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Transitioning agri-food systems into circular economy trajectories§

Luigi Cembalo[1,*],
Massimiliano Borrello[1],
Anna Irene De Luca[2],
Giacomo Giannoccaro[3],
Mario D'Amico[4]

[1] *Department of Agricultural Sciences, University of Naples Federico II, Italy*
[2] *Department of Agriculture (AGRARIA), University Mediterranea of Reggio Calabria, Italy*
[3] *Department of Agricultural and Environmental Science (DiSAAT), University of Bari Aldo Moro, Italy*
[4] *Department of Agriculture, Food and Environment (Di3A), University of Catania, Italy*

E-mail: *cembalo@unina.it, massimiliano.borrello@unina.it, anna.deluca@unirc.it, giacomo.giannoccaro@uniba.it, mario.damico@unict.it*

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**Corresponding author*

Circular Economy (CE) might be the paradigm to re-conceptualize future agri-food industries and recreate a balanced co-existence of ecological and economic systems. Research is then called to find solutions for transitioning into CE. The current paper will apply the theory of socio-technical transitions as a framework to build a step by step procedure to analyze and manage agri-food circular economy transitions and support stakeholders involved. The agro-ecological (cultivation and harvesting), agro-industrial (food processing) and consumption (food purchase) subsystems of agri-food supply chains are analysed to address the main challenges for the transition into CE. The current paper final goal is to generate an analytical framework, for practitioners and policy makers, to identify suitable technological, market, coordination and regulative solutions to orient future CE trajectories.

1. Introduction

The call to transform industrial systems through a circular economy (CE) model has gained prominence. Circular economy narrative proposes a shift toward a completely new way to satisfy societal needs (Borrello et al., 2020b), based on a clear and direct inspirational meaning: "the way we make things is wrong and we must change it" (Borrello et al., 2020a, p. 4069). Accordingly, scholarly literature has grown exponentially during the last years, proposing technical, managerial, and regulative

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solutions, and approaching crosswise several industrial systems. This paper focuses on the agri-food system, particularly with the goal to generate an analytical framework, for practitioners and policy makers to orient future agri-food CE trajectories.

Current industrial agriculture is based on an extractive model with the exploitation of non-renewable resources (e.g. fossil fuels and mineral phosphate) (Clay, 2013), as well as on the production of relevant amounts of wastes. A circular agri-food system would be based on restorative and regenerative practices, as well as on the commitment of several stakeholders, to mitigate the impact of current industrial agriculture. On the one hand, collaborations within and between the agro-ecological (primary production) and agro-industrial (commercial food production) agri-food subsystems might generate intra/inter-company material metabolisms to maximize the use of the inherent value of resources. On the other hand, CE practices would entail stakeholders' participation, with consumers eventually called to support companies engaged in CE. While nowadays there is plenty of technologies applicable in such type of collaborations, how making these technologies operational within fully functioning intra/inter-sectoral circular economy systems is still unclear (Borrello et al., 2016; Chinnici et al., 2019). Every single loop of a CE system could entail tackling major barriers such as political, legal, economic, social, and technological (Kirchherr et al., 2018) and building a circular agri-food system requires facing several challenges (Borrello et al., 2016). Therefore, once defined different agri-food trajectories (e.g. restorative in-farm practices vs. broader bio-economy utilizations) (Stegmann et al., 2020), facing these challenges is crucial to define which of these trajectories would be the most effective.

To this aim, the current paper provides an analytical framework for transitioning into circular agri-food systems, thus contributing to the field of inquiry of sustainable transitions management (Smith et al., 2005). Circular agri-food trajectories require extant supply chains to be adapted to CE principles (transitioning). Putting this differently, a CE model means to build on existent production-consumption systems to create an economy that "contribute to all the three dimensions of sustainable development", that limits material and energy throughout flow "to a level that nature tolerates" and "utilises ecosystem cycles in economic cycles by respecting their natural reproduction rates" (Korhonen et al., 2018, p.39). Resting on this assumption, the paper adopts as theoretical foundations a consolidated model of socio-technical transitions, i.e., the multilevel perspective (MLP) by Geels (2002, 2019). According to the MPL, transitioning socio-technical regimes go through a process by which niche innovations replace stabilized systems, mediated also by macrolevel (landscape) requirements and transformations. This process represents the background framework of this research. Even though in the future circular niche innovations are expected to undergo this process thanks also to landscape perturbations (e.g., the current COVID-19 pandemic caused also by conflicts in the human-environment interface, Zhou et al., 2020), an effective transition to circular agri-food systems should be governed, monitored (to verify the implementation of actually beneficial solutions) and stimulated (Smith et al., 2005). Therefore, the goal of this paper is to suggest a multi-step analytical guiding framework for managing transitions into agri-food CE systems. More specifically, the paper adapts the framework proposed by Gorissen and colleagues (2016) to the context of agri-food systems. As it will be shown further by means of the elaboration of each step of the framework, the governing transition starts from the study of the existing linear system at hand, identifying knowledge gaps and lock-ins for the transition to a circular counterpart. This analysis allows also to identify circular pioneers and closed-loop innovations to consider in the transition process. Starting from this initial assessment, the paper suggests the valuation and comparison of suitable transition trajectories from the ecological, social, and economic perspectives, thus addressing all the three sustainability pillars.

