Flow approaches in agrifood systems research: Revealing blind spots to support social-ecological transformation

Article Type: commentary

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Allain, S., De Muynck, S., Guillemin, P., Morel, K., Teixeira da Silva Siqueira, T., & Aissani, L. (2024). Flow approaches in agri-food systems research: revealing blind spots to support social-ecological transformation. *Agroecology and Sustainable Food Systems*, 1–23. https://doi.org/10.1080/21683565.2024.2421977

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Abstract:

Agrifood systems are called upon to transform in depth, as they are a major contributor to changes in the Earth system. The development of “flow approaches” - socio-environmental impact assessment methodologies (including lifecycle assessment, carbon footprint, ecological footprint) and metabolism methodologies – has been crucial to draw up this diagnosis. In a logical sequence between diagnosis and action, flow approaches are currently being used as decision support tools. But what are the biases induced by flow approaches when it comes to supporting real-world transformations? Based on our experience and interdisciplinary background, we raise the point that flow approaches offer a decontextualized and narrow framing of issues linked to agrifood systems (such as cumulations and transfers in place and time, inequalities and asymmetries along the chain of activities, long-lasting environmental impacts, among others). Some aspects are measured and emphasized while others are difficult to observe or are neglected. Flow approaches, alone, are not well suited to inform on environmental justice issues, radical transformations, and local governance issues. As in most cases methodological advances will not suffice to overcome the biases induced, we call for hybridizing methods and for widening analytical perspectives.

Keywords: social metabolism, LCA, environmental footprint, environmental justice, SDG 12: Responsible consumption and production

1. INTRODUCTION

Since the industrial revolution, and especially after the mid-twentieth century, the impact of human activities on the environment has drastically increased and has become one of the main drivers of changes in the Earth system that exceed geological forces, with irreversible consequences (Crutzen and Steffen 2003). Economic activities, in particular, generate polluting emissions that have an impact on water quality (eutrophication and acidification), on air quality (acidification, creation of low-level ozone and depletion of the ozone layer), on the climate, and generally on the health of ecosystems and human beings (Rockström et al. 2009). They also consume resources, notably non-renewables (fossils and minerals, water and land), generate new synthetic entities such as (micro- and nano-) plastics (Persson et al. 2022), and modify the habitability of various regions of the world for human and non-human populations (Pörtner et al. 2022).

Some of the biggest contributors to environmental impacts and spatial inequalities are global agrifood systems (Oteros-Rozas et al. 2019), which the Food and Agriculture Organization (FAO) (Anon 2021) defines as follows: "agrifood systems encompass the entire range of actors and their interlinked value-adding activities in the primary production of food and non-food agricultural products, as well as in food storage, aggregation, post-harvest handling, transportation, processing, distribution, marketing, disposal, and consumption"**.** The FAO has also pointed out that "agrifood systems interact with non-food supply chains through the purchase of inputs such as fertilizer, pesticides, and farm and fishing equipment, and the provision of intermediate inputs for the production of non-food commodities (e.g. maize for biofuel production or cotton for textiles)". Following Kleinpeter et al. (2023), we add to this definition the activities linked to nutrient flows and waste management.

In their dominant form, agrifood systems are characterized by long, globalized and ramified value-chains, geographical specialization and open biogeochemical cycles (nutrients, carbon), with no regard for fair and equitable value-sharing and environmental sustainability (Ericksen 2008). Rethinking the organization of agrifood systems and related narratives is undoubtedly one of the main paths to a desirable future.

Political hope for reducing the severe environmental footprint of dominant economic models, including the global agrifood system, has lain largely in productivity gains and technological innovations (i.e. decoupling). This hope has however been challenged, due to historical evidence and thermodynamic laws (Allain et al. 2022; Parrique et al. 2019) showing that the growth and complexification of socioeconomic systems are closely entangled with resource consumption and waste generation. Calls for transformative changes have increasingly been made, as well as demands for reopening the spectrum of possible socio-economic models. Meanwhile, regional and local actors are maneuvering within the leeway they have, to face global challenges. For instance, many innovations are emerging at local scale in agrifood systems, both technically (e.g. agroecological farming practices, innovative waste and water treatment) and at the organizational level (e.g. local food supply, water and waste management relying on industrial ecology approaches, collective governance).

