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ENHANCING GLOBAL FOOD SECURITY THROUGH ARTIFICIAL INTELLIGENCE: AN OVERVIEW

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ABSTRACT:

The use of Artificial Intelligence (AI) towards global food security has been a great tool over the decades in tackling the challenges facing food security globally. Unalterable demand of food globally, affect food security in general. This paper presents a review of the applications of AI in food safety, providing detailed account of the importance and application of artificial intelligence (AI) in relation to food availability, food accessibility, food utilization, stability and malnutrition that can impact the global food security as described by Food and Agricultural Organization (FAO) and Food Climate Research Network (FCRN). The objective of this review is to systematically summarize the food security definitions, global food security concept and highlight the role Artificial Intelligence (AI) could play to create tools that recognize malnutrition thereby, improving global food security. Our review demonstrated that there appears to be a connection between food insecurity and malnutrition, despite the fact that some malnutrition indices do not correlate as anticipated. Analysis of global food security can be used to highlight the interactions and conflicts between the factors that drive food affordability, food availability, food quality and safety, and nutrient-dense food that satisfies people's dietary needs and preferences for an active and healthy life. We strongly suggest that using artificial neural networks to address malnutrition will have a positive impact on global food security.

KEYWORDS: Artificial Intelligence, FAO, Food Price Index, Artificial Neural Network, Malnutrition, Food Security, Machine Learning.

1. INTRODUCTION

1.1 Overview of Global Food Security

The availability of food in a nation (or geographic area) and the capacity of its citizens to obtain, afford, and source sufficient foods are referred to as food security. According to the United Nations' Committee on World Food Security, food security is defined as meaning that all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their food preferences and dietary needs for an active and healthy life (IFPRI, 2020). The availability of food irrespective of class, gender or region is another element of food security. There is proof that food security was a concern thousands of years ago; in times of famine, central authorities in ancient Egypt and China were known to release food from storage. At the 1974 World Food Conference, the term "food security" was defined with an emphasis on supply; food security is defined as the "availability at all times of adequate, nourishing, diverse, balanced and moderate world food supplies of basic foodstuffs to sustain a steady expansion of food consumption and to offset fluctuations in production and prices" (FAO, 2003). The first World Food Summit, held in 1996, stated that food security "exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life"(FAO, 2013). This paper focuses on providing detailed account of the importance and application of Artificial intelligence in relation to food availability, food accessibility, food utilization, stability with malnutrition that can impact the global food security as described by Food and Agricultural Organization (FAO) and Food Climate Research Network (FCRN). This article examines and highlights the ways in which AI technologies can improve agriculture and the global food security positively.

The toxic cocktail of conflict, climate change, and the COVID-19 pandemic had already left millions exposed to food price shocks and vulnerable to further crises. Now the war in Ukraine with its knock-on effects on global supplies of and prices for food, fertilizer, and fuel is turning a crisis into a catastrophe. The 2022 Global Hunger Index (GHI) score shows that progress in tackling hunger has largely halted. Other indicators reveal the tragic scale of the unfolding crisis. The State of Food Security and Nutrition in the World 2022 reported that in 2021 the number of undernourished people an indicator of chronic hunger rose to as many as

828 million. Further, according to the Global Report on Food Crises 2022, the number of people facing acute hunger also rose from 2020, reaching nearly 193 million in 2021. These impacts are now playing out across Africa South of the Sahara, South Asia, Central and South America, and beyond (Klaus et al., 2022).

The tools and strategies used to achieve food security must align with food safety, and public health as well as sustainability. Food chains are complex and not transparent; hence we believe a One Health approach is needed to assess trade-offs and achieving sustainability (Boqvist, et al., 2018). The United Nations sustainable development goals include eradication of hunger. To feed 10 billion persons by 2050, we need to get the trade-offs right between sustainability, food security, food safety, and make better use of food already produced. The hierarchy of strategies for reducing food losses and waste are in descending order source reduction, reusing or reprocessing surplus foods, recycle food as feed for animals, recover the energy as biofuels, nutrients as compost, or raw materials for industry, while as last resorts one may consider recovering the energy by incineration or dumping as garbage in landfills (Ivar, et al., 2020). These factors will also affect food prices and availability.

The climate and other environmental parameters of current food systems can be substantially influential, significantly weakening the natural resources upon which our food security depends. While positive advances in many fields have helped tackle food security worldwide with improved yields by hector, increased feed production for livestock, increased aquaculture production, and increased labor productivity, they could negatively impact the environment. New policy strategies must be implemented to reduce the environmental effects while enhancing health outcomes and preserving the companies and their livelihoods for the many people employed in the food systems. Dialog and new partnerships between all stakeholders in the food system, including policy-makers, farmers, processors, retailers, and consumers, are required to transform food systems. In view of the diverse stresses on food systems, the current and even the potential issues of the global food system must be addressed. The question is how to properly provide sufficient diets while reducing environmental degradation without destroying the ecosystems that maintain the livelihoods of many farmers and their profitability. At the local, national, and global level, actions through dialog and collaborations with all members of the food system, including producers, manufacturers, distributors, and others, will have to be taken. Although productive collaboration with industry and individuals is important, potential approaches should

concentrate on seeking synergies between climate change and environmental priorities; albeit with unavoidable trade-offs that require careful management. Holistic strategies can be employed to build incentives to ease the transition from business-as-usual to achieve better food security (Meng-Leong. et al., 2020).

