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A Vision of the Food System, 2045 CE: Materiality Methods Can Define What Is Resilient and Critical †

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Abstract: This keynote and future paper summarises the methods that are being utilised to define the requirements of national populations' natural resource demands for the consumption of food and beverage products so that strategies may be more effectively developed to deal with crises. The methods are presented as part of a material analysis of the UK food supply system, and they are used to demonstrate sustainable practices in food manufacturing. Our current conclusions show that the limiting factors in the food system must be focussed on human-centred activities that interact with material flows, which are often overlooked in sustainability assessments. This is critical if we intend to tackle issues of security, resilience, and sustainability incisively.

Keywords: materiality; security; sustainability

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1. Introduction

This abstract is written for our keynote presentation at the International Conference on Industry 4.0 for Agri-food Supply Chains: Addressing Socio-economic and Environmental Challenges in Ukraine, held from 24 to 25 July 2023 at the University of Leicester, UK. This keynote further develops a previously published study [1] in which a narrative of food security was established in response to the current Russian State war on Ukraine.

Sustainable practices in the food system have been transformed by thought leaders associated with the delivery of the Green Revolution, Globalisation and Sustainable Development programmes. Each of these globally transformative programmes has fallen short of achieving their intended goals, and we report that this is because the measurement of progress has not been reactive enough in the face of crises. This reactivity has become more critical, and it has been emphasised in manufacturing practices because human values are not fully built into the applications of technology and extremely variable geopolitical conditions that continue to confound sustainable outcomes. Solutions have been identified by considering the production of life-securing services and products in the most hostile environments in which re-thinking the current manufacturing systems is a necessity [2]. The development of analytical methods that can provide timely assessments of materiality and criticality in food systems are required to deliver these technology solutions, and they have been previously tested using statistical data from the UN Food and Agricultural Organisation (FAO) [3]. These methods identify the most important food materials used by specific nations and thus develop a more focussed materiality of food systems and materials. The approach is similar to the approach used by engineers to assess materiality issues in product and market development, which consider the criticality of the supply of materials by mass, availability and environmental impact [4]. Digital technologies are known to be transformational in implementing these methods because they provide the means to develop increased reactivity and resilience. As such, they can transform the supply of agri-products, food ingredients and infrastructural materials used by the food system [5].

There are similarities in this approach to a Life Cycle Impact Assessment (LCIA), and the methods reported herein simplify the in-depth analysis used in LCIA and LCA so that reactive resilience can be deployed with confidence. The assessment of control, limits and materiality across the food system has had limited application. The specific methods for assessing the effectiveness of material flows are extremely well developed, but they have not been integrated for application. Notably, factories are where we begin to rigidly control the inefficiencies within energy or material flows, and an example of this is the development of new manufacturing strategies such as the production of fresh produce in Controlled Environment Agriculture (CEA) facilities—the so-called vertical farms. These are reforming manufacturing operations by reducing the criticality of specific materials, such as in the timely and projectable supply of fresh ingredients [2].

2. Analysis of Food System Data to Assess Supply Resilience

The assessment methodology tested and developed herein focusses on (1) commercial responses to supply chains impacted by climate change; (2) the utilisation of materials, including losses and waste; and (3) the supply of healthy diets. These three areas provide the interpretive focus for the assessment of food category data obtained from national food supply and balance databases so that a ranked assessment of food security is possible. Figure 1 shows how this method is initiated by assessing the critical supply of food categories at a national scale; this is achieved by calculating the ratio between the production quantity of the agri-food category and the Domestic Supply Quantity (DSQ) of the same category. The DSQ is calculated as the total national production mass and import mass, subtracting the total export mass. This means that a production-to-DSQ ratio value of one identifies that production is equal to supply, a ratio above one indicates that production exceeds supply and a ratio below one indicates that production is a limiting component of supply. This approach supports other database methodologies that identify limits to nutritional supply and can be used to support the application of LCA and carbon footprinting methods. Figure 1 shows the Production to DSQ ratio in terms of a Red Amber Green (RAG) risk register. Once the ratio is calculated, the data must be ranked, and Figure 1 shows an example of how risk can be segmented by thresholds for risk assessment, demonstrated herein this via a simplistic RAG register.

