Co-designing and implementing best-fit farming practices ('COMBINE') JHI-B3-1

Agri-food systems mapping

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February 2023

Introduction

Agrifood systems comprise a set of dynamic, complex interactions encompassing production systems and their supply chains, and components of the food value chain, with associated socioeconomic, policy and biophysical sub-systems, and their associated barriers and drivers of food flows (Ericksen, 2008; Zhang et al., 2018). In agrifood systems, an analysis of the cause-effect relationships is important to determine agrifood system outcomes. There are numerous drivers that shape the agrifood system that range from global to regional to local scales. This report articulates the fundamental domains of the food system in the Scottish context and how they interact to achieve the goals of productivity, sustainability, and resilience of agrifood systems. Agrifood systems are under pressure from the rapidly growing human population, pressures on natural resources including biodiversity losses, increasing greenhouse gas (GHG) emissions, and climate change. Farmers play a critical role in the agrifood system; they are at the centre of food production and make numerous decisions that can affect the structure and resilience of the system. The behaviour and characteristics of different actors and subsystem elements also have a huge bearing on the outcomes of a particular food system. It is also important to understand the relationship between food and nature and in this report, we discuss the positioning, relationship, and role of ecosystem services in the agrifood systems (Homann-Keetui et al 2020) . In Scotland, the food system has been affected by many drivers and events, including EU exit, which have implications for trade routes, regulations, and agricultural subsidies. Other factors include extreme weather, disease outbreaks e.g., COVID and wars (Ukraine-Russia war) in the region.

The main objective of this report is to map the agri-food system by identifying key components therein and interactions between them.

Approach/Methodology

Through literature review, expert consultation, and stakeholder engagements we developed the agrifood system map, which captures the key components, drivers, and linkages. To begin to understand this more broadly, we sought to unpack some connections between the natural and the human system by identifying the ecosystem elements and associated ecosystem services. We went on to explore the interconnections and feedbacks among the food system components through causal loop analysis. Through the same process, the key ecosystem services and functions were identified. The first stage of the agrifood system map development was to consider the landscape and identify the elements therein that have either direct or indirect connections to other subsystems, linking ultimately to food production. Then we went on to identify key ecosystem elements, functions, and services and how they are connected to the different subcomponents of the food system. For the purpose of simplification, the elements were aggregated into broader classes. In the second step, the links between and within the social and ecological components were defined. Since the ecosystem services (ESS) are broadly defined as the benefits human populations derive,

directly or indirectly, from ecosystem functions (Costanza et al., 1997), and represent an interface between ecological and anthropogenic systems (Felipe-Lucia et al., 2022), this was used as the first step in constructing the ecological portion of the conceptual model (Figure 2). This stage consisted of identifying the relevant ESS that benefit agricultural/farming systems. We created a simplified ESS classification based on the Common International Classification of Ecosystem Services system (CICES) version 5.1 (Haines-Young and Potschin, 2017). Through literature review we identified the ecological entities and processes of an agricultural system that support the provision of the chosen ESS. Ecosystem entities are any particular part of the ecosystem either biotic or abiotic. The ESS are realised as benefits by the agricultural system and distributed to the other players of the anthropogenic subsystems. The benefits shape the type and magnitude of the relationships between the different components of the anthropogenic sub systems.

To further understand how changes in the production domain will affect other system elements, we used causal loop analysis. The causal loop diagrams were developed through researchers' knowledge informed by literature (Zhang et al., 2018). A causal loop diagram is a visual representation that characterises the interconnections between the nodes of a network. It represents the dynamics within the network by exploring the feedback between the network elements (Probst and Bassi 2014). The feedbacks introduce nonlinearity to the system and often takes a circular path, with a change in one element ultimately influencing itself via a series of intermediate elements (Probst and Bassi 2014). In a causal loop diagram (CLD), feedback can be both positive and negative. Building a CLD is useful way to identify system nodes and how the stakeholders perceive them to affect each other (Zhang et al., 2018). It is often more informative when generated by a team rather than using ideas from one person. CLDs can also help to identify the most dominant connections (that hold the network together) and identify some critical entry points.