1.2 Analyzing GFSI and FFPI dataset

Considering the Global Food Security Index variables, as published by the EIU, The GFSI examined the core challenges of affordability, availability, and quality in 113 countries. All the countries were invited by the Economist Intelligence Unit (EIU). The 113 countries were the respondents to the EIU which participated and contributed data to the GFSI. It was a dynamic model built from 34 unique indicators of food security drivers across developing and developed countries. However, the GFSI examines factors affecting food insecurity beyond hunger. It also includes a factor concerning natural resources and resilience. It assesses the exposure of global food security to climate change impacts, its impacts by natural resource risk, and its adaptation to these risks (Meng-Leong. et al., 2020).

FAOSTAT data are provided as a time-series from 1961 in most domains for 245 countries in English, Spanish and French. The Food and Agriculture Organization Corporate Statistical Database (FAOSTAT) website disseminates statistical data collected and maintained by the Food and Agriculture Organization (FAO) (How, M.-L. 2019). The FAO Food Price Index is an important indicator of global food commodity price movements. Periodic revisions to price series and the base weights in the formulae of the FFPI, as well as the FGFCPI, are necessary to ensure their relevance. The revised FFPI and FGFCPI replaces current corresponding indices, July 2020.

According to Meritt Cluff, & Shirley Mustafa, (2020), very strong statistical correlation of the current and revised series will assure continuity of the FFPI as the revisions was implemented in July 2020.

The need to choose FAO Food Price Index (FFPI) over Global Food Security Index (GFSI) dataset cannot be over emphasized therefore, in this our current paper we provides an approach which facilitates discussions about global food security with descriptive analytics, in conjunction with predictive simulations through Artificial Neural Network using the indicators and data from the FAO Food Price Index (FFPI).

1.3. Cohesive Analysis of the FFPI

The FAO Food Price Index (FFPI) is a measure of the monthly change in international prices of a basket of food commodities. It consists of the average of five commodity group price indices weighted by the average export shares of each of the groups over 2014-2016. A feature article published in the June 2020 edition of the Food Outlook presents the revision of the base period for the calculation of the FFPI and the expansion of its price coverage, to be introduced from July 2020. A November 2013 article contains technical background on the previous construction of the FFPI. Food markets will face many more months of uncertainty related to the COVID-19 pandemic. However, while most markets are braced for a major global economic downturn, the agri-food sector is likely to display more resilience to the crisis than other sectors. World total meat production is forecast to contract in 2020, depressed by animal diseases, COVID-19-related market disruptions, and the lingering effects of droughts. International meat trade is likely to register a moderate growth, largely sustained by high imports from China (FAO, 2020).

In spite of uncertainties posed by the pandemic, FAO's first forecasts for the 2020/21 season point to a comfortable cereal supply and demand situation. Early prospects suggest global cereal production in 2020 surpassing the previous year's record by 2.6 percent. Based on conditions of crops already in the ground, planting expectations for those still to be sown, and assuming normal weather for the remainder of the season, world cereal output is forecast at 2 780 million tonnes (including rice in milled equivalent), nearly 70 million tonnes higher than in 2019, setting a new record high. Based on FAO's first forecasts for production in 2020 and consumption in 2020/21, world cereal inventories by the end of national marketing seasons in 2021 are forecast to reach a new record of 927 million tonnes, an increase of 5.0 percent (44 million tonnes) from their already high opening levels. The expected increase in cereal stocks would result in a slight rise in the global cereal stock-to- use ratio, from 32.5 percent in 2019/20 to 32.9 percent in 2020/21, indicating a generally comfortable supply situation when compared to the 21.2 percent low registered in 2007/08. Of the total cereal stocks, as much as 47 percent are expected to be held in China, where national stocks could increase for the second consecutive season and reach a new high of at least 439 million tonnes (FAO, 2020).

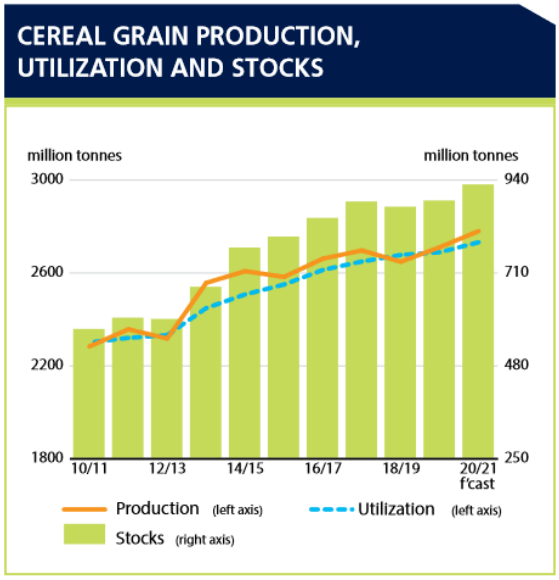

Figure 1: Cereal Grain Production Utilization and Stocks.

Source: FAO. 2020 Food Outlook - Biannual Report on Global Food Markets: June 2020. Food Outlook, 1. Rome. https://doi.org/10.4060/ca9509en

2. Artificial Intelligence in Improving Global Food Security

According to Nikita Duggal. (2022), an artificial intelligence program is a program that is capable of learning and thinking. It is possible to consider anything to be artificial intelligence if it consists of a program performing a task that we would normally assume a human would perform. From a bird's eye view, AI provides a computer program the ability to think and learn on its own. It is a simulation of human intelligence (hence, artificial) into machines to do things that we would normally rely on humans. Artificial intelligence (AI) has been used to enable farmers to grow higher-quality crops and to achieve higher food production per acre. The world's rising food demands are being met with leading technological developments. The growth of digital agriculture and its associated technology have opened up a number of new data analytics-related opportunities (Kleineidam, 2020).