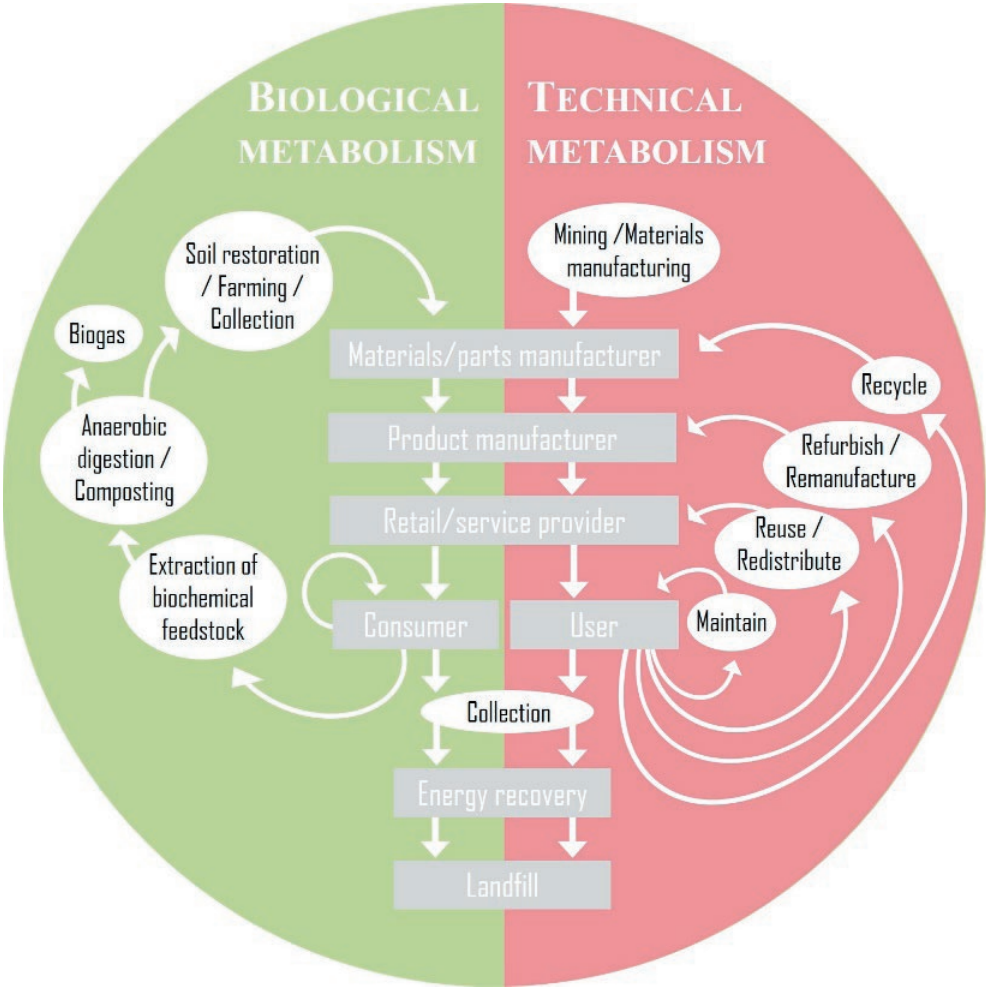
This paper contributes to the existing literature by providing a set of guidelines on how approaching to agri-food circular economy transitions. The great potential of the CE narrative is that stimulates the creation of novel industrial solutions by design (EMF, 2012). Political efforts are currently pushing investments and research in this direction, lately with actions included in the recent Horizon 2020-funded European Green Deal Call (e.g., the call LC-GD-3-2-2020: Demonstration of systemic solutions for the territorial deployment of the circular economy). However, building new intra/intersectoral collaborations based on closed-loop metabolisms is not an easy task, as well as assessing their desirability is not trivial. The following sections seek to provide instructions on how approaching systematically to this challenge.

2. Literature review

2.1 Theoretical background on circular economy

The fast changes occurred after the industrial revolution have conveyed a dualistic representation of ecological and economic systems (Heikkurinen et al., 2016). Rather than supporting a worldview in which economy is a subset of the environment — that is, arguably, "the way things really are" (Gibson, 2001, p.11) — current economic system exploits ecosystems, nowadays reduced to 'source' and 'sink' of resources and wastes needed to foster economic growth. Circular Economy (CE) is the latest policy and academic approach to address this current and long-standing issue (*e.g.*, European Commission, 2015; Lieder and Rashid, 2016; Sauvé et al., 2016; Murray et al., 2017). CE narrative posits a paradigm of economic development in which economic growth and natural resource consumption are decoupled (UNEP, 2011; Ghisellini et al., 2016) and where, thanks to regenerative and restorative industrial design (Morseletto, 2020), the traditional "take-make-dispose" linear pattern of resource consumption is abandoned (EMF, 2012). A CE model would extend the life cycle of materials, making the waste of one industry the input of the same or another industry and thus maximizing the utilization of the value embedded in them (*cf.* the industrial ecology concept and the life's principle "waste=food"; Frosch and Gallopoulos, 1989; Benyus, 2002). Furthermore, it would generate economic value from waste produced at each

Figure 1. Metabolisms in the Circular Economy.



