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A Framework of Collaborative Multi-Actor Approach Based Digital Agriculture as a Solution for the Farm to Fork Strategy

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Abstract. The Agri-food sector is tied to food and national security. Regardless of the circumstances, the degree of economic justification, and territorial readiness, all governments are investing to make sure that at least they could meet the local demand. But challenges in front of the Agri-food sector making this difficult. The suggested solution is collaborative multi-actor approach-based agriculture, which could be reached by utilizing emerging technologies. Smart or Precise agriculture are not new concepts, but most of the cases are still demonstration and not feasible on a large scale. In this paper, the concept of “Collaborative Multi-Actor Approach based Digital Agriculture” (CMDA) would be discussed from different perspectives, and the architecture of technology, business challenges of Implementation, and the Impacts would be analysed. The output will provide a framework of "Collaborative Digital Agriculture" as a solution for the European Farm to Fork strategy.

Keywords: Emerging Technology, Collaborative Digital Agriculture, Agri-Food Industry, Farm to Forks Strategy, Multi-Actor Approach, Digitalization, United Nations Sustainable Development Goals

1 Introduction

The agri-food sector is crucial not only from an economic point of view but from political, social, health, and environmental [1]. Food security is part of any plan, which plays an essential role in regional and national security[2]. Covid-19 Pandemic once again shows the importance of the Agri-food industry and the potential consequence risk of failure in the Food Value Chain (FVCs)[3]. In the European Union (EU), with more than 22 Million agricultural workers[4], including farmers and 4 million staff in food and drink industries, the Agri-food sector plays a vital role in the economy [5]. European Commission released the "European Green Deal," which gives a broader perspective cover different domains to transform the EU into a fair and prosperous society [6],[7]. The introduced "Farm-to-Fork" strategy with a holistic approach is the heart of the European Green Deal, targeting fair, healthy, and environmentally-friendly food systems[8]. This means the FVC from farming to processing, transportation, and

retailers, and finally, consumption by the final user would be considered in any plan. On the other hand, Sustainable Development Goals (SDGs) proposed by the UN, dealing closely with the agri-food industry, and the goals would be highly affected by this industry. The agri-food industry is still stuck to the traditional ways and needs a paradigm shift to cope with all the mentioned challenges[9]. Digitalization is the central pillar, and emerging technology is a solution to achieve the goals[10]. Concepts such as "Smart Agriculture", "Precise Agriculture," and "Agriculture 4.0 ", are used to show this digital transformation in the agri-food industry. The "4.0" trend is almost in all industries with many success cases, but the nature of the agri-food industry made this transition difficult. There are many scientific articles discussing technology assessment, acceptance, and adoption in the agri-food industry (e.g. [11]–[16]) focused on emerging technologies such as big data(e.g. [17]), artificial intelligence(AI) (e.g.[18], [19]) , UAVs (e.g. [19]), robots (e.g. [20]), self-driving systems (e.g. [21]), Internet of Things (e.g. [22]), and blockchain (e.g. [23]), and the barriers are identified and ranks in different research works. The challengers could be categorized in different ways, but one of the main issues is the nature of agriculture, such as distributed small farmers, seasonal mode, price sensitivity. All these characteristics lead us to new models, which are known as "Collaborative Agriculture", "CoFarming", "Cooperative Agriculture", "Crowd Farming" and similar ones[24]. Although they are not with precisely the same meaning but all common in Collaboration.

In this paper, we would like to discuss "*Collaborative Digital Agriculture*" from a *holistic perspective*. The result is from a qualitative research methodology and via the in-depth interviews, open-ended questionnaires, and several facilitated and guided meetings in different formats with different actors in the agri-food industry and ecosystem. Organizations, advocate associations, farmers, distributors, technology developers/providers/enablers, and research centres from different countries, including Portugal, Spain, Italy, Romania, France, Germany, Switzerland, Emirates, and Turkey, Iran, Tunisia were involved in this research. The main concentration was to know "How to develop a long-term strategy for the successful implementation of technology in FVC align with the Farm to Fork strategy?" Also, this exploratory study investigated impact of the CDA application outcomes on the 17 United Nations Sustainable Development Goals(UN-SDGs).

2 Holistic Perspective

Collaborative Digital Agriculture (CDA) is an ideal solution for most of the challenges of the agri-food Industry. This strategy vertically connects the nodes but should also horizontally cover all the processes to change the traditional dominant game. CDA is not just a technological challenge but a multidimensional dilemma in which a holistic approach is essential. In this section, beyond the technology itself, the main concerns and challenges are discussed and evaluated in a systematic way to understand how the digitalization process in the agri-food sector could impact the stakeholders involved in each of the life cycle phases and the society. The approach is based on the "Technology Assessment" models and theories to making sure the short and long-term consequences

in different areas such as societal, economic, political, business ethical, legal, would be considered. Figure 1 shows the holistic view of CDA.