Malnutrition:

Malnutrition undermines a person's ability to lead a healthy life and occurs when a person is not able to obtain the right variety of nutrients in the right amounts from their diet. It is an umbrella term that includes over nutrition (an excess of food energy), under-nutrition (a lack of food energy and macronutrients such as protein), and micronutrient deficiencies (insufficient micronutrients such as iron, vitamin A or iodine) (FCRN, 2018). The application

of Artificial Intelligence (AI) could be used to create tools that recognize malnutrition thereby, improving global food security. According to Vikram J. Christian et al., (2020), Malnutrition may be linked to microbiota immaturity and/or dysbiosis. Certain strains of bacteria from the poorly nourished children may be contributory to the inflammatory cascade which limits the benefit of the supplemental nutrition and consequently limits the child's growth and development. Between food insecurity and malnutrition there appear a link, although certain indices of malnutrition do not correlate, as expected, with food insecurity.

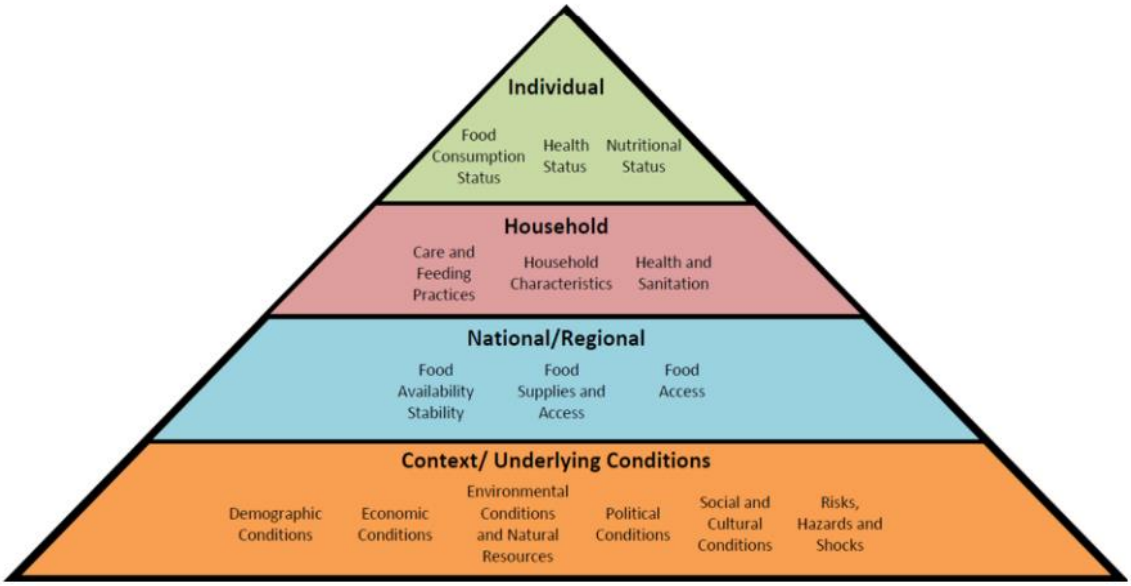

Figure 2: Levels of Food Security.

Source: Gibson, M. (2012)

Food Availability:

Food Availability is one of the four components of food security and it addresses the supply side. It refers to the physical inflow and presence of safe and nutritious food at a given time and in a given place (e.g., at a local market or in a country). The food availability is directly related to enhancing global food production. Increasing both the crop and animal productivity and land productivity in a sustainable manner are thus, human thinking. It is possible that a machine to learn from its experience by adjusting their responses based on new inputs provided, performing the human-like tasks. The machines can be trained to process a large amount of data and recognize a pattern in them. Finally, AI is a data processing system or computational systems that take data as inputs and process them to lead to a user-friendly output (Gadanidis 2017). Bestelmeyer et al., (2020) developed an AI based tools that manage site-based scientific data and big data in the effort to scale up agricultural research with

artificial intelligence with a view to help farmers and land managers make site-specific decisions. These tools provide early-warning of pest and disease outbreaks and facilitate the selection of sustainable cropland management practices. How, M.-L. (2019), rather than always being led by AI, people should take the lead by using AI to augment human cognitive capabilities. AI technologies are used to produce vaccines against various kinds of diseases. According to De La Fuente et al., (2018), intelligent big data analytic techniques used to predict the correct protective antigens have provided solutions to produce vaccines for prevention and control of tick-borne diseases.

Food Accessibility:

Individuals and households must be able to acquire sufficient food to be able to eat a healthy, nutritious diet, or have access to sufficient resources needed to grow their own food (e.g., land). Access can be affected by: Affordability, Allocation, and Preference. Affordability: The ability of individuals, households or communities to afford the price of food or land for producing food, relative to their incomes. Allocation: The economic, social and political mechanisms governing when, where, and how food can be accessed by consumers and on what terms. For example, food may be unequally allocated according to age and gender within households. Preference: Social, Religious, and cultural norms and values that influence consumer demand for certain types of food (e.g. religious prohibitions or the desire to follow a specific dietary pattern such as vegetarianism), (FCRN, 2018). The AI technology has been recognized as an application to increase the efficiency in food value chains (Di Vaio et al., 2020). For an equal and efficient food supply, it would be important to identify the areas with inadequate access to safe and nutritious food. Regions with insufficient spatial and socioeconomic access to nutritious food are named as food deserts (Widener and Shannon, 2014). In a recent study, big data analytics and ML have been used to develop a food desert identifier that traces areas with inadequate food access in Cuyahoga County in the United States (Yiyuan, 2020).