Source: Borrello et al. (2020a), adapted from EMF (2012).

stage of supply chains, including post-consumption (Fischer and Pascucci, 2017). According to the CE framework proposed by the Ellen MacArthur Foundation (EMF, 2012), two types of materials constitute the current industrial system: biological and technical nutrients (Fig. 1). While biological nutrients are biodegradable and can re-enter natural metabolisms (Smol et al., 2015), technical ones follow technical metabolisms through reuse, remanufacture or material recovery (Tukker, 2015). The current paper concerns biological nutrients, more specifically focusing on the agri-food system.

In biological metabolisms, CE aims at maximizing the value generated from biological nutrients through different practices and technologies, contributing to prevent and effectively manage wastes and by-products (Mohan et al., 2016). Biological nutrients are assumed to flow from one company to another, imitating (*i.e.* complying with) the processes of organic mineralization-synthesis occurring in biological ecosystems. Undergoing cascades of consecutive industrial processes, biological nutrients can be processed to produce biochemicals and biomaterials and then fuel biogas plants to produce energy and digestate. Furthermore, regenerative agricultural practices can valorise agricultural losses and residues in-farm.

Even though a set of attributes of a CE system seems to be widely accepted by scholars, “there remains a lack of clarity about what “circular” actually means in practice” (Gladek, 2019). Several efforts have been made so far to devise a suitable definition of CE. To illustrate the extent of current conceptual endeavour, Kirchherr et al. (2017) gathered from the scholarly literature 114 definitions of CE. While some authors “seem to have no idea about what [CE] is” (Kirchherr et al., 2017, p.229), others argue that it is not clear yet in which way it differs from sustainability and which type of relationship occurs between the two concepts (Geissdoerfer et al., 2017). One interpretation of the latter issue is the one suggested by Sauvé et al. (2016). According to these authors, sustainability has broader societal objectives compared with circular economy. However, CE is a tool for sustainability, based on reshaping production and consumption models, that gives “a clear angle of attack to help solving environmental problems” (ibid., p. 55). In a nutshell, CE is a way to achieve sustainability, that proposes a set of solutions (e.g., cradle-to-cradle processes, industrial symbiosis, replacing downcycling with upcycling, circular business models). Starting from their implementation by pioneering innovators at niche level, these solutions are expected to replace in the future well-established linear systems, after having undergone a transition process.

2.2 A brief overview of transition theory

The theory on socio-technical transitions (Geels, 2002, 2010, 2019; Smith et al., 2005) explicitly addresses issues related to the dynamics of change. It defines a transition as a transformation, often radical, in response to a “… a number of persistent problems confronting contemporary modern societies” (Grin et al., 2010, p. 1). To illustrate, a transition requires disruptive changes “in the ways of organizing (structures), ways of thinking (cultures) and ways of doing (practices)” (Gorissen et al., 2016, p.3). Literature shows a great interest in this field of inquiry providing different lenses to increase the operational aspects of transitions. Among these: the multilevel perspective, where interactions are mainly seen between scales; the multiphase perspective, where the development is seen between phases; and the multipattern perspective, that describes how a transition is possible thanks to different patterns (Rotmans, 2012).

Applying transition theory to the CE, the common idea emerging from the different perspectives is that circular innovations should propagate and substitute

Table 1. Guiding framework with elements to consider for a transition management.

Type	Description
Analyzing the system	Understand how the current systems functions, what does and what does not work, what is appropriate and what is not
Envisioning	Imagine how we would like the future system to look like and function, what is desirable, what is sustainable
Exploring trajectories	Explore how we can evolve from the current situation to the envisioned system and what trend breaks are required
Experimenting	Explore how the chosen trajectories can be translated into practical actions and how the trend breaks can be induced
Assessing	Monitor the transition process through follow-up and reflection on all actions, events, policies and strategies that influence the transition in question; and hence feed a process of social learning, which is a prerequisite for eventual success
Translating	Translate the lessons learnt into change-inducing actions in order to incrementally transform ("transitionize") the system, closer to a dynamic sustainable equilibrium

Source: adapted by Gorissen et al., 2016.

linear solutions (Borrello et al., 2020a). Putting this differently, a socio-technical transition into CE in different industrial systems would entail the emergence of several incremental processes of innovations at niche level (*i.e.*, transition trajectories), that would eventually lead to replacing the linear way to fulfil societal needs (cf., Kwakkel and Yücel, 2014). Among the three approaches mentioned above, transition trajectories are best described by the multilevel perspective (MLP) (Geels, 2002). The MLP focuses on how sustainable configurations change over time from a continuous interaction among processes at niche level (radical innovations promoted by pioneer activities), system level (technical, political, social, and cultural, business models or infrastructural configurations), and landscape level (e.g., demographics, cultural repertoires, societal concerns, geopolitics, macroeconomic trends, ecological dynamics, wars, financial crises, and oil prices shocks) (Geels, 2002, 2019; Borrello et al., 2020a). The way it is supposed to operate is illustrated by Geels (2019, p.190): "(a) niche-innovations gradually build internal momentum, (b) niche innovations and landscape changes create pressure on the system and regime, and (c) destabilization of the regime creates windows of opportunity for niche-innovations, which then diffuse and disrupt the existing system."