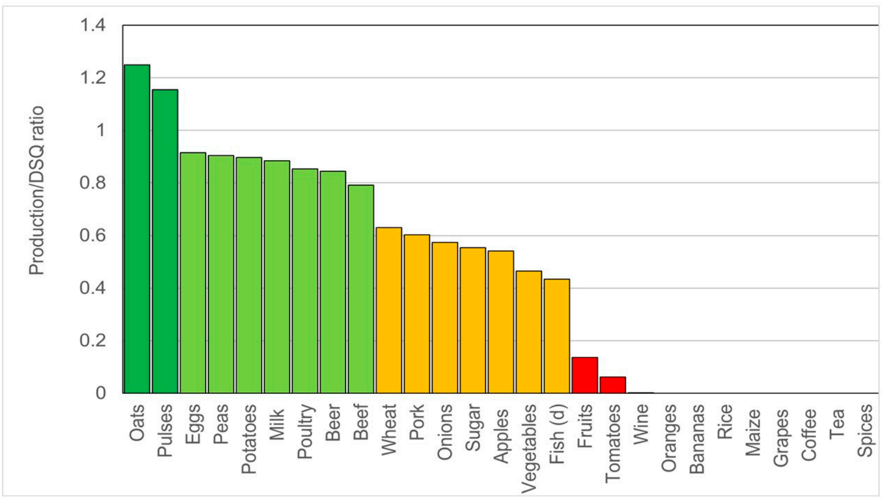

Figure 1. The ratio of UK Production to Domestic Supply Quantity (DSQ). DSQ is calculated as the addition of production and import mass, subtracting exports, to UK production in 2020. Data obtained from FAOStat Food Balance Databases. See Table S1 for the data utilized utilised to produce this figure.

3. Analysis of Food System Data to Assess Nutritional Resilience

Figure 2 develops these insights further by demonstrating how the ratio can be used to inform materiality in our food system, using the specific food category percentage supply of Calories and protein to the diet of UK citizens. This assessment is crucial because it provides an incisive view of valuable Calories and protein, which are part of the material value of the food system for specific food categories. The immediate outcome of the materiality shown in Figure 1, which demonstrates limitations to integrating the mass balance assessment shown in Figure 1 and the nutrition profiles shown in Figure 2 with carbon footprints and LCAs of the food categories. Figure 2 demonstrates this point well because the actual supplies of Calories and protein align well with what is considered a healthy and balanced diet; however, this is clearly not the case if national health outcomes are considered. As such, the impact of this analysis is the requirement to develop a greater diversity of food categories. Supplying Calories and protein in meals and diets must be a goal of UK food policy so that micronutrients and other factors are considered more effectively.

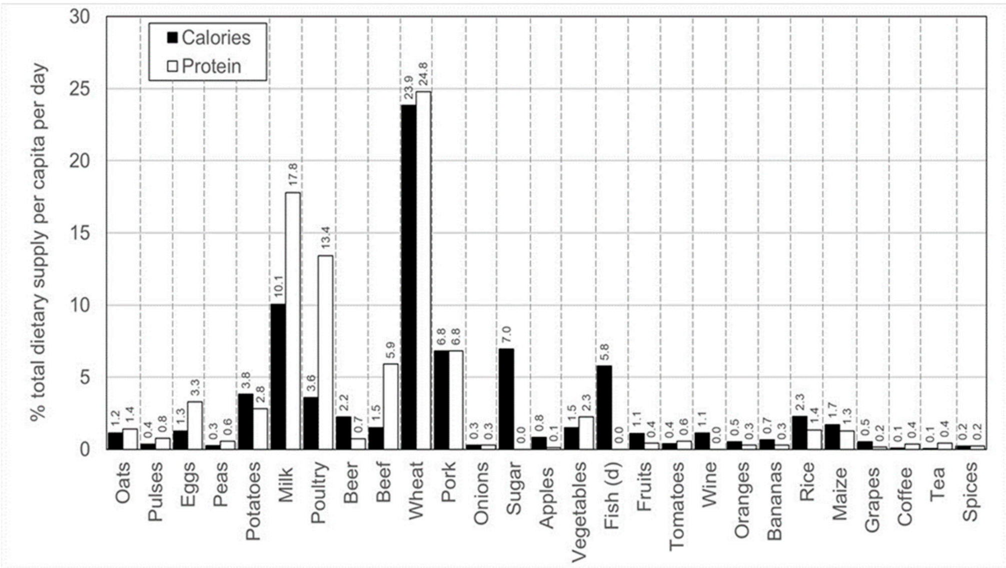

Figure 2. The percentage of total calorific and protein supply from different food categories in the UK in 2020, data obtained from FAOStat Food Balance Databases. See Table S1 for the data utilized utilised to produce this figure.

Figure 1 demonstrates the principle of first ranking those food categories that are most at risk, and this must be a pre-requisite for any security assessment that seeks to guide resilience in food supply. The consideration of materiality within the food system can help to enable sustainable practice in developing food supplies because food categories can be ranked by requirement, distribution effort and the services required to produce them [3]. Together they can define the criticality of specific food categories and the services that support their supply.