The symptoms of the “global crisis” are however increasing and the quantity of matter extracted, used and turned into built stocks, waste and pollution on Planet Earth, has never been so big (Haas et al. 2020).

Since the year 2000, energy and matter flow approaches have become very popular in academia to reveal the “material side” of our economies (Bringezu et al. 2003). These flow approaches adopt material and/or energetic metrics to characterize the functioning of cities (urban metabolism (Zhang 2013)), nations or regions (societal metabolism (Gerber and Scheidel 2018)), to trace the footprint of products and value chains (Godar et al. 2015), to ecodesign products, and to design circular industries (industrial metabolism (Wassenaar 2015)). Weight equivalent or energy equivalents are among the most frequently used metrics, since they enable large-scale accounting that differs from classical economic values[1]. An increasingly wide spectrum of economic activities and resources (with the creation of large databases) has been integrated. Methods have also been developed to evaluate the efficiency, viability and even fairness of activities, and to articulate these evaluations to prospective and anticipatory thinking, for instance about the vulnerability of agrifood systems (in the face of pandemics, climate change, and energy crisis).

Growing attention is being paid not only to the input flows of matter and energy, but also increasingly to their outputs in terms of environmental and social impacts. This has led to the development of lifecycle thinking, which has for instance extended the assessment of an agricultural product’s impacts from “farm to fork” and then from “cradle to grave” (Caffrey and Veal 2013). Many assessment methods and applications are now available for this purpose.

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[1] For example EROI (energy returns on investments, Cleveland et al 1984); embodied energy (Odum 1984), HANPP (human appropriation of net primary production, Imhoff et al 2004); and ecological footprint (Wackernagel et al 1998), among others.

In the following, we use the term “flow approaches” to refer generally to socio-environmental impact assessment methodologies (including lifecycle assessment, carbon footprint, ecological footprint, etc.) and metabolism methodologies. All these approaches relate to material and energy flows. Some explicitly focus on the identification and quantification of these flows between the socio-technosphere and the biosphere to estimate the consequences of the former on the latter; others include only flows in their metrics and analysis, or additionally cover other aspects of social-ecological interactions.

The counterpart of the “flow approaches” boom (**fig. 1**) is that it unavoidably creates a framing bias on how we consider – and *a fortiori* reduce – the impacts of production and consumption systems. Some aspects are measured and emphasized while others are difficult to observe or are neglected. Behind methodological and robustness issues, flow approaches are known to be techno-economic centered (Cherp et al. 2018), although their use is oriented towards more and more complex issues, including governance.

We acknowledge the advances made since the beginning of flow approaches and their success in raising awareness on the link between consumption/production choices and the socio-environmental crisis. However, with regard to the above-mentioned issues, we consider that the focus of flow approaches, as they spread in technical, economic and political arenas, is too narrow to consider transformative social and organizational options for change. What is unseen and mismeasured cannot lead to collective action.

The insights of this paper were elaborated during a week-long interdisciplinary workshop on material flows linking cities and hinterlands, and involving researchers from various fields – ecological and agricultural economics, agroecology, environmental engineering and assessment, geography, urban ecology and sustainability sciences – and approaches – participatory-action research, engineering and expertise, and academic research. The aim of this paper is to highlight some limitations in flow approaches, which currently make them inaccurate to properly guide collective choices. As in most cases methodological advances will not suffice to overcome the biases induced, we argue for hybridizing methods and for widening analytical perspectives.