According to the MLP, "transition management takes a process approach that aims to change the dominant culture, structures and practices of unsustainable systems by linking innovations at the microlevel to macrolevel changes in mindsets" (Loorbach et al., 2010, p.137). Since a change involves a wide spectrum of actors (*i.e.*, companies, governments, researchers, etc.), a governance perspective is needed to analyze processes of transformation aiming at developing strategies to accelerate the transition. Gorissen and colleagues (2016) suggest a combination of mutually reinforcing operational steps and activities related to the transition management (Tab. 1). These activities constitute a guiding framework rather than a chronological sequence of steps. The current paper describes specific activities adapting these indications to a specific industrial sector, namely agri-food systems.

3. Analytical framework

3.1 Analyzing the system

The first step of the guiding framework of Gorissen and colleagues (2016) following this logic has suggested understanding the current system and its functions, with the definition of challenges and lock-ins that make the transition slow or not observable at all. Most of agri-food supply chains may be conceptualized as a three-block system constituted by primary production (agro-ecological subsystem), commercial food production (agro-industrial subsystem) and consumption (Fig. 2).

Starting from this configuration a number of challenges can be identified for transitioning into a CE model (Tab. 2). To illustrate, each subsystem has to face four main challenges preventing the adoption of circular strategies, namely technological, market, coordination and regulatory. The four challenges are derived adapting and summarizing the contents of two recent papers concerning CE challenges (Borrello et al., 2016 and Kirchherr et al., 2018), thus being generalizable to a great extent. The challenges presented are generated by different issues per each subsystem (Tab. 3). The challenges are the following:

- Technological: both farms and processing companies use technologies and practices often conflicting with CE principles (*e.g.*, Løes and Adler, 2019). Transitioning into CE might not be easy depending on different factors (*e.g.*, farm structure, farm size). Furthermore, assuming different CE trajectories, it is not sure what would be their impact, as well as which trajectory would significantly improve the *status quo*. As it will be better explained later, this issue requires specific impact assessments of different technology implementation scenarios.
- Market: transitioning into CE entails new ways of doing business in the agro-ecological and agro-industrial subsystems. Circular business models (CBMs), in which value creation is based on maximizing the economic value of materials, must be adopted (Lewandowski, 2016; Linder and Williander, 2017). Although consumers are increasingly interested in non-hedonistic aspects of food (Giannoccaro et al.,

Figure 2. Stylized configuration of agri-food supply chains.

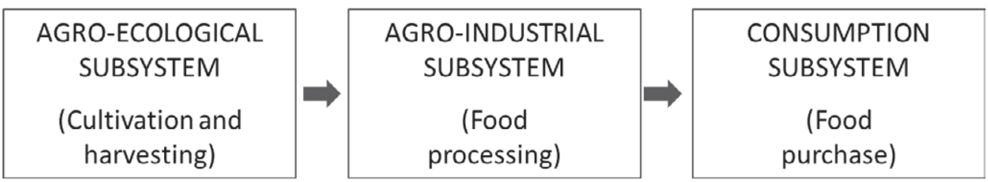


Table 2. Challenges for the transition into agri-food circular systems.

Supply chain subsystems	Challenges			
	Technological	Market	Coordination	Regulatory
Agro-ecological	- Adoption of circular farming technologies and practices;	-Adoption of circular business models	- Farmers' willingness to participate to CE trajectories;	- Obstructing laws and regulations
	- Lack of data on impacts.		- Organization of farms (within this subsystem; between this subsystem and the following; with actors of other supply chains)	
Agro-industrial	- Adoption of circular processing technologies and practices;	-Adoption of circular business models	- Entrepreneurs' willingness to participate to CE trajectories;	- Obstructing laws and regulations
	- Lack of data on impacts.		- Organization of supply chain (within this subsystem; between this subsystem and the following; with actors of other supply chains)	
Consumption		- Consumers' interest, acceptance and participation		

Source: adapted from Borrello et al., 2016 and Kirchherr et al., 2018.

2019b), their habits are far from being changed. As for this barrier, CE entails a more participative consumer (Borrello et al., 2017; Camacho-Otero et al., 2018) willing to be engaged and to support circular supply chains through his preferences.

- Coordination: CE entails cooperation among firms for the exchange of biological materials. Thereby, new organizational arrangements and specifically designed contracts must create incentives for participation to CE, integrating and coordinating actors in the process of exchange materials, realize common investments, and coordinate activities (Raimondo et al., 2018; Giannoccaro et al., 2019a). However, one of the most pressing barriers for CE is finding farmers and entrepreneurs keen to participate in CE trajectories not only by adopting novel technologies, but also by adapting their business models and organizational structures (Zhu et al., 2011).
- Regulatory: CE strategies may also conflict with the established regulative framework (Hartley et al., 2020). To illustrate, Italian legislation imposes the invol-

vement of intermediate companies for the pre-treatment of wastes and by-products, thus decreasing the economic efficiency of circular interactions (Simboli et al., 2015). Another example is one of organic production standards that in some cases conflict with the farm adoption of recycled materials (Løes and Adler, 2019).