4. Analysis of Food System Data to Assess Logistical Resilience

Distribution and logistical operations are often critical limitations in securing sustainable food chains; an example of this is provided by what has happened in the Ukraine food system. Agricultural production has managed to continue during war and conflict since 2014 and most incredibly since 2022; this is likely to change dramatically in 2023. What has been crucial during conflict is that it is not only production capability but also the importance of transport from global regions; in 2023, there are critical signs that reductions in production will have a global impact. Table 1 shows that agricultural production alone is not enough to provide security, and critical distribution routes, such as shipping through the Black Sea ports of Ukraine, are critical to the distribution of agricultural commodities.

Table 1. The top ten ranked nations importing Ukrainian agricultural products from 31 July 2022 to 27 June 2023. The data were derived from the Humanitarian Data Exchange (2023) Black Sea Grain Initiative Vessel Movements, https://data.humdata.org/dataset/black-sea-grain-initiative-vessel-movements (accessed on 1 July 2023).

Departure Port	Country	Commodity	Tonnage	Departure
Chornomorsk	China	Maize	75,790	2 June 2023
Yuzhny/Pivdennyi	Spain	Wheat	74,904	18 January 2023
Yuzhny/Pivdennyi	The Netherlands	Maize	74,500	30 August 2022
Yuzhny/Pivdennyi	China	Maize	72,600	24 December 2022
Yuzhny/Pivdennyi	China	Maize	71,970	27 December 2022
Yuzhny/Pivdennyi	China	Maize	71,500	18 February 2023
Chornomorsk	China	Maize	71,500	15 January 2023
Yuzhny/Pivdennyi	China	Maize	71,500	24 December 2022
Yuzhny/Pivdennyi	Spain	Wheat	71,500	22 December 2022
Yuzhny/Pivdennyi	Indonesia	Wheat	71,400	14 December 2022

In geo-political conflict and war, the most vulnerable communities and nations are the most impacted, and Table 1 shows that the shipping of agricultural products from Black Sea ports in the past year for wheat and maize exceeded 70,000 tonnes per ship. Notably, Table 2 shows that similar tonnages will be transported to more Calorie-deficient regions of the world that are dependent on Ukrainian export, and these shipped cargoes all carry wheat. The data shown in Tables 1 and 2 are from the Humanitarian Data Exchange, and they do not provide a secure outlook for global food security within the next 1–5 years. Further data showing the impact of agri-transport agreements during the Russian war are available and demonstrate the critical requirement for logistical services to support production in order to deliver global food security [1].

Table 2. The first ten ranked low- and middle-income nations importing Ukrainian agricultural products from 31 July 2022 to 27 June 2023. The data were derived from the Humanitarian Data Exchange (2023) Black Sea Grain Initiative Vessel Movements, https://data.humdata.org/dataset/black-sea-grain-initiative-vessel-movements (accessed on 1 July 2023).

Departure Port	Country	Commodity	Tonnage	Departure
Chornomorsk	Sudan	Wheat	65,340	25 August 2022
Yuzhny/Pivdennyi	Yemen	Wheat	55,318	12 November 2022
Yuzhny/Pivdennyi	Yemen	Wheat	53,300	4 March 2023
Yuzhny/Pivdennyi	Yemen	Wheat	37,000	29 August 2022
Odesa	Sudan	Wheat	30,000	13 May 2023
Odesa	Ethiopia	Wheat	30,000	24 April 2023
Chornomorsk	Yemen	Wheat	30,000	24 March2023
Odesa	Ethiopia	Wheat	30,000	21 March 2023
Chornomorsk	Ethiopia	Wheat	30,000	21 January 2023
Chornomorsk	Ethiopia	Wheat	30,000	3 December 2022

5. For Discussion

We often cite the requirement for resilience in our food system, which is described as the ability to buffer and withstand rapid change. Conflict and war have prevented food security; policy narratives first made us aware of this in the 1970s, when they highlighted war and conflict in Eastern Africa. We now continue to face the impact of climate change, so expediently identifying critical materiality has become an important role for scientists to champion; without this, we will fail. The current war has maintained agricultural production, but remote sensing data indicate that 2023 will be a year of an drastically reduced production in Ukraine, and famine will follow in North Africa and the Middle/Near East if action is not taken now. The studies and methods reported herein must be communicated. They utilise what are largely open data systems, and it is our duty as food scientists to make policy makers aware of what the evidence is telling us. We can do this more openly and expediently than ever before, and it must be a common goal of our scientific community. The most important application of these methods and research is to optimise the use of energy in the food supply and bring climate change strategies into the industry that will prepare us for crises and enhance workforce understanding of these practices.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/engproc2023040023/s1, Table S1: The data utilized to produce Figures 1 and 2.

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