Food Utilization:

People must have access to a sufficient quantity and diversity of foods to meet their nutritional needs but must also be able to eat and properly metabolise such food. It is mainly involving on food safety and quality, the quantity of food a person eats, and the efficiency of conversion of food to energy inside the human body. Food safety and quality is the one that can be used to achieve food security in general under the aspect of food utilization. The

artificial intelligence can be successfully used to enhance food security by improving these practices and techniques (Chamara et al., 2020). The AI will help achieving food safety and quality by controlling those biological and environmental factors. Babawuro et al., (2015) proposed an intelligent temperature control technique for fresh cassava roots postharvest storage system using a fuzzy logic controller. Where the storage temperature is controlled by simulating two inputs (error in temperature and rate of change in the error) and one output (change in fan speed).

Food Stability:

Food may be available and accessible to people who are able to utilise it effectively, but to avoid increases in malnutrition and in order for people not to feel insecure, this state of affairs needs to be enduring rather than temporary or subject to fluctuations (FCRN, 2018). There are several challenges of food stability that are directly linked with food availability, food access and utilization. These challenges include, increasing the demand for quality foods and the quantity, adaptability to new and variable climates, pest and disease outbreaks. The AI can also be used to notice about the climate influences and to improve the warning system of extreme weather events. The Earth System Model with the ML techniques can be used to understand the full climate system that has not occurred with the direct equation analysis or visualization of measurements (Huntingford et al., 2019). A suitable way of water resource management may be a distributed network approach using block-chain technology for a decentralized immutable community water transactions record (Lin et al., 2017). Block-chain data securitization protocols come together with AI algorithms trained by remote sensor water data to distribute water.

2.1 Application of AI in Malnutrition

Artificial intelligence (AI) offers a scalable solution to these shortcomings when addressing malnutrition. Algorithms based on AI consist of various modeling strategies, including supervised learning, unsupervised learning, deep learning, and cognitive learning (US Department of Agriculture 2018). Nutrition impacts patients' general health, occurrence of diseases, and hospital systems at large. Although malnutrition screening tools exist, healthcare systems are not using these resources optimally and systematically. Modeling strategies, including the metamodel sensitivity analysis or machine learning-based approaches, can help identify a larger population of patients at risk for malnutrition (Vaibhav Sharma et al., 2020).

Nutrition is critical to both health and economic development. Both undernutrition- and obesity-related diseases contribute substantially to the burden of disease in these societies. The direct and indirect economic costs incurred by individuals and populations are often unsustainable and contribute a significant barrier to economic and social development. Malnutrition could have adverse effects on health, which could result in increased health-care costs, reduced productivity, and lower economic growth (Meng-Leong How & Yong Jiet Chan, 2020). Artificial Intelligence (AI) can be democratized to enable analysts who are not trained in computer science to also use human-centric explainable-AI to simulate the possible dynamics between malnutrition, health and population.

According to Estrella Funes et al., (2015), the interest in using Artificial Neural Networks (ANNs) as a modeling tool in food technology is increasing because they have found extensive utilization in solving many complex real-world problems. The ANNs are an emerging computer technology that can be used in a large number and variety of applications such as, control, monitoring and modeling, recognition, detection research for patterns, predicts on-line, image processing, optimization and signal processing therefore, the need to implement Artificial Neural Networks in malnutrition is called for. These applications can use in several fields as production of manufacturing, agriculture, business, marketing, medicine, transports, energy, trade the greater, etc.

Artificial intelligence dramatically reduces or eliminates the risk to humans in many applications, Some early milestones (AI) includes work in problems solving which included basic work in learning, knowledge representation, and inference as well as demonstration programs in language understanding, translation, theorem proving, associative memory, and knowledge-based systems, and some expectation of (AI) in daily life are Communications, Time management , Health & safety and Goals, informational needs etc., (Shukla Shubhendu S., & Jaiswal Vijay 2013). With these expectations and milestones, the Application of AI in Malnutrition will amount to positive results in addressing global food insecurity.

3. Related Literatures, Reviewed

According to Meng-Leong. et al., (2020), artificial intelligence (AI) enhanced agriculture requires automated data collection, decision-making, and corrective action by robotics to enable the early identification of crop diseases, to provide livestock with timely nutrition and to maximize agricultural inputs and returns based on supply and demand. Meng-Leong. et al., (2020), on his paper perform a unified analysis of data from the Global Food Security Index

(GFSI) that has a small scale of dataset, the dataset was utilized to reveal the interplay and tensions between the variables that underlie food affordability, food availability, food quality and safety, and the resilience of natural resources without considering malnutrition as a factor that can affect global food security. This present paper emphasis on application of artificial intelligence (AI) on global food security for aiding humans through a cohesive analysis of data from the FAO Food Price Index (FFPI) because of its large scale of dataset and considering malnutrition as a factor that may affect global food security.

Saeed, et al., (2021), proposes two machine learning models for the prediction of food production. The adaptive network-based fuzzy inference system (ANFIS) and multilayer perceptron (MLP) methods are used to advance the prediction models, advancing models for accurate estimation of food production which is very essential for policymaking by stakeholders' and managing national plans for food security. In his study, only three variables were used to evaluate livestock production, namely livestock yield, live animals, and animal slaughtered, and two variables were used to assess agricultural production, namely agricultural production yields and losses.

According to Xinxin et al., (2021), Machine learning (ML) has proven to be a useful technology for data analysis and modeling in a wide variety of domains, including food science and engineering and the use of ML models for the monitoring and prediction of food safety is growing in recent years, monitoring potential food safety hazards along the entire food supply chain is important in order to guarantee the correct functioning of food safety management systems. Xinxin et al., (2021), didn't vividly consider the complete four components of food security: Food availability, food accessibility, food utilization, and stability including malnutrition on his paper.

Ngozi Clara Eli-Chukwu, (2019). Presents a review on the applications of AI in soil management, crop management, weed management and disease management. A special focus was laid on the strength and limitations of the application and the way in utilizing expert systems for higher productivity. In her review, she also detailed the concept of AI in agriculture on its flexibility, high performance, accuracy, and cost-effectiveness. The review stated that the sector faces numerous challenges in order to maximize its yield including improper soil treatment, disease and pest infestation, big data requirements, low output, and knowledge gap between farmers and technology but didn't consider it as drawback towards global food security.

