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Eco-innovation and digitalization of agri-food companies towards the circular economy: A pilot project for the evaluation of the impacts and circularity indicators for the agri-food chain

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**Abstract.** The circular economy aims to close the material cycle with a reduction in resources consumption and emissions released into the environment through the concept of productive metabolism. Indeed, the circular economy could provide tools to improve and optimize sustainability within the food system. The sector could, therefore, benefit from the development of strategies to promote a more circular approach to its operations. The application of the Circular Economy and the 3R approach (reduce, reuse, recycle) in the agri-food sector is essential to transform society and make production systems and communities more circular. This work aims to analyze the behavior of Italian companies in the agri-food sector for the development of a model that focuses on eco-innovation, digitalization, and ecological transition capable of embracing the principles of circular economy and climate neutrality through the creation of models for assessing the circularity and sustainability of businesses. Therefore, companies could benefit from a scientifically robust, tested, and validated reference model that can become a point of reference in the ecological transition process in the sector. To this end, it is planned to carry out an in-depth analysis of the literature that will allow the definition of a reference framework for circular agri-food supply chain and specific circularity KPIs applicable to the entire agri-food sector. Starting from the identification of the main environmental impacts of the sector, this work explores which circularity practices can be implemented. Furthermore, the indicators to measure circular practices in the sector will be identified, tested, and validated through a pilot phase with selected stakeholders.

**Keywords.** Circular Economy; Agri-food; Sustainable agriculture; Sustainability indicators; LCA.

**N.1. Introduction**

In recent years, climate change and the resources consumption have been at the center of the media and politics scene. Achieving a climate-neutral circular economy is today one of the primary objectives of all national and international policies. The European Union, in November 2018, published its long-term strategic vision for a climate-neutral economy by 2050 with the communication "A clean planet for all - A long-term strategic European vision for a prosperous, modern, competitive and climate neutral "(28/11/2018 - COM (2018) 773) (European Commission, 2018).

With this communication, the European Union presented its vision to achieve zero net greenhouse gas emissions by 2050. The European vision for a climate-neutral Europe is, however, also strongly based on the achievement of a circular economy as a key factor for this sustainable transition (Directorate-General for Climate Action -European Commission, 2019). In a historical moment also characterized by the pandemic emergency, the ecosystem must be understood as a planet but also as an economy and more generally as a container of social well-being. This is especially true for the agri-food sector. The agri-food sector is, in fact, responsible for both an excessive use of natural resources and various environmental damage (Shukla et al., 2020). This research project is placed in a national and international economic-social context in which the concept of global sustainability can become not only a necessary component for the survival of companies but, increasingly a competitive variable for the creation of value within of production chains (Poponi et al., 2021). Agriculture contributes between 21-37% of GHG emissions (food waste is responsible for 8% of these emissions) and over 58% of nitrogen emissions (300 times more harmful than CO2). This sector is also one of the main drivers of biodiversity loss, as it uses about 1/3 of the planet's earth for food production and accounts for 70% of freshwater withdrawals (Shukla et al., 2019).

The impact of agribusiness also entails enormous social costs. It has been estimated, in fact, that by 2050, with a population close to 10 billion, food production would increase by 70%. Furthermore, 1.3 billion tons of food are wasted every year and 820 million people go hungry. Ultimately, the effects of climate change will hit developing countries hard, where large numbers of people are employed in agriculture, as land productivity will decline (Shukla et al., 2019).

Agriculture is, in fact, at the same time the main cause and the main victim of the ongoing environmental crisis (Acampora et al., 2020). Agricultural practices, in fact, produce significant volumes of GHG emissions, the main cause of climate change. However, this sector suffers the most negative impacts of climate change, in terms of reduced productivity and higher risks related to food security. At the same time agriculture has great potential in the fight against climate change, in addition to reducing GHG emissions, through the introduction of sustainable agricultural practices, it is the only sector that has the ability to remove GHG from the atmosphere in safely and economically without reducing productivity (Mayhew, 2016).

For this reason, significant efforts have been made to introduce sustainability practices and indicators in the agri-food industry (Merli et al., 2018a). In particular, the sector could benefit from the development of strategies to promote a more circular approach to its operations (Ellen MacArthur Foundation, 2019; Jurgilevich et al., 2016). The application of the Circular Economy (CE) and the 3Rs approach (reduce, reuse, recycle) in the agri-food sector is essential to transform society and make production systems and communities more circular (Poponi et al., 2021, 2019).

The circular economy was, in fact, recently introduced as a pillar to guide all production and consumption activities and to simultaneously promote economic gains and reduce the environmental impact (Merli et al., 2018b). The European Union defines CE as: "*an economy in which the value of products, materials and resources is maintained in the economy for as long as possible and the generation of waste minimized*" (Rizos et al., 2016). While many industries are redefining their operating principles considering this approach, the potential of CE in the agri-food chain is still largely unexplored.

By adopting a circular approach, the sector could identify paths that combine the improvement of environmental performance with that of the reuse of secondary raw materials, which could arrive as inputs to the production process, also generating economic benefits (Ghisellini and Ulgiati, 2020; Tunn et al., 2019).The first step in this direction is the identification of potential areas for implementation of the CE in the agri-food sector, together with the development of specific indicators that could measure the circular potential of the industry. Today, both the implementation of circular principles and a system of circularity indicators in the agri-food sector are still missing (Acampora et al., 2017).

A fundamental part of the corporate sustainability strategy is the identification of indicators to measure performance. Indeed, to promote CE, it is necessary to measure the effectiveness of the strategies introduced at national, regional, or local level. Therefore, it becomes essential to introduce monitoring and evaluation tools as indicators to measure and quantify these progress (Geng et al., 2012; Su et al., 2013).