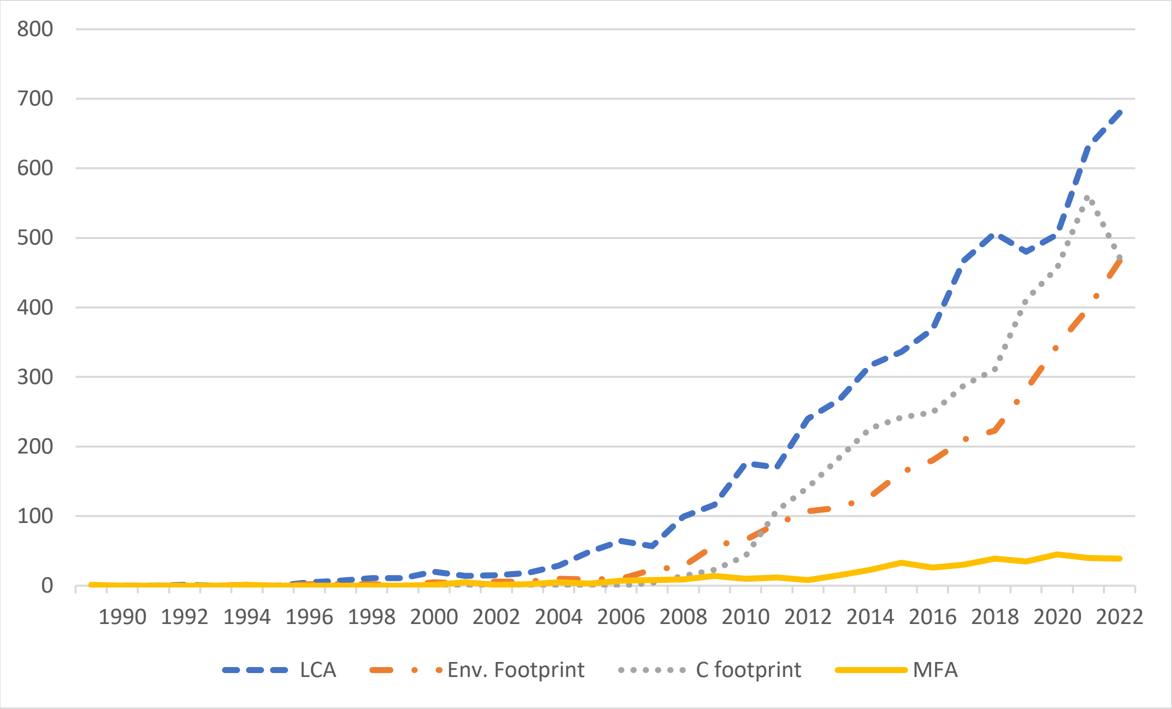

Fig. 1: Scientific production in four strands of flow approaches applied to agrifood systems

(SCOPUS database, 1989-2022)

LCA = Life cycle assessments

Env. Footprint = environmental, ecological, water footprints

C footprint = Carbon footprint

MFA = material and/or energy flow analyses

Four database searches were applied to provide an overview of different flow methods (without aiming for exhaustivity):

TITLE-ABS-KEY ((agrifood OR agricult* OR agrofood OR farm* OR "food system*") AND ("life cycle assessment" OR "life cycle analysis"))

TITLE-ABS-KEY ((agrifood OR agricult* OR agrofood OR farm* OR "food system*") AND ("environmental footprint" OR "ecological footprint" OR "water footprint"))

TITLE-ABS-KEY ((agrifood OR agricult* OR agrofood OR farm* OR "food system*") AND ("carbon footprint"))

TITLE-ABS-KEY ((agrifood OR agricult* OR agrofood OR farm* OR "food system*") AND ("material flow analysis" OR "energy flow analysis" OR "social metabolism"))

2. THE SHORTCOMINGS OF FLOW APPROACHES – A NARROW AND DECONTEXTUALIZED MODEL OF ACTIVITIES AND ACTORS

2.1. Contested reductions: provisioning rather than production; quantity rather than quality; orders of magnitude rather than contextualized analyses

Flow approaches, by essence, spotlight quantities of matter and energy that move from one physical compartment to another. In the case of agrifood systems, these flows are numerous but the main interest has to do with provisioning the different parts of the food production chain and ensuring food security, a question that garnered renewed attention in the Covid-19 context. Another focal point is the supply of energy from agricultural products, co-products and wastes, which has increased in the energetic transition context. However, any spotlight shadows other aspects, in the present case, socio-technical systems of production (which are much broader than provisioning flows alone) and flow qualities (by contrast with flow quantities). A production system embeds technologies and techniques, processes, work organizations, and infrastructures, which are connected in a complex way. These socio-technical connections create lock-in effects and historical dependencies, limiting the possibilities for innovations to emerge and spread (Geels 2005). Provisioning and quantities are only the tip of the iceberg, and without a more comprehensive look at production systems, many forces (e.g. technological choices, the nature of processes) driving flows of matter and energy become neglected. These reductions are not neutral, especially when research is tied to policy, as the Brussels case exemplifies (see Box 1).