The agri-food system structure

At the heart of agrifood systems, the food value chain is comprised of food production, processing, retail, and consumption. The value chain and its specific nodes are connected to, and influenced by, the flow of goods and services that occur within broader socioeconomic and environmental systems. Different food systems have different goals and outcomes but chief among them is contributing to food and nutrition security. Other system goals may include environmental welfare, resilience, and sustainability. Socioeconomic and environmental drivers influence the state and dynamics of agrifood systems and related outcomes. Changes in any part of the food system may cause some changes in other parts of the system and may have ramifications for the outcomes. Governance in food systems plays a critical role.

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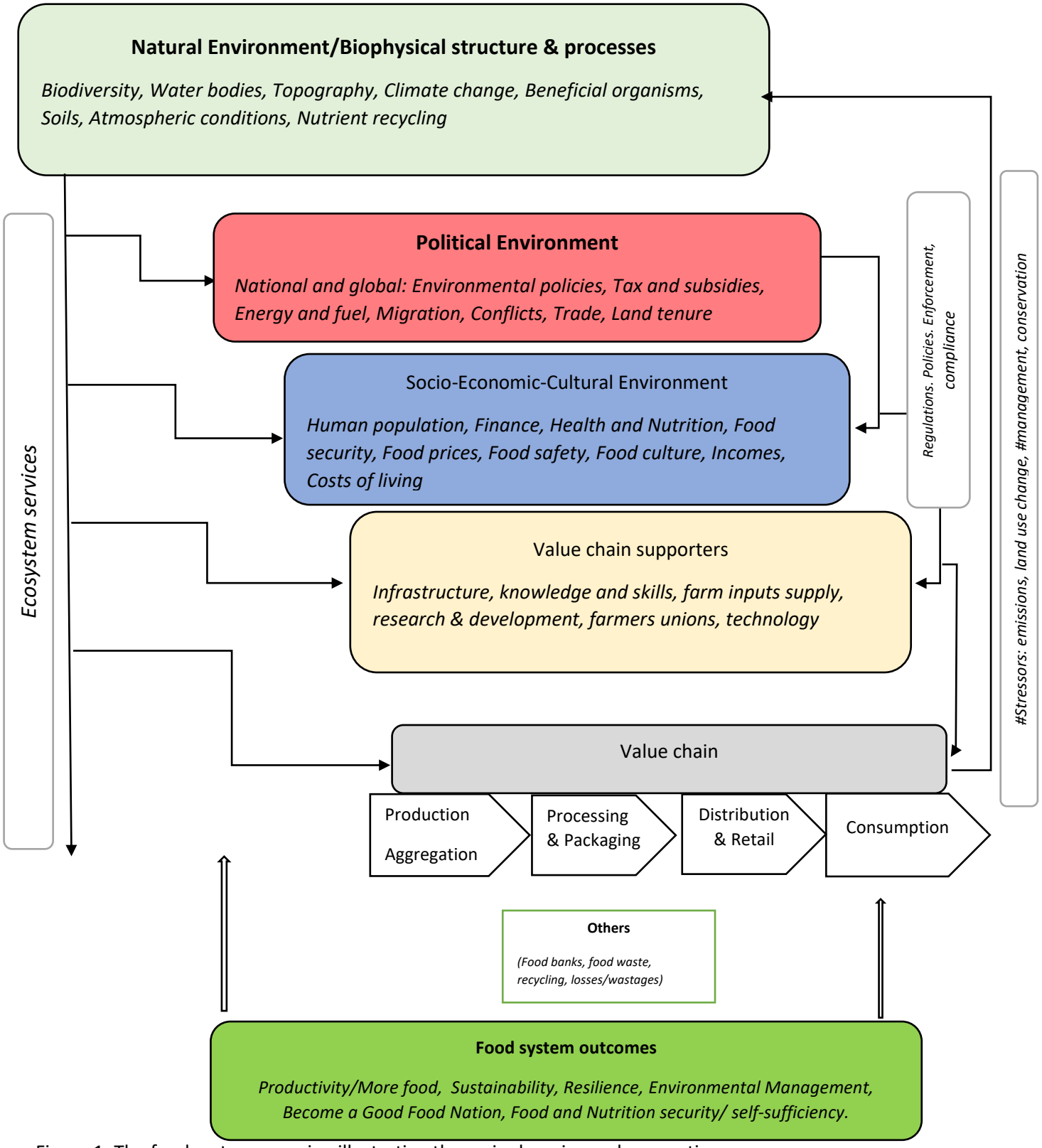

Figure 1: The food system mapping illustrating the main domains and connections.