According to Rayda Ben Ayed & Mohsen Hanana, (2021), the estimation of the global food production must be increased by 60–110% to feed 9-10 billion of the population by 2050 thus, the sustainability of agriculture field is the key to guarantee food security and hunger eradication for the ever-growing population. The review reported the importance of artificial intelligence and machine learning as a predictive multidisciplinary approach integration to improve the food and agriculture sector, but didn't consider malnutrition as a factor that would affect food security even the other four components of food security.

Shriya Sharma et al., (2021) in his review, looked at several AI technologies that have been utilized to provide high-quality products on food items and how it has affected the food security assurance. The reviewer, shows how show how ML (Machine Learning), DL (Deep Learning), NLP (Natural Language Program), Computer Vision, and Robotics (a subset of AI) are used to produce high-quality food items but didn't talk about the food availability, food accessibility, food utilization, stability and malnutrition as factors relating to global food security.

Chamara et al., (2020). Reviewed AI applications in relation to four pillars of food security (food availability, food accessibility, food utilization and stability) as defined by FAO, in detail. The AI technologies are being applied worldwide in all four pillars of food security even though it has been one of the slower adopted technologies compared to the rest. Nevertheless, it warrants exploring the capabilities of AI and their current impact on the food systems. Malnutrition undermines a person's ability to lead a healthy life and occurs when a person is not able to obtain the right variety of nutrients in the right amounts from their diet, the reviewer didn't see and consider malnutrition as a factor that could affect global food security.

According to Maximo Torero 2021, integration of robotics and AI in agriculture will play a key role in sustainably meeting the growing food demand of the future, he also talks about the risk of alienating a certain population, such as smallholder farmers and rural households, as digital technologies tend to be biased toward those with higher-level skills. In the paper, the crucial role of Robotics and artificial intelligence towards Food Security and Innovation was highlighted and the risks of unequal access and digital exclusion of digital technologies revolutionize. The paper talks also on digital agriculture towards food security, in all this malnutrition was not considered.

Zhe Liu et al., (2023), in his study clarified the future development direction of research on AI in food safety by systematically and comprehensively understanding the state of current research and its trends. The review was conducted to promote the development of research on AI in food safety. Specifically, the visualization tool Cite Space was used in this review to perform several key bibliometric analyses on literature samples retrieved from the WoS database and to explore the development status and evolution trend of AI in food safety in a visual way, but malnutrition was not mentioned as malnutrition undermines a person's ability to lead a healthy life and occurs when a person is not able to obtain the right variety of nutrients in the right amounts from their diet, which tis present paper intend to cover.

Saurabh Sharma et al., (2021), described agri-food sector as an endless source of expansion for nourishing a vast population, but there is a considerable need to develop high-standard procedures through intelligent and innovative technologies, such as artificial intelligence (AI) and big data. In the paper, it is was found that utilization of AI techniques and the intelligent optimization algorithm also led to significant process and production management but the need to solve problems caused by malnutrition using artificial intelligence was not mention.

According to Varsha Sahni et al., (2021), the artificial intelligence approach provides efficient solution that helps to increase the lifetime of farming activities. Therefore, in farming, the concept of artificial intelligence is implemented which makes the task so effective and simple. The study centers on the AI applications according to four mainstays of food security that is food accessibility, food availability, food use, and strength but without considering malnutrition as a mainstay that will affect food security without been considered and in their study, there was no data available to support the study.

AI could significantly improve packaging, increasing shelf life, a combination of the menu by using AI algorithms, and food safety by making a more transparent supply chain management system. With the help of AI and ML, the future of food industries is completely based on smart farming, robotic farming, and drones (Indrajeet Kumar et al., 2021), but the paper didn't capture the four mainstays of food security and malnutrition.

Ilianna Kollia et al., (2021), an emerging field in the food processing sector, referring to efficient and safe food supply chains, 'from farm to fork', as enabled by Artificial Intelligence (AI). The field is of great significance from economic, food safety and public health points of views, the paper focuses on effective food production, food maintenance

energy management and food retail packaging labeling control, using recent advances in machine learning which will be helpful in food security but including malnutrition will be more helpful.

Vijaya Lakshmi & Jacqueline Corbett (2020), amidst the rising issues of food security and climate change, the agricultural sector has started deploying artificial intelligence (AI) in business operations. While many potential AI benefits are anticipated, a comprehensive understanding of the objectives motivating AI adoption and its impacts is lacking, which could be more encourage even by applying it in malnutrition scenario.

According to Biaojun Ji et al., (2007), Over 270 ANN yield prediction models were developed and tested for at the province, regional and local spatial levels and ANN models proved to be superior for accurately predicting rice yields under typical Fujian climatic conditions, with this superiority proven with Artificial neural networks its implementation in malnutrition will yield positive results in tackling global food insecurity.

Artificial Neural Networks (ANNs) have been applied in several areas such as, science and technology, engineering, agriculture, life sciences and medicine as they have a remarkable ability to provide accurate results (Sumit Goyal 2013), Artificial Neural Networks (ANNs) having proven remarkable accurate results in these areas, applying it in malnutrition could be a worthwhile.

Juhwan Kim et al., (2018). proposed a statistical method for analyzing patent data on AI technology to improve our understanding of sustainable technology in the field of AI, they We collected patent documents that are related to AI technology, and then analyze the patent data to identify sustainable AI technology. a statistical method that combines social network analysis and Bayesian modeling was developed. Recent developments in artificial intelligence (AI) have led to a significant increase in the use of AI technologies. Many experts are researching and developing AI technologies in their respective fields therefore, the need to Improve Global Food Security Using Artificial Intelligence in malnutrition is called for.

