Use of a Socio-Ecological Framework and MFA to Assess the Resilience of Local Food Chain Systems

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ABSTRACT
This paper proposes the basic procedures to examine the biodiversity of food chain systems using cross-disciplinary methods based on social, ecological, and material dimensions. The application of SES and MFA methods to track internal and external disturbances in the food chain highlights some of the flaws and gaps in this decision support system approach. In contrast to the single method, this SES-MFA overlapping approach contributes more information, including the literature on local food governance. Furthermore, the SES-MFA method would offer recommendations to researchers and policy practitioners to manage changes in the food chain system to attain uninterrupted biodiversity sustainability.

Keywords: *Socio Ecological System (SES); Material Flow Analysis (MFA), Food, Food Governance.*

1. INTRODUCTION

The biggest global challenge, as reported in the Sustainable Development Goals (SDG-2), is to ensure that the food supply available can accommodate the world's growing population [1]. At the country's level, the agenda of the local food security policy is clear at the moment, but the pattern of environmental threats may shift to an unexpected scenario due to climate change, leading to an increase in the carbon footprint of about 37 percent for the food industry in 2019 [2]. The need for integration and monitoring of the local food chain inventory data is critical to the fulfilment of the SDG 2 agenda and the Paris Agreement Goals, thus advocating for a global temperature rise of below two degrees Celsius [3]. The most significant contribution is the SES approach, also known as the Human-Environmental System linked to MFA. This is because it maps out the entire transformation process of food commodities according to the upstream, middle, and downstream subsystems.

1.1. The Socio-Food Transformation System

The involvement of a network of subsystem units, which involves different and complex processes, requires intervention in the socio-food system management that combines the communication of food chain agents with functions, structures, and institutions from the economic, social, and environmental aspects. The five subsystems encompass the first subsystem (agriculture), the second subsystem (marketing), the third subsystem (consumption), the fourth subsystem (disposal of food) and the fifth subsystem (environment) [4]. This requires the development of ecological and social aspects embedded in it. An extensive review of the literature on food distribution networks at the *mukim*, district, state, and national levels, including the integration of model and data uncertainty elements, is required to get an accurate picture of "what" and "how" food transformation works from sector to sector or from upstream to downstream. For instance, the issue of imbalance and instability of food resources that plagues low-income households in underdeveloped countries takes place in the third subsystem. In the first and second subsystems, the food chain is often disrupted by natural (climate change, earthquakes, etc.) and man-made (conflicts, wars, economic crises, etc.) events, causing the local food system to be less resilient.

To appreciate and manage food resources, the actual food system transformation is required, and the characterisation of the food system should not rely on a food web model or a single disciplinary approach but should lead to the transformation in total. On top of the effects of simulating the food chain across a wider range, a comprehensive modelling of the five food subsystems

is able to provide key insights to plan alternative scenarios for the main issues of food price inflation, food waste disposal, circular economy and bioeconomy, the potential of food waste recycling, greenhouse gas emissions, nutrient loss, and a proposed plan to fulfil increased regional 'food bank' needs.

2. METHODOLOGY

The research options incorporate social, ecological, and technological perspectives that value the green lustre nexus, yet it is important to maintain sensitivity. One of the ideal approaches is the multidisciplinary diagnostic approach, which develops the Socio Ecological System (SES) and Material Flow Analysis (MFA) System framework to diagnose the sustainability performance of the food transformation process. Practical strategies are adopted to improve the resilience of local food systems, focusing on short and long supply chains via platforms for activities involving production, storage, processing, distribution, retailing, and disposal of agro-food waste, as well as regulating shocks and disruptions in the food chain.

The integrated assessment procedure of the SES and MFA framework for the food chain system is in accordance with the three phases as follows:

a) Developing the MFA-food database

b) Establishing the SES-food System Framework

c) Developing an Integrated SES-MFA Framework for food chain systems

a) Developing the MFA-food database

As a start, the development of a databank involving inflows, outflows, stocks, and trade values of food imports and exports using MFA techniques is essential to characterise "hot spots" in the food ecological system. A triangulation approach created using the quantitative and qualitative indicators of the social system includes actors, institutions, and cultural norms obtained from the scientific and grey literature, as well as interviews with industry, political, community, and local government experts. Uncertainty analysis was also performed in the last step of the MFA workflow. The details of the data formulation as well as the production of the MFA diagram can be referred to in the Ghani (2021) [5] study.