Box 1: Reductionist approaches to food and energy systems in the Brussels Region

The political agreement on "burden sharing" between the Belgian regions set a target for energy production from renewable sources at 0.073 Mtoe (or 849 GWh) for the Brussels-Capital Region in 2020. This is one of the reasons given by the Brussels Government for creating a regional biogas plant (Government of the Brussels-Capital Region, 2019) – a technological choice oriented towards energy production, and economic profitability, that –barely took into account other relevant fields: quality of outputs, autonomy of actors, reduction of flow intensity, and the spatial structure of flows. This choice could place the Brussels Region in a situation of path dependency, particularly because: i) it is difficult to imagine that the Region will invest in the next few years in new centralized treatment infrastructures (e.g. central composting unit), given the significant investments made in the biogas plant; and ii) there is a risk that local biowaste treatment initiatives (e.g. decentralized collective composting) will not scale up significantly, given the convenience of centralized organic waste sorting (orange bag in front of the home). This choice also risks generating multi-scale tensions between actors who want to implement socio-ecological innovations. For example, green waste (including shredded material) produced in the Brussels Region is increasingly considered as a resource for many local stakeholders who need it to supply their activity (composts from citizen neighborhoods of about 10t/year/unit, municipal composts of several hundred tons per year per unit, urban entrepreneurs who collect biowaste by electric bicycle and compost it in meso composts of tens of tons per year per unit, etc.). The macro technological choice to install a biogas plant could therefore absorb most of the available green waste streams, to the detriment of socio-ecological practices in use at lower scales (micro, meso). Focusing the management of biowaste on energy supply needs, without a concerted and multi-actor platform allowing for an equitable distribution of flows, nor attention to the quality of outputs (industrial digestate vs. composts from a variety of treatment practices), therefore seems problematic.

Many applications of flow methods rely on generic databases, which are valuable sources of information about orders of magnitude in resource intensity use and the impacts of agrifood systems (e.g. (Renner et al. 2020)). For instance, Life Cycle Assessments (LCA) quantifying greenhouse gas emissions and land use have helped to highlight the environmental performance of farming systems (Siqueira and Duru 2016) and diets (Clark and Tilman 2017). These conclusions help identifying micro and macro levers of change towards a more ecological agrifood system.

However, because the origin of the references used for assessments is often unclear or inaccurate for specific conditions, assessments can lose their reliability at local scale. The problem does not come from the method itself but from a naïve use of results to aid policy choices and technological orientations at the regional or local scale. This is for instance the case when comparing end-of-life processes for food waste – industrial anaerobic digestion versus nearby composting – in an urban region. A rough comparison would favor the former, based either on flow quantities (see Box. 1) or on conventional LCA (Le Pera et al. 2022). However, the two processes are actually difficult to compare because they serve not only waste management but also other functions: energy generation from anaerobic digestion, and societal functions (social link, community empowerment) in the case of nearby composting. In addition, the two options rely on very different socio-technical rationales (economy of scale versus reduction of waste collection), hence putting into question the relevance of a comparison that is only quantitative. Assessing the local desirability of each option through this single lens could even be counterproductive (Box. 1).

2.2 A view "from the inside", masking extraction and disposal functions

Although the decreasing stocks of usable resources and the increasing quantity of waste have been alerting scholars for at least half a century (Boulding 1966), the study of agrifood systems through material flows does not easily integrate consideration of upstream resource extraction and downstream disposal or 'sink' functions (burial, emission, discharge, export).

In agrifood systems, the relative contribution to greenhouse gas emissions of pre- and post-production activities has been increasing, compared to that of farm activities (Tubiello et al. 2021). Other major environmental problems result from upstream and downstream flows of the food system (extraction and disposal). A well-known example is the deforestation impact and social conflicts of the agribusiness economy, in which soybean is a major input (Sauer 2018). Other issues, such as water contamination are also gaining attention, but mostly at the watershed scale (e.g. eutrophication), rather than across longer distances (e.g. sargassum accumulation (Djakouré et al. 2017)). The processes of collection, sorting, digestion, and composting or incineration of biowaste, associated with downstream flows, also involve the production of various pollutants: not only nitrogen and carbon emissions but also micropollutants such as microplastics (Weithmann et al. 2018) and heavy metals (Zheng et al. 2022), which remain under the radar.