The natural environment

The umbrella of the food system is the biophysical environment. This includes such things as the climate, soils, bio-geochemical and atmospheric processes, topography, and nutrient cycles. The food system activities function within the limits of the natural environment and hence often conform to the boundaries of the natural systems. On the other hand, processes that take place in the food system may have

implications on the natural environment. For example, processing, some specific farming methods, energy and fuel use, and other industries may directly or indirectly harm the natural system. In this report we present an example of reduced pesticide use as a best practise and explore the implications for yields and ecosystem elements of the system.

Policy environment/Governance

Agrifood system governance is importance as it plays a key role in such things as compliance and regulatory processes, and cross border trade. Policies are key in driving some activities in the agrifood system. There are numerous policies that have been implemented to ensure that agrifood system processes cause minimal to no harm in the natural system. In Scotland and the UK wide, there are climate change related policies, environmental policies, waste disposal and many other regulations that aim to ensure healthy natural environments. One such policy is the move towards Net Zero on greenhouse gas emissions.

Socioeconomic/cultural environment

The socioeconomic environment has some implications for the structure of the food system, through variation in household incomes, food culture, food safety and security, health and nutrition, finance, and the human population size. For example, incomes may directly affect consumption patterns. The socioeconomic environment has a strong influence on what food is produced, and how it is produced and distributed. Scotland aims to be a Good Food Nation by promoting healthy diets and this has repercussions for the type of food it produces.

The agrifood value chain

The value chain is at the core of the agrifood system with farming being the backbone of the system. There are many diverse kinds of farming systems ranging from arable, to mixed and livestock-only systems. The production system is often the start point of any agrifood value chain, which is then followed by processing. In some agrifood systems, farmed products are aggregated (e.g., by grain merchants) before the food goes into processing and packaging and then to distribution, retail, and consumption. Different food types have different chain structures and lengths. Consumption plays a critical role in forming production and other value chain processes. This is because consumption is a subject of many things that include affordability, health, diet and other preference measures, and food safety and availability. The COMBINE project is targeting farm level interventions thus it becomes important to understand how the changes on farm will cascade along the value chain and to other subcomponents of the food system.

The value chain supporters

The value chain support system has immediate and direct impact on the chain itself. Value chain supporters can take any form ranging from infrastructure, governance/regulatory bodies, service provision, knowledge and skills, input supply, research, and development, technology, and farmers unions, co-operatives, and industry bodies (e.g., levy boards). These support organisations can target various parts of the value chain, while some are specific to agrifood production, others may be specific to processing or retail. For instance, infrastructure can be cross cutting from agricultural production, product processing all the way to food consumption depending on what kind of infrastructure is under consideration.

Ecosystem services and the Agrifood System

An understanding of the ecosystem services in the agrifood system is important to ensure alignment between food system activities and domains with the goals of natural environment welfare. The relationship between the natural and social environment in agroecosystems is either management or ecosystem services. Below

we present this relationship in the form of a socio-ecological network (SEN) diagram as an expansion of the ecosystem service cascade (ESSC) (Haines-Young and Potschin, 2011). While the original ESSC principally describes the production chain delivering ecosystem services (ESS) to human wellbeing, the presented diagram acts as a conceptual framework that highlights the key elements, processes, and relationships of both natural and anthropogenic systems including interactions between the anthropogenic subsystems and the resulting societal feedbacks on the natural subsystems. It demonstrates the relationship between ecological status, the delivery of ESS, the influence of socio-economical components on ESS demand and management practices (pressures and mitigation efforts), and the resulting increase or decrease of stressors. The diagram is composed of sub-systems which contain elements that can interact with other elements from both within the same sub-system and between different sub-systems. The agricultural/farming system acts as the focal point of the diagram where the natural and anthropogenic systems meet.

