimes, the model creates a bias where the forecast is reliant upon a specific variable.	(Wang et al. 2020)
L2 regularization (Ridge regression)	a. Shrinks the parameters towards zero as much as possible. b. Avoids over-discarding variables as it rarely excludes variables completely.	a. Provides the only summation of square of weights of food security-related variable. b. Displays non-sparse solution. c. The output provides only one solution, restricting the user from comparing the results. d. Does not allow feature selection. e. Unrobust to outliers due to square term. f. Interpretation is more ambiguous as the set of active variables remains stable.	(Wang et al. 2020)
Elastic-Net regression (Adaptive LASSO)	a. The ability to combine the benefits of both regression models (lasso and ridge regression).	Not Applicable.	(Kostov and Davidova 2013)

b. It does not conveniently remove the high collinearity coefficient of the selected approach.
c. It enhances the accuracy of the prediction.

5. Optimization and modeling food security

After variable selection techniques have been discussed, the results of the assessments must be measured and compared. So, this section is meant to review the use of optimization modeling approaches and efficiency analyses in food security assessments to assess the efficiency of individual countries or firms. Efficiency is defined as the ratio of outputs to inputs, and it may also be described as the distance between input and output quantities. The importance of applying those estimated efficiency tests on certain studies is to get a conclusion of the performance of a homogenous set of systems, where a set of systems can be, for example, set of countries, set of hospitals, or set of districts that we need to measure who is performing better (Al-Sheeb et al. 2019), after providing a set of explanatory variables (inputs & outputs) (Asmare and Begashaw 2018). Furthermore, optimization and mathematical models are used to enhance the performance of food systems by taking into account multiple dimensions, such as supply chains, production, and operations in the food sector (Namany et al., 2019). The practical implications of the recent research on efficiency measurement have been dominated by efficiency analysis utilizing parametric and nonparametric approaches. Nonparametric frontier approaches are such as the: Free Disposal Hull (FDH) Data Envelopment Analysis (DEA), where the parametric approaches that are mostly used are: distribution-free Approach (DFA), Thick Frontier Approach (TFA), Stochastic Frontier Approach (SFA) (Murillo-Zamorano 2004; Elhmoud et al. 2021). However, the choice of estimation method has been a point of argument (Asmare and Begashaw 2018). Because decision-makers are usually interested in ranking the examined alternatives based on their performance, researchers have started discussing other new methods for assessing efficiency and ranking alternatives (Carrillo and Jorge 2016; Lotfi et al. 2012).

Namany et al. (2019) has introduced a new methodology to contribute to the food security sector's decision-making. The authors utilized Energy-Water-Food (EWF) nexus in a multidimensional approach, considering Qatar's environmental and economic performance of multiple technology options. They implemented and studied three scenarios. The first and second scenarios discussed the current technologies configurations on EWF. In the last scene, they developed a stochastic optimization model to determine the optimal energy and water mix that can impact food security to attain a 40% self-dependency in perishable food production. The findings from the study showed the number of investments needed to reach 40% self-sufficiency and the impacts of investing in technologies on the environment and the country's economy. In terms of food security and related technological integrations, they mentioned that smart agriculture might be brought to the food sector to improve its operational efficiency. Finally, Ibrahim et al. (2019) evaluated OCED countries' efficiency in terms of Water- Energy-Land-Food (WELF-nexus) to maintain the sustainability of current and future generations. The order of countries model generated after applying DEA was used to estimate the WELF efficiency of each country and the annual average efficiency of the countries in 3 years; 2007, 2012, and 2016. To assess the impact of drought on WELF efficiency, Ibrahim et al. (2019) have also performed a sensitivity analysis, where they noticed a decrease of about 13% on average WELF efficiency that was observed earlier. Study results were good for decision-makers and governments to establish policies and strategies to achieve WELF-nexus efficiency.