3.1 Some AI Applications in Food Security Related Reviewed Literatures

Table 1: Some AI Applications in Food Security Related Literatures Reviewed.

S/N	Authors	Year	Research Title	Objectives	Technique	Findings	Gaps/Limitations
1	Meng-Leong How, et al.,	2020	Predictive Insights for Improving the Resilience of Global Food Security Using Artificial Intelligence	To use human-centric artificial intelligence-based probabilistic approach to perform a unified analysis of data from the Global Food Security Index (GFSI).	Bayesian Network	Using the user-friendly AI-based BN method, in various scenarios can be simulated to measure the predictive conditions at the global system-level for food safety outcomes.	It uses only one semi-supervised machine learning method for illustrative purposes. It applied only to the BN model generated from the current 2019 version of the GFSI dataset, which has small data sample size.
2	Saeed, et al.,	2021	Prediction of Food Production Using Machine Learning Algorithms of Multilayer Perceptron and ANFIS	To use advancing models for accurate estimation of food production and for policymaking and managing national plans action for food security.	ANFIS model with Generalized bell-shaped (Gbell)	The results disclosed that the ANFIS model with Generalized bell-shaped (Gbell) built-in membership functions has the lowest error level in predicting food production.	Only three variables were used to evaluate livestock production, namely livestock yield, live animals, and animal slaughtered, and two variables were used to assess agricultural production, namely agricultural production yields and losses.
3	Xinxin et al.,	2021	Application of machine learning to the monitoring and prediction of food safety: A review	To presents a literature review on ML applications for monitoring and predicting food safety.	ML	Results show that most studies applied Bayesian networks, neural networks, or Support vector machines.	The combination of more data sources could be taken into account for future ML applications in food safety. These two aspects had been identified by some included studies and other articles, and each aspect will be

							discussed below.
4	Ngozi Clara Eli-Chukwu	2019	Applications of Artificial Intelligence in Agriculture: A Review	To have an optimal yield in agricultural harvest using AI for flexibility, high performance, accuracy, and cost-effectiveness.	ANN	Agriculture is the bedrock of sustainability of any economy. It plays a key part in long term economic growth and structural transformation though, may vary by countries.	The system delay in response time and accuracy affects a user's selection of task strategy. It involves high data cost and require big data.
5	Rayda Ben Ayed & Mohsen Hanana	2021	Artificial Intelligence to Improve the Food and Agriculture Sector	To report the importance of artificial intelligence and machine learning as a predictive multidisciplinary approach integration to improve the food and agriculture sector.	ML	Very harsh socioeconomic conjecture, is difficult to fulfill without the intervention of computational tools and forecasting strategy	The high costs of creation and maintenance of the smart machines as well as the cleaver computers could be considered as technological limits.
6	Shriya Sharma et al.,	2021	Food Quality Assurance using Artificial Intelligence: A Review Paper	To show and look at several AI technologies that have been utilized to provide high-quality products on food items and how it has affected the food security assurance.	ML, DL, NLP, Computer Vision, and Robotics	AI is a human-machine partnership that has taken manufacturing and quality assurance to the next level. AI ensures precise, low-cost, sanitary, efficient, large-scale, high-quality production.	Many sectors and procedures are still deprived of the benefits of AI; once completely adopted, it will undoubtedly help us realize the ideal of totally automated manufacturing that can be operated with a single click.
7	Chamara et al.,	2020	Role of artificial intelligence in achieving global food security: a	To review AI applications in relation to four pillars of food security (food availability, food	ANN	The article reveals how AI technologies could benefit global agriculture and	The immense potential of this novel technology should be exploited fast in the journey

			promising technology for future	accessibility, food utilization and stability) as defined by FAO, in detail.		food sector, and examines the ways by which AI can address the prominent issues in Sri Lankan.	towards global food security.
8	Maximo Torero	2021	Robotics and AI in Food Security and Innovation: Why They Matter and How to Harness Their Power	To ensure that digital technologies are inclusive and become a driver for development, were countries will make technology affordable and invest in institutions and human capital, so that everyone can participate in the new digital economy.	GIS techniques	Digital agriculture also represents an opportunity for young people as agriculture value chains can be developed to create new service jobs in rural areas, making agriculture an attractive sector for youth.	The governments must invest in creating an environment that can avoid concentration of benefits and minimize inequality and the means of cost of accessing technologies should be affordable for all users.
9	Zhe Liu et al.,	2023	Artificial Intelligence in Food Safety: A Decade Review and Bibliometric Analysis	To discover the historical trajectory and identify future trends, and to analysed the literature concerning AI technologies in food safety from 2012 to 2022 by CiteSpace.	ML	The study clarified the future development direction of research on AI in food safety by systematically and comprehensively understanding the state of current research and its trends	The possibility of missing data from the WoS database used moreover, all the analysis work in this paper was based on the literature samples we retrieved rather than all published articles in the field of AI.
10	Saurabh Sharma et al.,	2021	Sustainable Innovations in the Food Industry through Artificial Intelligence and Big Data Analytics	To address the research concerning AI and big data analytics in the food industry, including machine learning, artificial neural networks (ANNs), and	Machine Learning, and Artificial Neural Networks (ANNs)	The utilization of AI techniques and the intelligent optimization algorithm also leads to significant process and digital technologies are a boon for the	There are social challenges like the adoption by the workforce and a lack of decision support tools in BDA.