Life Cycle Assessments (LCA) inform on a wide set of negative externalities, but despite advances, they still face the problem of the relevance of "characterization factors" (used to translate a flow into an impact), especially when the impact is place dependent. There have been attempts to use spatialization to spotlight areas that are highly resource intensive or specifically sensitive to an environmental impact (Aissani 2019). However, this spatialization approach in LCA is not generalized and is heavily dependent on expert practices.

More importantly, the paradigms developed to analyze agrifood systems offer a view "from the inside", allowing for diagnosis of the efficiency, resource-intensity or autonomy of farming and food systems (Renner et al. 2020). Although highly informative, these analyses are not designed for identifying the costs borne by the spaces and actors outside agricultural production or consumption basins. For example, the dependence of specialized agrifood systems on imported fertilizers (for crops) and nitrogen-rich feed (for livestock) is a matter of concern (Le Noë et al. 2016), but the focus is on the economic and agronomic vulnerability of the agricultural production, especially in the global North. Likewise, many studies characterize the “outsourcing” or “linearity” of a system in terms of nutrients, raw materials, energy and/or water, for example (Billen et al. 2014), but fail to provide any specifications on the geography of these relations of dependence. In short, informing extraction and disposal functions is constrained by the limited capacity of available methods and databases to spatialize flows; but these blind spots are also symptomatic of a Western-centered and productivity-driven knowledge base on agrifood systems.

2.3. Governance and justice issues reachable only within reduced perimeters

Reorganizing activities in order to close nutrient loops and redistribute values and burdens requires new modalities of coordination of people, nature, activities and technologies. This seems more easily achievable within a small perimeter than across large and loose webs of actors. However, there is no doubt that the most impactful systems are those embedded in global networks. Research and action for environmental justice would benefit from a better spatialization of flows. Places that cumulate functions of extraction and disposal remain weakly identified (Bahers et al. 2020). This raises the issue of recognition – since the people and ecosystems that carry most of the burden of agrifood systems (namely extraction and disposal functions) are not clearly identified. The distribution and organization of flows also generate injustices relating to distribution. For instance, if compost made from urban organic waste is sold to peri-urban farmers, micropollutants can accumulate on the long run in vulnerable peripheral areas. Moreover, agrifood systems are much larger than their organic fraction and generate macroplastics, per- and polyfluoroalkyl substances (PFAS), among other pollutants of low bio-degradability, through transportation, distribution, storage, and cooking for instance. This creates considerable issues of intergenerational injustice. The last dimension of environmental justice – participation – is not specifically linked to flow approaches but to the use of engineering tools as authoritative arguments rather than as partial insights. Examples of flow approaches used as tools to collectively redesign agrifood systems are exceptions, and when they do exist, experiments on them are run within reduced geographical perimeters (Gabriel et al. 2020).

2.4 Little capacity to support systemic transformations

Innovations often occur in niches, carried out by actors who are experimenting with and testing new options, which by definition are evolving. This implies a lack of stabilized knowledge, data, and references on innovations (Morel et al. 2020). The lack is moreover compounded by the fact that academic research and funding are mostly locked in supporting the improvement of dominant mainstream technologies and systems, rather than focusing on radically alternative ones (Meynard et al. 2018) or exnovation, that is, bans, destabilization, and shutdowns of certain technologies and innovations(David 2017). This lack of knowledge makes it difficult to assess the extent to which and the conditions in which the wide diversity of technological and organizational alternatives could contribute to enhancing sustainability of agrifood systems. For example, relevant data on alternative farming practices, food, water and waste technologies are not commonly found in flow inventory databases (van der Werf et al. 2020).

The types of metrics and indicators used in flow approaches also determine the comparison between different technological and organizational options. For example, LCA do not account well for some key concerns linked to agrifood systems, such as soil degradation and biodiversity. Moreover, LCA is based on a decoupling rationale (decoupling between environmental impacts and growth domestic product) but is not suited to other types of transformation such as degrowth or absolute sustainability. In a decoupling logic, the central expectation for agriculture is its productivity, and environmental impact is commonly expressed per unit of product. It thus favors input-intensive production systems and land sparing logics, since environmental impacts are mathematically diluted by higher levels of production. As our experience shows, proponents of productivist agriculture can even instrumentalize flow approach results to gain political support. At the very least, biases linked to the limits of available knowledge and the choice of productivity-centered functional units can, by cumulation, reinforce societal and political belief in business-as-usual transition trajectories(van der Werf et al. 2020).