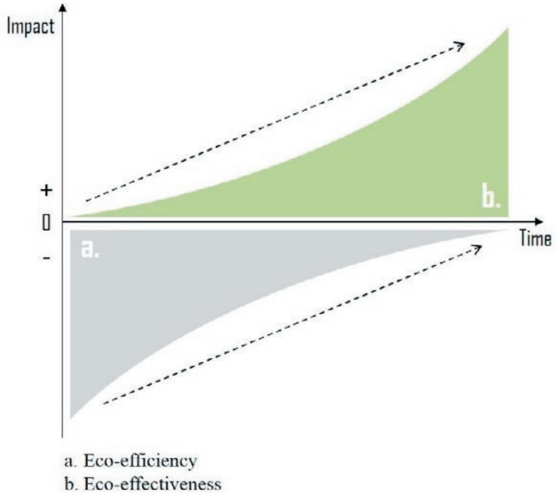
3.2 Envisioning and Exploring trajectories

Exploring how a system can evolve from the current situation (envisioning) and exploring how trajectories can be translated into practical action are the second and third steps of the MLP guiding framework. The current paper considers these two steps together since envisioning a system and looking at (experimenting) the trend-breaks required for a transition are meant to be an outcome of a

Table 3. Agri-food supply chain challenges and issue per subsystem.

		Technological	Market	Coordination	Regulatory
Agro-ecological subsystem	Issue	Product-specialized farms and strong territorial specialization	Smallholders farms	Weak cooperative setting	Linear model regulation
	Challenge	Innovate to regenerative farming practices and byproduct valorization	Innovate to Circular Business Models	Participate to circular interactions by cooperating with other farmers and along the supply chain	Setting regulation facilitating the exchange of farms/ firms biological materials
Agro-industrial subsystem	Issue	Highly specialized technology	Smallholders firms	Weak vertical integration	Linear model regulation
	Challenge	Supply of wastes and by-products to downstream industries Adoption of novel recycling technologies	Transition to sustainable (circular) business models	Participate to circular interactions by cooperating with farmers and downstream industries	Setting regulation facilitating the exchange of biological materials
Consumption	Issue		Linear pattern of consumption		
	Challenge		Commitment to support circular supply chains through consumers' preferences		

Figure 3. Eco-efficiency vs. eco-effectiveness.



Source: Borrello et al. (2020a), adapted from Braungart et al. (2007).

process where technical solutions are taken under consideration and innovation trajectories are defined. It is out of the scope of the current paper providing the latter in detail. However, some suggestions on how to proceed are provided. Starting from the list of challenges, the *status quo* of each subsystem has to be compared with alternative trajectories based on CE principles and has to be assessed to choose among different alternatives (Fig. 3).

Issues reported condition the choice of trajectories that can be translated into practical actions. Each subsystem needs to be studied through a specific approach keeping in mind the *eco-effectiveness* of the whole system. Eco-effectiveness is a pillar of CE. To briefly describe eco-effectiveness, we start from the well-known concept of eco-efficiency. Eco-efficiency is a way to improve economic performance by reducing environmental impacts (Dyllick and Hockerts, 2002). Although reducing the use of energy, water, and resource inputs, as well as waste and pollutants, are welcome, these strategies keep on taking for granted linear material flows (Braungart et al., 2007). Eco-effectiveness goal, on the contrary, "is not to minimize the cradle-to-grave flow of materials, but to generate cyclical, cradle-to-cradle 'metabolisms' that enable materials to maintain their status as resources" (EMF, 2012, p.23). Therefore, whereas eco-efficiency strategies seek to reduce negative effects ("doing things right"), eco-effectiveness is based on envisioning new ways to produce materials, design products, and structure industrial systems and business models ("doing the right things") (Herrmann et al., 2015). Put differently, eco-efficiency approaches sustainability starting from negative environmental effects, with the final goal of striving for zero impacts. On the contrary, based on novel design, eco-effective innovations are ideally conceived to have zero impact from the beginning and to produce positive effects over time (Fig. 3).

The design of circular eco-effective products can be achieved by applying the concept of upcycling. Singh and colleagues (2019) define upcycling as "a process in which products and materials that are no longer in use, or are about to be disposed, are instead repurposed, repaired, upgraded, and remanufactured in a way that increases their value". Upcycling is meant, then, as a strategy that offers many subsequent lives to material objects, also with completely different functionalities (Bridgens et al., 2018). Contrariwise, the common recycling concept entails that recycled products or materials have a lower value than those they come from (Borrello et al., 2020a).

3.3 Experimenting

The experimenting step is crucial to explore how the chosen trajectories can be translated into practical operational activities. The current paper suggests a list, though not exhaustive, of possible empirical methodologies to address the mentioned challenges per each subsystem of agri-food supply chains.