				various algorithms.		food industry, where AI and big data have enabled us to achieve optimum results in real time.	
11	Varsha Sahni et al.,	2021	Modelling Techniques to Improve the Quality of Food Using Artificial Intelligence	To create artificial intelligence and methodology for assessing and optimizing food quality and safety initiatives in the food sector	Artificial Intelligence	The artificial intelligence approach provides efficient solution that helps to increase the lifetime of farming activities and offers consistent data across a scope of timescales.	Lack of availability of data.
12	Indrajeet Kumar et al.,	2021	Opportunities of Artificial Intelligence and Machine Learning in the Food Industry	To overcome the issues in demand-supply chain and also lacks in food safety of food industries using automation which is completely based on Artificial Intelligence (AI) or Machine Learning (ML).	Artificial Intelligence (AI) and Machine Learning (ML)	With the help of AI and ML, the future of food industries is completely based on smart farming, robotic farming, and drones.	The data used to support the findings of this study are available from the corresponding author only upon request.
13	Ilianna Kollia et al.,	2021	AI-Enabled Efficient and Safe Food Supply Chain	To effectively improve food production, food maintenance energy management and food retail packaging labeling control, using recent advances in machine learning.	Artificial Intelligence (AI) and Machine Learning (ML)	The use of state-of-the-art machine and deep learning methods helps in producing an efficient and safe pipeline implementation.	Applying deep learning methods in distributed environments is still an open research and development problem.
14	Meng-	2020	Artificial	To show how	AI-based	The nutritional	The exploratory

	Leong How and Yong Jiet Chan		Intelligence-Enabled Predictive Insights for Ameliorating Global Malnutrition: A Human-Centric AI-Thinking Approach	artificial intelligence (AI) can be democratized to enable analysts who are not trained in computer science to also use human-centric explainable-AI to simulate the possible dynamics between malnutrition, health and population indicators in a dataset collected.	Bayesian predictive modeling	and health status of vulnerable populations could be ameliorated.	character of predictive analytics using BN analysis makes the simulated counterfactual findings suggestive rather than definitive.
15	Estrella Funes et al.,	2015	A Review: Artificial Neural Networks as Tool for Control Food Industry Process	The objective of this paper is to provide a preliminary understanding of ANNs and answer why and when these computational tools are needed, how they are used and their possible applications inside food industry and giving as example the field of the olive grove and olive oil industry.	Artificial Neural Networks (ANN)	The use of Artificial Neural Networks as a modeling tool in food technology is increasing because they have found extensive utilization in solving many complex real-world problems.	Older artificial neural networks have limitations and the interest in ANN's field continues growing and optimizing better for solving, controlling or modeling all class of problems that can appear.
S/N	**Authors**	**Year**	**Research Title**	**Objectives**	**Technique**	**Findings**	**Gaps/Limitations**
16	Vijaya Lakshmi & Jacqueline Corbett	2020	How Artificial Intelligence Improves Agricultural	The objective was to deploy AI in growing crops that involve larger	Artificial Intelligence (AI)	Results suggest that AI is primarily being applied to increase	AI applications in agriculture are still nascent, so the motives and the challenges of

			Productivity and Sustainability: A Global Thematic Analysis	land mass to enable efficient, cost-effective, less labour-intensive farming practices.		productivity and efficiency and secondarily to address labor shortages and environmental sustainability concerns.	technological innovation, as well as the impacts of AIT remain unexplored.
17	Biaojun Ji et al.,	2007	Artificial neural networks for rice yield prediction in mountainous regions	To investigate whether artificial neural network (ANN) models could effectively predict Fujian rice yield, and evaluate performance relative to variations of developmental parameters and compare the effectiveness of multiple linear regression models with ANN models.	Artificial Neural Networks (ANN)	Over 270 ANN yield prediction models were developed and tested for at the province, regional and local spatial levels and lack of convergence also indicated that use of monthly rainfall and wind speed means for February–November did not adequately account for rice yield variability.	It more time consuming to develop than multiple linear regression models, ANN models proved to be superior for accurately predicting rice yields under typical Fujian climatic conditions.
18	Shukla Shubhendu S., & Jaiswal Vijay	2013	Applicability of Artificial Intelligence in Different Fields of Life	To highlight the features of Artificial Intelligence (AI), how it was developed, and some of its main applications.	Artificial Intelligence (AI)	Artificial intelligence dramatically reduces or eliminates the risk to humans in many applications.	Problems in neural network research, includes creating algorithms to make the connections, to determine which sets of data should be connected.
19	Sumit Goyal	2013	Artificial neural networks (ANNs) in food science – A review	To highlights the systematic information available in the literature concerning the implementation of ANN models for predicting properties of dairy products,	Artificial Neural Networks (ANNs)	The paper shows that over the last decade research related to ANN based predictive modelling in food science has picked up.	The shelf-life evaluation conducted in the laboratory is a long time-consuming process, and does not fit well with the speed requirements of the food industry.

				fruits, vegetables and meat.			
20	Juhwan Kim et al.,	2018	Sustainable Technology Analysis of Artificial Intelligence Using Bayesian and Social Network Models	To propose a statistical method for analyzing patent data on AI technology, to improve our understanding of sustainable technology in the field of AI.	Social Network Analysis (SNA) and Bayesian Regression Modeling	A sustainable technology from the results of Bayesian modeling and SNA visualization using patent data was found.	Further research on more advanced modeling, such as deep learning, for the methodology of the sustainable technology analysis will be carried out.