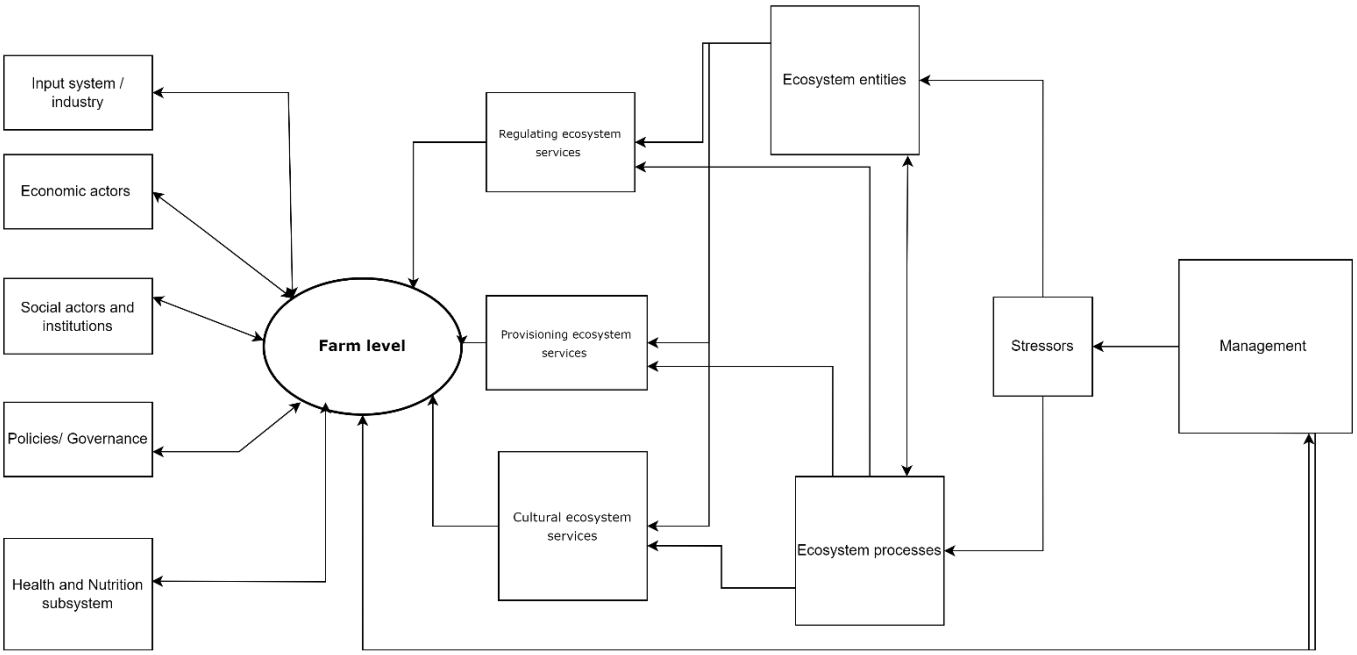

Figure 2. A representation of the flow of ecosystem services within the agri-food system

The social-economic players that interact with the agricultural/farming system are represented by five subsystems: economic, inputs, health and nutrition, policy, and social actors and institutions. Human activities (management), which are the response of the farmer to the demands and interactions with the socioeconomic components, are the major drivers for generating pressures and mitigation efforts. Pressures and mitigation efforts increase or decrease stressors that alter the ecosystem's characteristics (entities and processes) resulting in changes in ESS provision. In addition, the amount of ESS exploitation influences the magnitude and type of pressures (Grizzetti et al., 2016).

The causal loop relationships

In line with the overall objective of COMBINE, a causal loop model was developed to address the impact of promoting best practice through the living lab approach. Through the causal loop analysis, we built a simple model to show the implications of the changes on system subcomponents. Below is a diagram that represents a schematic structure of the causal loop diagram (CLD), illustrating some common relations and dynamics of the food system. This CLD highlights some selected feedback loops that might arise if there is a reduction in pesticide use as an example of best practice.