Despite the growing interest of scholars and professionals, research on indicators and methodologies to measure the level of application of CE strategies is still in its initial phase, particularly at the micro level (Elia et al., 2016), therefore, more efforts to establish a set of reliable indicators are needed. Some authors point out that using only one set of indicators at the micro level may fail to capture the full development of CE in different enterprises (Banait, 2016). To avoid this, each firm should set firm-specific indicators based on its existing characteristics, conditions, and problems (Su et al., 2013).

In this context, eco-innovation and the digitalization of agri-food businesses will play a fundamental role (Muscio and Sisto, 2020). In fact, the numerous innovations available, which allow for an increase in real-time information on the systems and professional skills of the subjects involved, represent an enabling factor for the development of circular agriculture. The components of Agriculture 4.0, sustainable from an environmental, social, and economic point of view, are fueled by the development of new ICT solutions, technological innovation in sensors, optical instruments, and robotics. In addition, advances in know-how and research on production systems and agri-food processing, all focused on cloud computing, will drive the ecological transition in the sector.

## N.2. Material and Methods

This project aims to analyze the behavior of Italian companies in the agri-food sector for the development of a model that focuses on eco-innovation, digitalization, and the ecological transition. The application of the principles of circular economy and climate neutrality will be analyzed through the creation of models for assessing the circularity and sustainability of businesses. The main aim is to create a scientifically robust, tested, and validated reference model that can become a point of reference in the ecological transition process of companies in the sector.

To this end, an in-depth analysis of the literature will be carried out, that will allow the definition of a reference framework and specific circularity KPIs applicable to the entire agri-food sector. In particular, starting from the identification of the main environmental impacts of the sector, this project explores which circularity practices can be implemented. Furthermore, the indicators to measure circular practices in the sector will be identified, tested, and validated through a pilot phase with selected stakeholders.

# N.3. Results and Discussion

This is a multi-stakeholder research project in which companies from the agri-food chain take part, with the scientific contribution of the researchers of the Roma Tre University Business Studies Department and the cross-industry vision of Enel X (the global business line of the Enel group that offers services for innovation, the energy transition and the circular economy).

The main actors involved in the project are Italian companies in the agri-food sector, in particular, those willing to start or consolidate virtuous paths of sustainability and circular economy, enhancing technical, managerial and scientific skills, with the aim of contribute to the transition to new business models.

The aim of the research project is to analyze the behavior of Italian companies in the agri-food chain to develop a model of sustainability that focuses on eco-innovation, digitalization, and ecological transition. Finally, through the creation of models for assessing the circularity and sustainability of businesses, it will analyze the level of application of the principles of circular economy and climate neutrality.

This research project is divided into the following phases:

* Planning and implementation of a continuous research activity aimed at mapping the scenarios and their evolution (next 5/10 years) of the agri-food sector, with specific attention to the main macro-trends and the effects on the national and international context.
* Carrying out activities of the dissemination of research results through conferences, workshops and digital initiatives, publication of papers and reports.
* Design and implementation of targeted training activities on research topics aimed at the development of talents and the transformation of technical skills, also following the expected generational change in the medium term. Participation in European calls on circularity.
* Establishment of a platform for listening and multi-stakeholder engagement, capable of involving the main operators of the food chain and of intercepting and analyzing the most significant trends underway in the sector, both internationally and nationally.

In detail, the following activities are planned:

* Analysis of the state of the art, through a systematic literature review of scientific literature and gray literature and the construction of a database of national and international projects related to the topic. Furthermore, an exploratory analysis based on case-study analysis of successful companies and related circularity indicators and impact assessment models in the agri-food sector will be developed.
* Development of the conceptual model and identification of industry-specific circularity KPIs in the food sector, processed on the basis of aggregated and anonymous data and development of the monitoring model. These KPIs can be used by partner companies to improve their circularity performance.
* Preparation of an annual report on the macro-trends of the sector and the ability of companies to apply the principles of eco-innovation and the circular economy along the entire supply chain, with concrete proposals for a real “circular” turning point, having as its object a chapter dedicated to the methodology for identifying the circularity KPIs.
* Data analysis to study the food sector in terms of innovation, digitalization, and circularity, identify the gaps and suggest a path for improvement to companies in the sector.
* Coordination of engagement, training and research activities for the annual report and development of any partnerships and institutional sponsorships.

**N.4. Conclusions**

The results of this research project are a benefit for the scientific community, but also for operators in the sector who will benefit from them for the purpose of the effective ecological transition of the sector based on a more structured strategy guided by scientific references. Understanding the dynamics of the agri-food sector in terms of ecological transition and circular economy can provide useful policy indications to increase the innovation potential and undertake training and communication actions aimed at entrepreneurs to improve their ability to design and implement effective innovative processes. It can also provide important elements for identifying priority areas of intervention towards which direct financial resources. This is because the research project aims to study the implementation of models for evaluating the circularity and adherence to the principles of ecological transition which are embedded in the reality of farms in the agricultural supply chain. Moreover, through careful data collection and subsequent creation of specific reports companies will be provided with sustainability information useful for decision-making process. The long-term aim is to introduce the principles of the green revolution, the ecological transition and the circular economy into the corporate strategies and sustainability assessments of companies in the sector, which are already very active. Through technological innovation and the digitization of business processes in the area of ​​environmental sustainability the aim is to propose increasingly sustainable products and foods on the market, in step with international competition. Furthermore, the agri-food sector represents both a productive and scientific excellence which, however, still presents both structural and system deficiencies but thanks to the new methodologies, including the one proposed in this project, it can also be a driving force for development of related sectors. such as tourism, the bioeconomy and more generally the green economy.

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