b) Establishing the SES-food System framework

The construction of the social-ecological system framework begins with three steps, namely: 1) defining the study system according to the relevant spatial and temporal scale; 2) identifying the drivers of social and ecological system attributes embedded in the four food subsystems; and 3) developing the SES-food conceptual model framework, by analysing and interpreting the final data according to the SES template developed by McGinnis and Ostrom (2014) [6-7]. For attribute characterisation in two-level system coding, four key components, namely system unit, resource unit, governance unit, and resource user unit, will be applied. Feedback, actions, and interactions between subsystems and attributes will enable simultaneous reflection and consideration of decisions and evaluation of the resilience of food chain systems using the key variables. Finally, the element of press interference is important to meet the criteria to establish the SES framework.

c) Developing an Integrated SES-MFA Framework for food chain systems

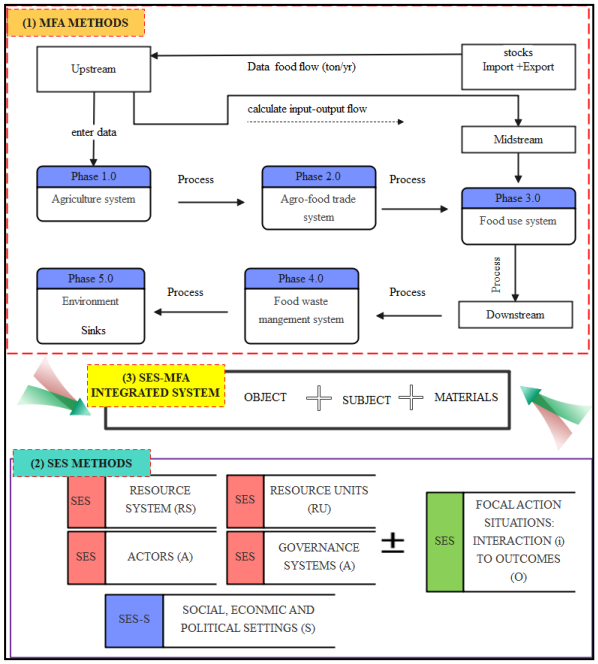

Figure 1 Consolidation sheet of SES framework with MFA for food systems

Using databank and diagrams of the MFA-food model, the essential knowledge outlined in subjects, objects, and materials serves as "the way researchers observe things in the ecological and social world." Finally, through the development of an integrated SES-MFA model framework for an ideal food chain system, the overlapping of important information in terms of social, ecological, and material dimensions will give rise to hot spot positions and generate positive and negative feedback loops. Furthermore, the randomised, uncertain SES-MFA data can be used for the adaptation and setting of alternative scenarios of eco-social food system diversity that are more sustainable. The acceptance of this SES-MFA conceptual framework will help policymakers understand the relationship between human and material impacts on food ecosystems in order to achieve universal biodiversity sustainability.

3. CONCLUSION

The unifying framework of the socio-ecological framework and MFA procedures explains the current modelling of the local food flow system, is highly dependent on the progress of the various variables and indicators that have been used, and needs to take into account the range of uncertainty of the excluded data. The participation of the MFA method is based on local inductive-deductive data insights, and the knowledge of the system is useful to support the transdisciplinary approach of SES-food studies. The investigation of the integration of parsimony variables from the ecological domain and the social domain necessitates the exchange of information about interactive networks containing social and material specifications that collaborate, such as socio-material integrated assessment for agri-food systems, which is also beneficial to managers and policymakers. In order to understand the complexity of the human-environment relationship in the food system model, the assessment of material flow management needs to be translated into a set of diagrammatic model frameworks that have subsystem and process trajectory phases that are continuous with each other. The extension of circular coil formation from SES-MFA modelling will support local agri-food systems in dealing with embedded shocks faster and more effectively in the future.

This case study suggests three basic steps in integrating the MFA method into the SES framework to produce tangible benefits to the management and well-being of the food system according to the local scenario. If the data repository is small and limited, additional long-term research is recommended to close the gaps in knowledge that exist in this proposed study. From the highlights of previous literature, integrated socio-ecological modelling studies with different methods are important to elicit additional characteristics of system components, including agents, processes, properties, interactions, and local socio-ecological system conditions that are constantly changing. Future adaption of new disciplines from the fields of pure science and social science will interact with socio-ecological modelling and will be able to provide policymakers with more effective solutions for enhancing the sustainability of the global food system.

AUTHORS' CONTRIBUTIONS

All the writing in this manuscript is entirely contributed by the author's own original ideas.

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