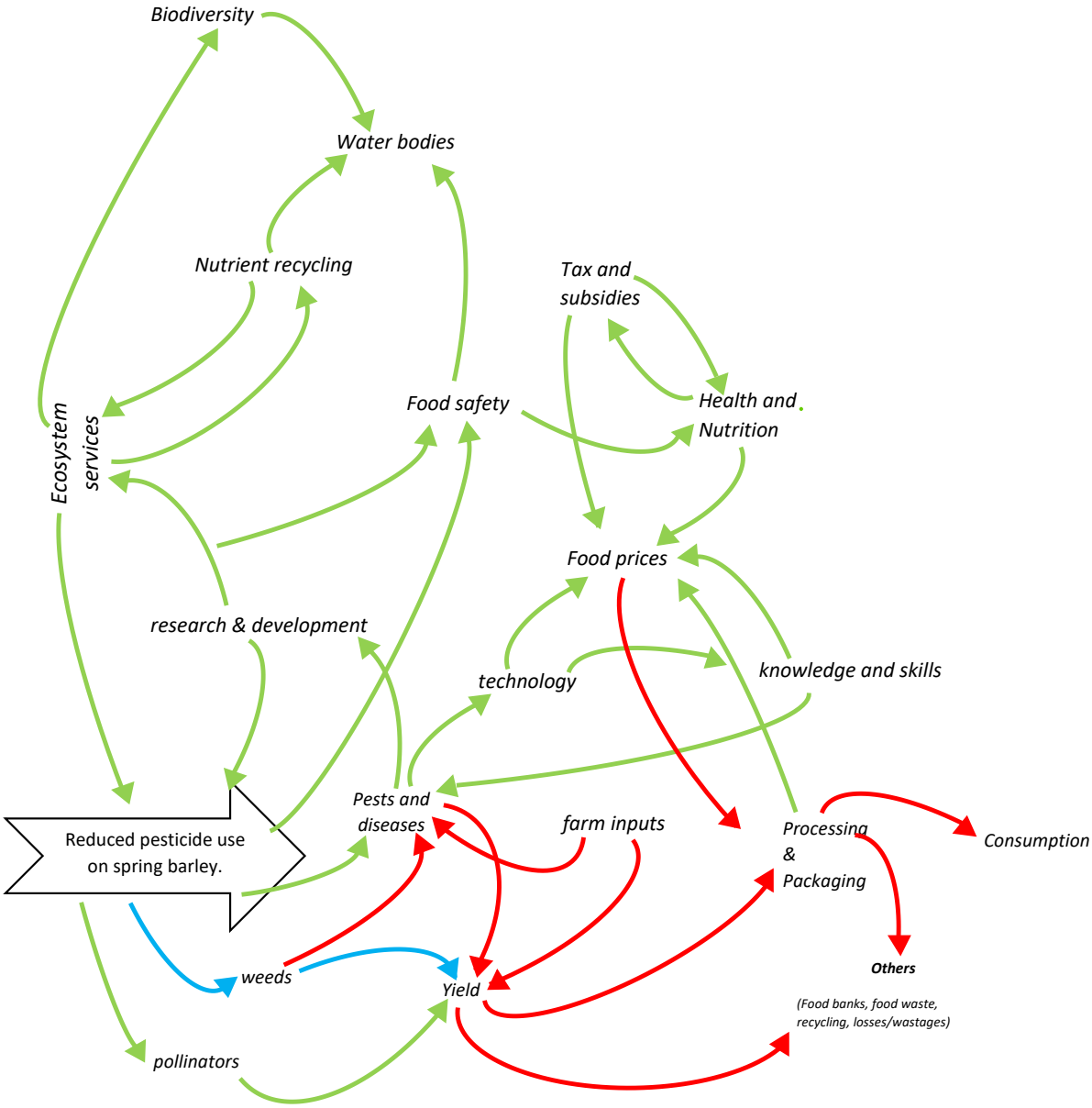

Figure 3. The Causal loop diagram exploring the implications of reduced pesticide use on agrifood system components. Green lines, represent a positive effect of one component on another, red lines represent a negative effect, and blue lines for no change.

The CLD (Figure 3) does not capture all elements and relationships but is restricted to the key components with the objective of producing a simplified diagram that stakeholders can contribute to. This will also help to understand the impacts of farm level interventions not only on the agrifood system but on the ecosystem components and the ecosystem services. The causal loop diagram shows the implications of reducing pesticide use both on the crop yield, and on the other facets of production in the ecosystem on farm.