3. RESEARCH DIRECTIONS TO CONNECT FLOW APPROACHES WITH A SYSTEMIC AND TRANSFORMATIVE GOAL

Based on the above-mentioned limitations, we argue that a research effort needs to be made towards extending “flow approaches” and reconnecting them with systems thinking (**Fig. 2**).

3.1. Extending the perimeter of flows and issues under consideration

We argue that three inter-related subjects need to be considered simultaneously: improving our understanding of extraction and disposal functions; the spatialization of flows; and the integration of environmental justice issues – be they matters of of recognition or of distribution. Furthering the research effort in these three domains is certainly a prerequisite to increase the capacity of flow approaches to support fair and sustainable transitions of agrifood systems.

The growing research on food supply chains uses the concept of foodsheds “to describe the linkages between food-producing and food-consuming regions at different scales” (Schreiber et al. 2021). Work on local or regional self-sufficiency (e.g. Metropolitan Foodshed and Self-sufficiency Scenario (Zasada et al. 2019)) thus shows that these foodsheds go beyond regional and national borders. However, while these types of models focused on production and consumption certainly do integrate environmental resources as limiting factors (soil fertility, altitude and rainfall), they do not integrate the environmental footprint of inputs (energy, machinery, animal and plant seeds, fertilizers, and machinery). This extension of the assessment would certainly reveal much wider extraction and supply sheds, including for alternative and local supply chains (Schott 2019).

In fact, addressing the whole agrifood chain implies the analysis of upstream flows and very precise attention to the socio-ecological impacts of inputs. Some studies have attempted to explore these upstream flows. They have, for instance, pointed out the contradictions of agrifood systems’ relocation projects in the case of market gardening ((Guillemin 2020): pp. 282-291) or of the agri-energy bioeconomy (Marty et al. 2021). They have shown that farming systems relying on imported inputs have strong environmental and geopolitical implications, which need to be documented. Examples are dehydrated legume fodders in the Aube *département* in France needing South

African coal, or a market gardening system relying on a drip irrigation system produced in a territory under disputed occupation. Extraction is indeed a function in agri-food systems that is highly sensitive to geopolitical and environmental conflicts, due to the spatial concentration of certain resources. There is a research front here, that could identify influences in the agrarian extractivism literature (McKay et al. 2021) which studies the extractivist principles of agribusiness models, and in methods coupling multi-regional input-output analysis with LCA or other footprint assessments (Papangelou et al. 2021).

Another blind spot that has been emphasized is the downstream flows of the agrifood system, linked to its losses and to waste. The identification of "disposal" sheds would be valuable to locate the impacts of agricultural production and food consumption. It seems particularly important to identify and locate value-chain components that drive polluting emissions and downstream flows and wastes. Certain components of agrifood systems, particularly distribution and logistics, might appear specially impactful (Tubiello et al. 2021), since they are energy intensive and resort on the petrochemicals industry (e.g. plastic food containers). The development of new metrics, such as value-added-based responsibility (Piñero et al. 2019) could improve such reporting, and help to highlight levers of change, including exnovation, outside the strict perimeters of production and consumption.

More easily attainable may be advances that could be made on the organic portion of agrifood flows. At local level there is room for redesigning systems, since organic matter and nutrients are both a pollution and a resource, and waste flows do not operate over very long distances. At the metropolitan scale, the disposal function is concretely disconnected from agricultural production and could increasingly be analyzed and co-designed in an integrated approach that reconnects production, waste management and water management (De Muynck and Nalpas 2021). Many innovative systems for "closing loops" are underway, and the refinement and contextualization of flow methods and databases, coupled with participatory approaches, could support such advances. On a wider scale, the challenge is to redistribute the nutrient load across space and biophysical compartments, which would in this case require policy instruments of a legal or regulatory nature (e.g. rights to nutrients (Kahiluoto et al. 2015)).