3.3.1 Agro-ecological and agro-industrial subsystems

Most of current agri-food supply chains have to face four challenges (technological, market, coordination, regulatory) related to cultivation and harvesting, as well as to food processing. The ultimate objective is to trigger the adoption among farmers (especially smallholders) and entrepreneurs of circular technologies, business models, coordination strategies and to eliminate obstructing regulations for the adoption of CE trajectories.

A relevant decision to make is the geographic extension of the supply chain, namely the boundaries of the system at hand. An agri-food supply chain can be local, regional, composed of macro-areas, national or international, considering a path going from the location of providers to that of costumers. The criterion to identify the system boundaries depends on a trade-off among different factors, such as the need to have a thorough supply chain analysis, the need to simplify complexity, availability of data and relevance of the network elements for the supply chain at hand. Once decided how far the supply chain goes, it would be necessary to analyze current linear practices to have a comprehensive overview of farming/entrepreneurial practices with respect to farm/firm structure. Starting from this, alternative CE trajectories (*e.g.*, regenerative agriculture models, upcycling of by-products) can be selected. A methodological approach could be structured in three stages: i) data collection of official statistics regarding the structure and organization of the agri-food chain at hand in the target area/s; ii) identification and characterization of the most representative farm/firm typologies based on official statistics elaboration; iii) interviews with technical experts to gather information on current linear farming/entrepreneurial practices and technologies and the available alternative CE trajectories.

The market is also important. Its knowledge is relevant to generate guidelines for the most appropriate Circular Business Models (CBMs) to promote the adoption of CE trajectories at farm/firm level. A possible empirical strategy could be made of the following subsequent steps: i) mapping current factors constraining the transition towards CBMs through causal loop diagrams; ii) connecting technical solutions to the problems: coordinating the development of maps linking the constraining factors; and iii) connecting technical solutions to the actors: analysing the innovative ecosystems around the technical solutions introduced in the selected case.

A study concerning coordination is needed. It should focus on the attitude of farmers and entrepreneurs towards CE and on organizational elements. On the one hand, the study of coordination might examine stakeholders' perception of lock-ins to participate in CE by using semi-quantitative methods, combining a structured survey and experimental economics games like public good games or trust games. A Best-Worst Scaling (BWS) analysis would allow to rank circular trajectories on the base of readiness to be implemented, selecting market-driven incentives to enhance implementation. To assess stakeholders' willingness to adopt circular solutions, a survey could be submitted for getting information on farmers' stated preferences for technological, organizational, managerial items, under specific market incentives and regulatory frameworks. On the other hand, the organisational drivers towards agri-food management practices based on closed loops of nutrients, shared resources and diversified agro-ecological systems should be evaluated. It could be done by i) mapping potential circular agri-food systems; ii) identifying and analysing organisational drivers of resource efficiency, restoration and resilience in circular systems; and iii) using results obtained, it could be possible to co-create with stakeholders an interactive and online Circular Tool Kit (CTK) to identify key strategic issues related to the different trajectories.

A specific study on regulation is of paramount importance. A focus should be done on the identification of relevant attributes of potential public policies and laws that may foster the transition to CE trajectories. A possible empirical strategy could be analyzing the demand of policies and laws starting from the needs of practitioners in the sector. In order to design guidelines for a potential implementation of policy interventions able to encourage the development of CE trajectories, experimental works could be carried out implementing the Delphi method. Based on subsequent rounds in which experts are asked to provide their opinion on a certain issue, the Delphi method has already had wide adoption in agri-food research. For example, it has been used to develop food safety indicators and analyze food safety governance (Camanzi et al., 2019; Di et al., 2021), to design food label contents such as health claims (Hung et al. 2019) and to identify most relevant plant breeding techniques for future food security (Lassoued et al., 2018). The expected results would be the identification of regulatory, administrative and institutional factors, relevant for promoting the adoption of CE trajectories.

3.3.2 Consumption subsystem

In this subsystem, the aim would be to assess consumers' willingness to participate in CE models by buying food produced through CE initiatives. CE creates value by lending products extrinsic attributes related to the creation of resilient agri-food systems (Camacho-Otero et al., 2018; Borrello et al., 2017, 2020a; Giannoccaro et al., 2019b). Therefore, addressing one way to address consumers' issues consists in finding the conditions in which consumers can capture this value and support, through their purchase behaviour, companies engaged in CE. Specific research activities can cover different aspects. Here we suggest some that might be the following. A national representative sample of households to identify: a) consumer perceptions, expectations and preferences for food products with sustainable attributes; b) the most preferred products/attributes/innovations combinations; c) the most attractive segments of the market (targets) (Caracciolo et al., 2016; Giannoccaro et al., 2019b; Henchion et al., 2019; Staples et al., 2020). As for research designs, data could be gathered by means of choice-based conjoint models and analysis performed by means of statistical and econometric models (Anabtawi et al., 2020; Rizzo et al., 2020b). Also, non-hypothetical, incentive compatible (participants have real economic incentives to reveal their preferences, truthfully avoiding the hypothetical bias problem) framed field economic experiments could be implemented. More specifically, they could be useful to analyse consumer perceptions, expectations, and preferences for the selected attributes stemming from the national survey results. Among incentive compatible methods, BDM (Becker-DeGroot-Marschak) (Migliore et al., 2018; Riefler, 2020) and/or Random Nth price/Multiple price list methods (Strzok and Huffman, 2015; Jin et al., 2017; Lombardi et al., 2019; Rizzo et al., 2020a) might be implemented to elicit willingness to pay for innovative circular attributes. Non-hypothetical natural field economic experiments could also be performed in real food shopping environments (supermarkets, general and speciality stores), in targeted locations, to verify consumer preferences for the selected products, under different information treatments and with a control condition (Vecchio et al., 2016; Menapace and Raffaelli, 2017). Non-hypothetical real choice experiments with information treatment might be implemented and Structural Equation Modelling (SEM) procedure applied on data gathered (Voon et al., 2011; Vecchio et al., 2016; Boobalan et al., 2021).