Conclusion and Discussion

This report represents an early effort to understanding the food system in the Scottish context, and to unpack the connections therein. This will also be useful for identifying entry points and effects of changes on the whole or part of the system. We hope to do more on the role of ecosystem services in the food system and

how there may be affected by changes in the production domain. This will be used as a basis for further engaging with the stakeholders in the agrifood system as the COMBINE project progresses.

References:

Haines-Young. R and Potschin. M. 2017. Common International Classification of Ecosystem Services

(CICES) V5.1 Guidance on the Application of the Revised Structure. Available from www.cices.eu

Costanza. R., R. d'Arge, R. De Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R.V. O'neill, J. Paruelo. 1997. The value of the world's ecosystem services and natural capital. Nature 387: 253-260.

Ericksen PJ,(2008)Conceptualizing food systems for global environmental change research,Global Environmental Change, Volume 18, Issue 1,Pages 234-245,ISSN 0959-3780, https://doi.org/10.1016/j.gloenvcha.2007.09.002.(https://www.sciencedirect.com/science/article/pii/S0959378007000659

Felipe-Lucia M.R., A.M. Guerrero, S.M. Alexande, J. Ashander, J.A. Baggio, M.L. Barnes, Ö. Bodin, A. Bonn, M.J. Fortin, R.S. Friedman, J.A. Gephart , K.J. Helmstedt, A.A. Keyes, K. Kroetz, F. Massol, M.J.O. Pocock, J. Sayles, R.M. Thompson, S.A. Wood, L.E. Dee. Conceptualizing ecosystem services using social-ecological networks. Trends Ecol Evol. 2022 Mar;37(3):211-222. doi: 10.1016/j.tree.2021.11.012. Epub 2021 Dec 27. PMID: 34969536.

Grizzett. B., D. Lanzanova, C. Liquete, A. Reynaud, A.C. Cardoso. 2016. Assessing water ecosystem services for water resource management. Environmental Science & Policy 61: 194-203. doi: 10.1016/j.envsci.2016.04.008

Homann-Kee Tui Sabine, Roberto O. Valdivia, Katrien Descheemaeker, Trinity S. Senda, Patricia Masikati, Milton T. Makumbe, Andre F. van Rooyen, Chapter 8 - Crop-livestock integration to enhance ecosystem services in sustainable food systems, Editor(s): Leonard Rusinamhodzi, The Role of Ecosystem Services in Sustainable Food Systems, Academic Press,2020,Pages 141-169,ISBN 9780128164365, https://doi.org/10.1016/B978-0-12-816436-5.00008-1 [https://doi.org/10.1016/B978-0-12-816436-5.00008-1].

Potschin. M.B and Haines-Young. R.H. 2011. Ecosystem Services: Exploring a Geographical Perspective. Progress in Physical Geography: Earth and Environment 35. doi: 10.1177/0309133311423172

Probst, G., & Bassi, A. (2014). Tackling Complexity: A Systemic Approach for Decision Makers (1st ed.). Routledge. https://doi.org/10.4324/9781351287647

Zhang, W., Gowdy, J., Bassi, A.M., Santamaria, M., DeClerck, F., Adegboyega, A., Andersson, G.K.S., Augustyn, A.M., Bawden, R., Bell, A., Darknhofer, I., Dearing, J., Dyke, J., Failler, P., Galetto, L., Hernández, C.C., Johnson, P., Jones, S.K., Kleppel, G., Komarek, A.M., Latawiec, A., Mateus, R., McVittie, A., Ortega, E., Phelps, D., Ringler, C., Sangha, K.K., Schaafsma, M., Scherr, S., Hossain, M.S., Thorn, J.P.R., Tyack, N., Vaessen, T., Viglizzo, E., Walker, D., Willemen, L. and Wood, S.L.R. (2018). Systems thinking: an approach for understanding 'eco-agri-food systems'. In TEEB for Agriculture & Food: Scientific and Economic Foundations. Geneva: UN Environment. Chapter 2, 17-55.