3 .2. Accounting for the complexities of real ecosystems, human practices and organizations

The various functions that constitute agrifood systems, as well as other socioecological systems – extracting, producing, consuming and disposing of waste – are all inter-dependent. We can easily assume that the more we consume, the more we produce, extract resources, and generate wastes and pollutions. However, these different functions do not relate in a linear way. For instance, farming systems relying on agroecological approaches (e.g. integrated crop-livestock systems, agroforestry, permaculture, etc.) can reach high levels of production with limited use of external inputs as they tend to close nutrient cycles at the farm level (Sileshi et al. 2020; Morel and Léger 2016). At the same time, very efficient production processes, supposedly low resource and low waste, can trigger increases in demand and consumption through rebound effects(Horvath et al. 2019), and end up having bigger environmental footprints. Informing these complex relationships is key to activate virtuous levers of change and avoid maladaptation. Complex systems thinking, and especially the focus on the interactions it induces (dependencies, interdependencies, positive and negative feedback loops, emergencies), could be a way to reflect on the relationships between extracting, producing, consuming and disposal functions. Frameworks such as social-ecological metabolisms (Giampietro et al. 2009) or multi-level transitions to a circular economy (Iacovidou et al. 2021) pave the way for doing so, although key sociotechnical interactions underlying flows of matter and energy remain under-investigated. In this respect, pioneering practices and ground experiments are invaluable sources of knowledge.

Reconnecting flows with the activities, infrastructures and processes that originate, direct or drive them also involves contextualization. Identifying drivers (Papangelou et al. 2023), either levers or brakes, can help characterize links between the context and the dynamic evolution of a system. In agrifood systems, local conditions drive and constrain opportunities for change, so there is a need to account for the physical systems and ecosystems supporting food production, as well as for the institutions organizing resource-users-waste relationships. Social-ecological (Himanen et al. 2016) and socio-technical (Ceschin and Gaziulusoy 2016) systems approaches should therefore be more explicitly convened in flow approaches, and drive the evolution of assessment methods towards more comprehensive reflection on the diversity of agrifood systems.

Whether it is for modeling the system or its function(s) and its impacts, we call for a shift from modeling that is intended to be as 'objective' as possible (i.e. outside any other consideration and therefore out of context) to 'pluralistic' and ‘situated’ modeling. Objective modeling aims to represent a system univocally in space and time, whereas 'pluralistic' modeling aims to represent a socio-technical system with an equivocal inscription in time and space. Such a precautionary approach to modeling (Allain and Salliou 2022) could foster reflection on the framing biases introduced by conventional life-cycle, footprint or sociometabolic frameworks. Rather than producing above-ground assessments of processes, products, diets, or farming systems, these methods could, inside transdisciplinary and action-research, support the emergence, assessment, and implementation of alternative and locally-informed agrifood systems.

In order to implement this pluralistic approach, it is therefore necessary to have the capacity to navigate between the different methodologies, the many existing tools, the various databases, and the different conceptual frameworks, and to bring them into dialogue.