3.4 Assessing

The assessing step of this transition management approach is aimed to monitor the effectiveness of CE trajectories. This is part of a reflection and learning process aimed to identify best strategies and tune the elements of circular solutions. To this aim, Life Cycle (LC) approaches are useful to supervise impacts. We propose that the assessment step considers all three sustainability dimensions (environmental, economic and social) by implementing LC approaches at the agro-ecological and agro-industrial subsystems taken as a whole (De Luca et al., 2018). The objective would be to compare the observed linear production processes, with the alternative closed-loop trajectories identified in the previous steps, also in order to verify which are beneficial in environmental, social and economic terms (Fusco Girard and Nocca, 2017; Noya et al., 2017). Through LC protocols, it is possible to test environmental, economic and social performances of CE solutions, validating assumptions and generating feedback for improvement. A Life Cycle Sustainability Assessment (LCSA) is able to conclude the analysis by combining the three differentiated tasks: Life Cycle Assessment (LCA), environmental and conventional Life Cycle Costing (LCC), and Social Life Cycle Assessment (sLCA). These three methodologies have already found wide implementation in studies analyzing the impacts of the agri-food industry (see, for example, Roy et al., 2009 and Omolayo et al., 2021 for the LCA; Mohamad et al., 2014 and Peña and Rovira-Val, 2020 for the LCC; Prasara-A and Gheewala, 2019 and Sureau and Lohest, 2019 for the sLCA).

LCA is an environmental impact assessment methodology used to characterize and quantify the impacts in terms of specific mid-point indicators (e.g., Global Warming, Human Toxicity, Ecotoxicity, Water Depletion Potential) and/or end-point indicators (Human health, Ecosystem, Resources).

The economic impact assessment can be performed by using the LCC to analyze and evaluate the overall economic performances, identifying bottlenecks in adopting selected CE trajectories. LCC is a tool able to identify and quantify the main cost items, but also financial indicators of investment, throughout the life cycle stages, by classifying them in terms of initial costs, periodical maintenance costs, operational costs, and end of life disposal costs or residual value. In addition, eLCC (environmental Life Cycle Costing) can provide all costs associated directly covered by one, or more, of the actors involved in the products life cycle, including externalities that are anticipated to be internalized in the decision-relevant future.

Last, but not least, sLCA can be carried out to study whether the social performances (in terms of impact categories as, for example, working conditions, fair wage, psychosocial risk factors, etc.) of the CE trajectories identified (e.g., valorization of by-products) can be considered as significant improvements compared to conventional scenarios of production.

3.5 Translating

The last step of the analytical framework concerns the translation of insight emerged throughout former steps into actions able to actually stimulate circular trajectories. In this phase, the action of political actors is of paramount importance. Their actions should be aimed to support the implementation of CE trajectories and remove the barriers that prevent the adoption of circular solutions. On the one hand, policy makers are expected to provide financial support for researchers and practitioners directed to the implementation of the identified trajectories that have the best performances according to life cycle protocols. This support should be aimed to identify tailored case-specific solutions to address lock-ins related to the trajectories. By adopting participative and dynamic co-creation processes, this would provide farms/firms with a resilient structure able to face the challenges occurring during the transition. On the other hand, regulative barriers should be removed allowing the implementation of circular solutions. As for this, a process of harmonization of different regulations in order to assist CE not disregarding other pursued goals is necessary (e.g., considering waste management and organic farming practices, Simboli et al., 2015, Løes and Adler, 2019).

Even though the translation process cannot leave out of consideration public intervention, individual behavior of private actors is also crucial. Public intervention can provide incentives to private actors, but transitioning to CE requires a profound cultural modification. Even though it has remained implicit among the transition challenges considered in this paper, culture cannot be disregarded. Kirchherr and colleagues (2018) consider culture one of the most pressing barriers for CE, in terms, for instance of "hesitant company culture" and "lacking consumer awareness and interest". These criticisms might be expected to be reverted in the transition process by public intervention. However, at the macrolevel, Geels (2019, p. 190) considers "cultural repertoires" and "societal concerns" as landscape elements; furthermore, in his theoretical model, new socio-technical systems have a feedback impact on the landscape. By this logic, one could expect that future translating processes will include among its mechanisms a reciprocal influence of, on one side, novel and dynamic circular system configurations, and on the other side, cultural inclination of individual actors to engage in CE.