There are other optimization models and policy-making assistant tools approach applied by researchers in the food sector. For example, research has been done to evaluate and model the impacts of four water-land allocation alternatives on national food security and farming livelihoods in Egypt, to explore the links between food-land-water under low agriculture resources, particularly water and land. The four scenarios start with the base scenario, optimum land scenario, optimum water scenario, and optimal land and water scenario. The tracking of food security and sustainability aspects is the unique feature of the last scene they applied, which identifies the effect of applying the optimum water and land allocation policies on food security and water sustainability. They applied a nonlinear optimization modeling integrated with the welfare analysis approach on each scenario. They found that the optimum land model, optimum water model, and land-water optimum model compared to the base scenario will significantly increase the total crops production, thus enhancing food security status in Egypt. The welfare analysis technique can assist policymakers, and social planners in formulating strategies to help them accomplish food security goals (Gohar et al., 2021). Furthermore, a study was carried out to increase food security in Qatar by achieving efficient waste management. The PolicyCompass system, which was based on a Fuzzy Cognitive Map (FCM), the nonparametric

approach, paired with a policy graphic modeling interface, aiming to identify the relationships between organizational behaviors and practices in food supply chains concerning waste. The study's findings contribute to policymakers that could assist them in evaluating the applied policies and building more resilient food chains that could improve food security overall (Irani et al., 2017).

The diversity of using the parametric and nonparametric approaches to get optimized solutions in recent years has been noticed through this literature process. However, many publications were applying it in fields such as agriculture and sustainability that are not directly related to food security, and they can be employed on food security for providing optimized solutions or evaluating the performance of multiple entities SEE (Kutty et al. 2020a; Kucukvar et al. 2021a; Abdella et al. 2021; Onat et al. 2021; Kutty et al. 2020b). Generally, the parametric method is more appealing when there are significant measurement mistakes and random events in the data. Nonparametric analysis, on the other hand, maybe a preferable alternative when random disturbances are less of a concern. Thus, Parametric and nonparametric methods are complementary rather than competing methods (Asmare and Begashaw 2018).

6. Concluding Remarks

The authors conducted a microscopic review of food quality and safety for food security-related assessments, one of the leading topics and an influential indicator that plays a significant role in achieving sustainability and maintaining healthier nations. First, the review was based on searching for scholarly articles published in the last ten years that have discussed and considered food safety and quality as indicators to measure food security. Then, the paper highlighted diverse approaches used to select the variables assessing food security indexes. Finally, the literature continued and discussed the optimization tools used to measure countries' performance and rank them based on their food security score.

It has been found that almost all the global food security indexes do consider the nutrition values and the quality of the food provided and consumed by people, however many of them do not list those indicators under the name of safety and quality, which may de-emphasize the existence of indicators that are measuring the quality and safety of the food. GFSI is one of those indexes that measure food quality and safety, measuring the amount of nutrition, quality of proteins, diet diversification, and food safety (Thomas et al., 2017). The statistical techniques used to assign a specific weight that reflects one indicator's importance in an assessment is varied. Each technique fits a specific use; when some suit a small set of data measurements, the others perform better when used in large data sizes. The complexity of the results, ability to predict, and accuracy of the prediction attributes distinguish the methods listed in this review. Lastly, the optimization tools used to measure performance and provide a rank of the entities that food security is measured on are limited, whereas they are commonly used in other industries such as in sustainability, and agriculture assessments SEE (Bojnec and Latruffe 2013; Abdur-Rouf et al. 2018; Kutty et al. 2021).

The authors do believe that the growing interest around the world for finding the most reliable ways that could provide high accuracy measurements leaves room for improvement of the a) statistical-based variable selection approaches that can be adopted on global indexes measuring food security b) food security optimization studies that can compare food security models, and provide convenient results to assist on establishing and applying policies and achieving better levels of food security. It is also crucial now that governments, non-governmental organizations, policymakers, environmental specialists, and each induvial play a role in this challenge of food security and work on maintaining high-quality standards of food and reliable measurements.

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