ML = Machine Learning; RMS = Response Surface Methodology; FAO = Food and Agricultural Organization; AI-ALS = Artificial Intelligence-Enabled Adaptive Learning Systems; Natural Language Program =NLP; Deep Learning = DL

4. METHODS

4.1 Artificial Neural Network Model versus Bayesian Network

Artificial Neural Networks (ANN) are the modeling of the human brain with the simplest definition and building blocks are neurons. There are about 100 billion neurons in the human brain. Each neuron has a connection point between 1,000 and 100,000. In the human brain, information is stored in such a way as to be distributed, and we can extract more than one piece of this information, when necessary, from our memory in parallel (Maad M. Mijwel 2018). Storing information on the entire network: Information such as in traditional programming is stored on the entire network, not on a database. The disappearance of a few pieces of information in one place does not prevent the network from functioning.

1. Ability to work with incomplete knowledge: After ANN training, the data may produce output even with incomplete information. The loss of performance here depends on the importance of the missing information.
2. Having fault tolerance: Corruption of one or more cells of ANN does not prevent it from generating output. This feature makes the networks fault tolerant.
3. Having a distributed memory: In order for ANN to be able to learn, it is necessary to determine the examples and to teach the network according to the desired output by showing these examples to the network. The network's success is directly proportional to the selected instances, and if the event cannot be shown to the network in all its aspects, the network can produce false output

4. Gradual corruption: A network slows over time and undergoes relative degradation. The network problem does not immediately corrode immediately.
5. Ability to make machine learning: Artificial neural networks learn events and make decisions by commenting on similar events.
6. Parallel processing capability: Artificial neural networks have numerical strength that can perform more than one job at the same time (Maad M. Mijwel 2018).

Bayesian Network (BN): The exploratory nature of Bayesian Network (BN) predictive analytics makes the theoretical results realistic for discussions and education, but it is not definitive. Food security analysts should be able to explore different models that may better represent the dataset. As in any simulation analysis, the results depend on the computational model's dataset (How. et al., 2020). BN is computationally intense. In recent years, however, with the advancement of faster processors, BN can now even be run on notebook computers. As a result, BN is gaining widespread use by researchers (Schoot, et al., 2014). Moreover, BN is ideal for processing non-parametric data since it does not have to presume normal parametric distribution across the model's underlying parameters. The Bayesian approach makes simulations possible by integrating prior knowledge into data analyses, before producing predictive inferences it is not based on classical frequents approaches. As a result, when analysts use Bayesian data-analytical techniques, numerous null hypothesis tests are not needed (Hox, et al., 2012).

Therefore, in this current paper, we recommend the use of Artificial Neural Network Model in analyzing Global Food Security because of its numerous advantages over Bayesian Network.

4.2 Selecting Artificial Neural Network to Analyze Global Food Security

Artificial neural networks (ANN) aim to solve problems of artificial intelligence, by building a system with links that simulate the human brain. Educating the stakeholders for a proper understanding on strategies that can be used to increase global food security: Improving incomes, employment and enterprise opportunities for the poor, improving gender equality and reducing the negative impacts of climate change and environmental degradation and other specific objectives that enhance food security (IFPRI, 2020), will eradicate the ignorance of stakeholders towards food security and with the implementation of artificial intelligence such as artificial neural networks (ANN).

Artificial neural networks (ANNs) constitute a group of nonlinear regression and discrimination statistical methods with predictive capacity and which have been widely studied. ANNs correspond to computational systems that aim to imitate some properties of biological neurons (Raquel P. F. Guiné 2019).

According to (Raquel P. F. Guiné 2019), ANNs have proven to be particularly adequate to solve many different problems in the food processing, food engineering and food properties domains. Therefore, its usage has become quite frequent and in general the results obtained consubstantiate the fact of being a powerful tool, very practical and low resource consuming ANN classifiers have been successfully implemented for several tasks related to quality inspection and classification for various food products.

5. DISCUSSION AND CONCLUSIONS

Global food security remains a problem worldwide. Crop yields have declined in many areas due to decreasing investment in research, and water scarcity. Climate change is detrimental to food security in many areas and peaceful coexistence among the communities also contribute to food security. While agro-ecological approaches give some promise to improve yields, increased investment and policy reforms could significantly improve food security in developing countries. Climate change could impact global food security. The effects of climate change on crop production that could have ramifications for food supply. The stability of entire food systems can be threatened by short-term supply variability. Climate instability and transition are likely to exacerbate food insecurity. Therefore, it is imperative to make significant mitigation steps in favor of a “climate intelligent food system” (Meng-Leong How, et al., 2020). Governments and organizations active in the food industry are planning and preparing to prevent potential problems that may arise in the way of food security for future generations. To achieve food security goals, food is mainly supplied through domestic production. Therefore, studying a country's potential for food supply is the first step in planning for food security. Food production prediction gives a realistic view to policy makers and activists in the agricultural and food industries for long-term and short-term planning. Therefore, the present study tried to provide a suitable model with high predictive performance for predicting food production (Saeed, et al., 2021).

Artificial neural network (ANN) was selected because its model involves computations and mathematics, which simulate the human–brain processes, and its level of accuracy in modelling. An artificial neural network corresponds to a technique of numerical estimation

that allows simulate the learning and memorizing process (Raquel P. F. Guiné 2019).We choose FAO Food Price Index (FFPI) over Global Food Security Index (GFSI) because of its large scale of dataset, in this our current paper we prefer this approach of using data from the FAO Food Price Index (FFPI), in conjunction with predictive simulations through Artificial Neural Network using the indicators for more effective accuracy.

Researchers and decision-makers can use this model to predict the future of food security in a region. Therefore, for future research it is suggested that using, the proposed model of the present study to predict food production in different countries will provide appropriate solutions to combat food insecurity (Saeed, et al., 2021).

The use of artificial neural network in addressing malnutrition will affects the global food security positively and will go a long way in tackling the challenges facing the global food security. When lack of proper nutrition, caused by not having enough to eat, not eating enough of the right things, or being unable to use the food that one does eat, are detected by an artificial intelligence (AI), global food security will improve.

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