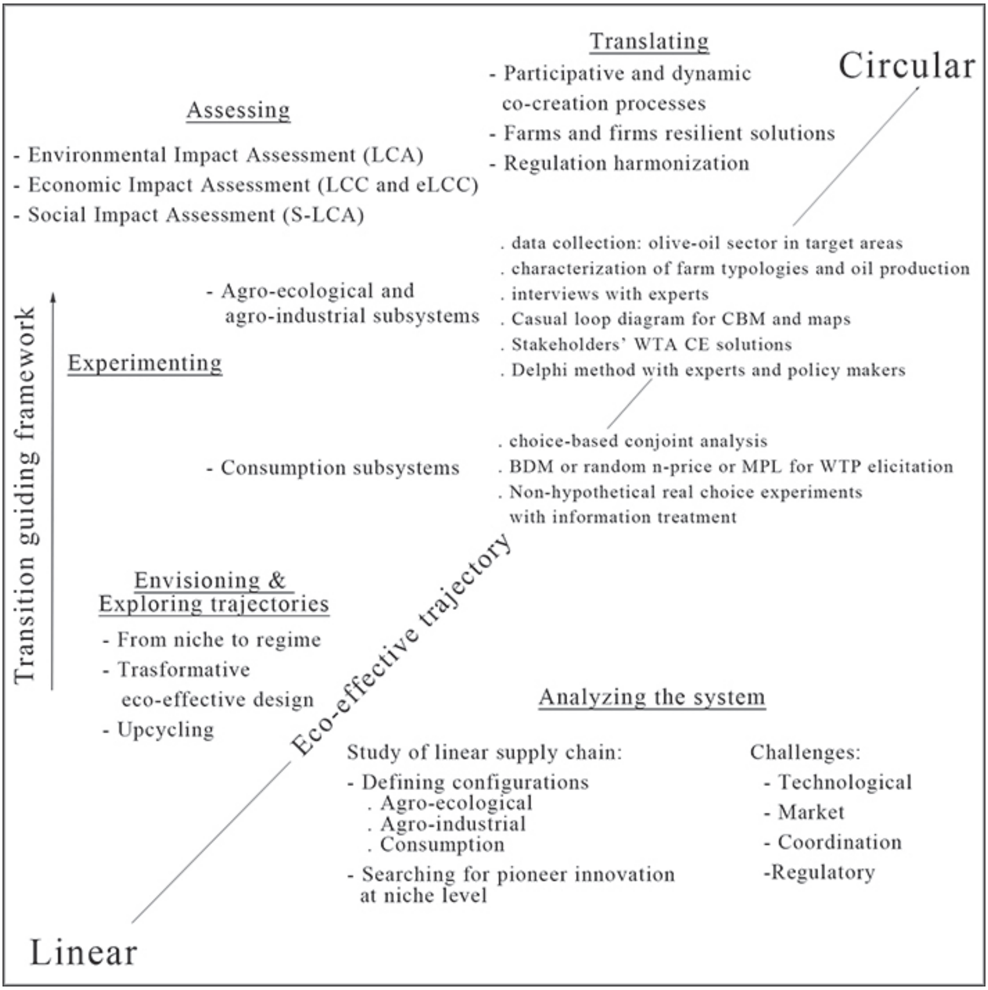
4. Conclusions

Grounded on the theory of socio-technical transitions, the current paper has suggested an analytical framework to identify suitable solutions for transitioning into agri-food circular economy trajectories.

One of the imperative issues that contemporary societies are facing is finding long-term solutions to recreate a balanced co-existence of ecological and economic systems. Circular Economy might provide in the coming decades the key paradigm to re-think the way we make things. Starting from the observation of the perpetual cycle of the elements within natural ecosystems, CE theorists suggest that future industries will have to adopt a restorative design to survive in a world where current exploitation rates of natural resources will be unacceptable. This might be particularly true for agri-food productions, where implementing CE would essentially consist in finding solutions to make value chains complying with biological metabolisms. This should be done by identifying integrated strategies considering the three blocks of industrial agri-food supply chains, namely primary production (agro-ecological subsystem), commercial food production (agro-industrial subsystem) and consumption.

To seek that circular agri-food systems will not remain a utopia, scholars are called to begin by applying and make operational the key elements of transition theory. A transition approach considers extant supply chains the arena on which building CE trajectories, by addressing the most critical challenges (technological, market, coordination, regulatory). Following this logic the current paper has suggested an analytical framework for effective transition management with two main objectives: i) study how to foster and manage the transition of agri-food

Figure. 4. Flowchart representation of the MLP guiding framework.



chains into a CE model; and ii) evaluate the impacts of different agri-food transition trajectories to CE.

We are aware that the range of approaches and methodologies is much wider than the one presented in the current paper. However, we believe that what is presented in this manuscript gives a systematic idea of a feasible analytical framework to implement and guide the transition of agri-food systems into CE (Fig. 4).

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