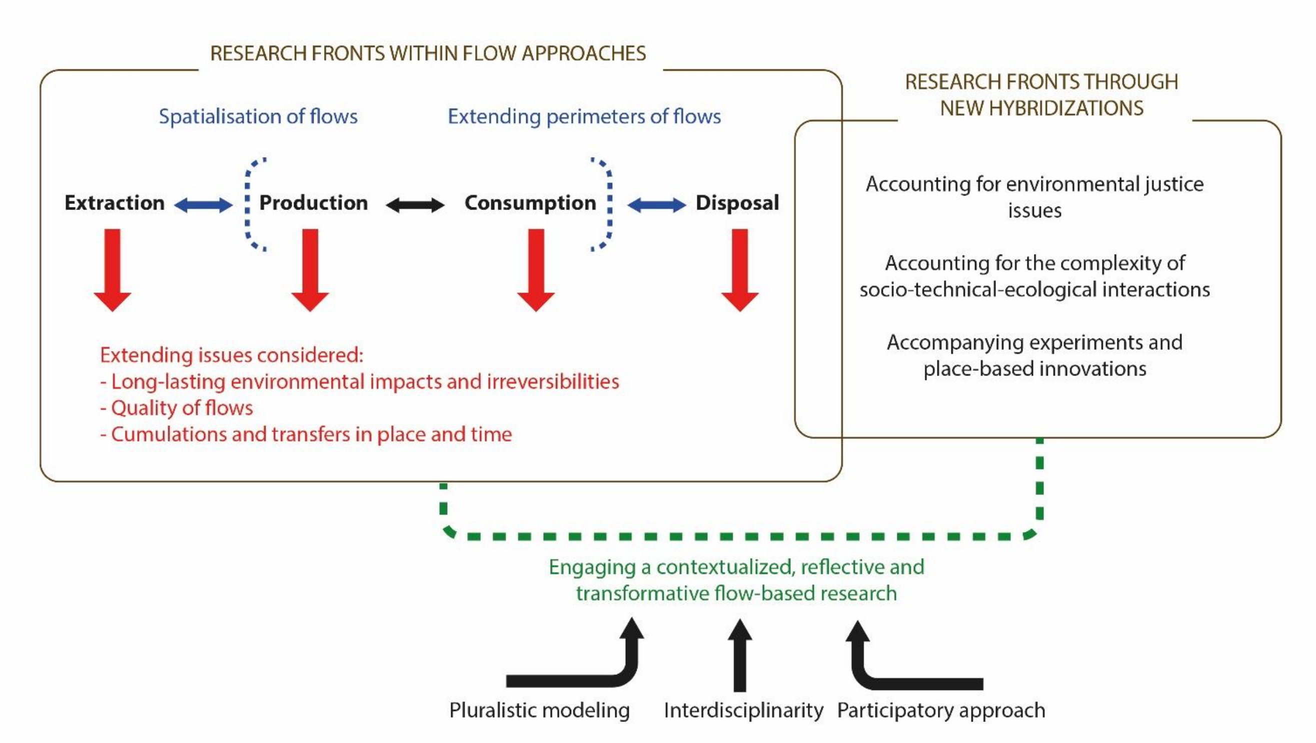

Fig. 2: Research fronts to foster the use of flow approaches for agrifood systems' transformations

4. CONCLUSION

The major changes occurring in the ways we produce, distribute, transform, consume, and dispose of agricultural products (not only food, but also feeds, fuels and waste) contribute to making social-ecological systems increasingly wicked, and disconnecting in time and space both causes and effects, pressures and impacts. Flow approaches constitute a framework that has the noteworthy merit of revealing some of these blurred links, and with them the extent of the “great acceleration” (Görg et al. 2020) of material, water, nutrient and energy consumption, as well as waste and pollution production, occurring in the last decades.

However, the insights gained from LCA, social metabolism, and environmental footprints, among other flow methods, do not suffice to induce collective action; there are actually serious doubts that increasing knowledge plays in favor of transformative changes. From a disruptive tool calling for a great transformation (Krausmann et al. 2008; Allaire and Daviron 2017) of our economies, and particularly of agrifood systems, flow methods have actually become mainstreamed and downscaled in their use, sometimes leading to oversimplifications or even instrumentalization. Some may see them as part of a “great derangement” (Nightingale et al. 2020): a dualistic conception of the world supporting technological fixes, such as intensive farming models or industrial waste management systems.

We therefore advance that an emerging science front lies not only in methodological sophistication, but also – and more importantly – in the capacity to hybridize flow approach results with other forms of knowledge and action about agrifood systems, such as environmental justice, socio-technical transition, and agroecology. There is certainly an unexplored playground at the crossroad between engineering approaches – moved by a “problem-solving” endeavor – and critical approaches – moved by a will to deconstruct prevalent socio-technical imaginaries – that could support transformations at different levels. This hybridization requires not only interdisciplinarity, but also a stronger commitment with stakeholders leading or experimenting with change.

ACKNOWLEDGMENTS

We are grateful to the various participants to and coordinators of the MOSAIC project seminars; presentations and discussions offered a fertile ground for elaborating this reflection. We are particularly indebted to Anne Trémier and Rémi Lombard-Latune, who were involved in the initial stages of this writing. We also thank Rachel Boutrou who was in charge of facilitating the week-long interdisciplinary workshop that set the stage for this paper, and, at the other end of the process, to Liz Carey-Libbrecht who corrected the written form of the manuscript.

DECLARATION OF INTEREST: The authors declare no conflict of interest.

FUNDING INFORMATION

This paper benefitted from the funding support of INRAE metaprogram BETTER.

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