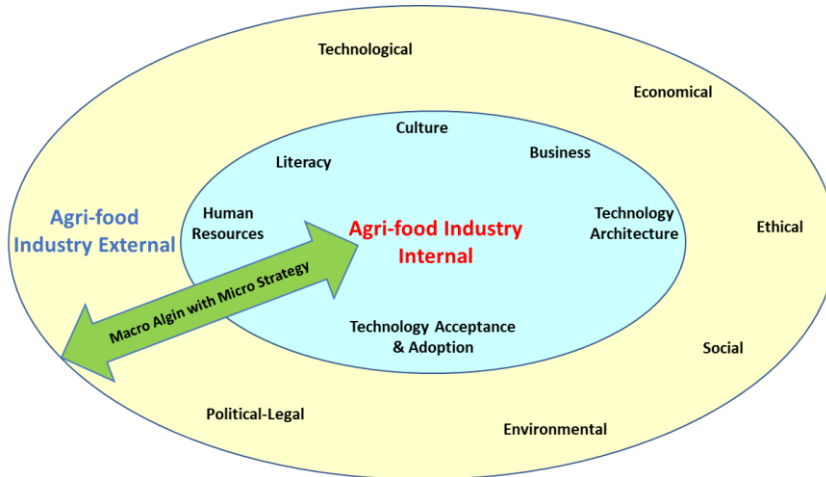


Fig. 1. The Holistic View of Collaborative Digital Agriculture

As could be seen, there are two main clusters, internal and external Agri-food industry, while the macro and micro strategy should support each other and be aligned to make CDA happens. In the following, the most critical issues of each one, extracted from interviews and meetings, are discussed.

2.1 Micro vs Macro Strategy

A wide range of innovative and affordable technologies have emerged to facilitate the creation, expansion, and streamlining of FVCs[25]. To successfully disseminate these technologies, entrepreneurs need to have Micro and Macro levels perspective to design-related strategies[26]. Successful business cases show new innovative technology would be successfully implemented when the micro and macro strategies meet each other. Considering the different nature of the micro and macro environments, having both strategies that suit each other and create synergy is great support for any business leader in the industry. CDA could not happen without these top-down, down-top aligned strategies. For example, technological innovation is the fuel that can run the engine of the agri-food business. The new technological solutions can build a smart agri-food value chain, while agri-food-tech start-ups are a meaningful solution across the agri-food value chain. They can provide a product, a service, or even an application that helps in the agri-food sector. The idea of empowering start-ups working on technology brings in a lot of insight, interest, and innovation in any industry. Agri-food is no exception. Agri-food-tech start-ups face problems such as rigid old business models, lack of commercial guidance, investor apathy, lack of subject matter experts or mentors, application of technology, urban investors' lack of understanding, climate change, etc.[27]. Some of these problems are so fundamental that they need a deeper

cultural shift, which can also happen by a start-up movement. Starting a start-up movement is a significant challenge that requires an organized effort by a large group of people that includes Businesses, Digital Innovation Hubs (DIHs), Governmental Organizations, Consumers, etc. But start-up movement needs both macro and micro levels support.

2.2 Agri-food Industry External

CDA, as a complex system, deals with politics, economics, ethics, and many other macro challenges that should be considered in any technological plan. Below some issues, concerns, and impacts related to CDA:

Environmental Challenge: The effect that humanity is having on the environment is becoming ever-clearer, and the COVID-19 pandemic outbreak is a wake-up warning! Genetic modification of crops, waste production, population growth, soil and water pollution, deforestation, urban sprawl, overfishing, acid rain, Ozone layer depletion, ocean acidification, air pollution, lowered biodiversity, the Nitrogen cycle, natural resource use, transportation, polar ice caps, and climate changes are most critical environmental issues [28]. Most of these issues are caused directly by the agriculture and Agri-food sectors. Soil and Water Pollution by Pesticides and Agricultural Waste are important issues among global warming, which should be considered in any technology plan for the agri-food industry. It is estimated that about 998 million tons of agricultural waste are produced yearly [29]. According to an estimate made by the Plant Protection Department (PPD), about 1.8% of the chemicals remain in their packaging [30]. These wastes have the potential to cause unpredictable environmental consequences such as food poisoning, unsafe food hygiene, and contaminated farmland due to their potentially lasting and toxic chemicals[31]. At every stage, food provisioning releases greenhouse gases into the atmosphere. Agriculture accounted for 10% of the EU's total greenhouse-gas emissions in 2012[32]. This means CDA which is a Farm-to-Fork strategy-based solution should be evaluated precisely to measure its positive and negative impacts while it is expected to have a positive impact on mentioned issues such as waste production, water pollution, deforestation, air pollution, natural resource use, transportation, soil degradation, and climate change.

Economical: CDA, more than a technology solution, is an economical solution. It supports small farms on large scale to be connected, benefits from emerging technology, and changes the lifestyle. The collaboration will give power to small players to be active, which will support regional and local development as well as increasing the share of the Agri-food industry in GDP and job creation. The horizontal collaboration will help for the natural optimization of FVC in the processes to elevate the productivity in this sector[33]. CDA also will empower farmers by involving them in digital data business while their products more than agricultural products will be information that could be used cooperatively and add value for the farmers to cover the cost of new technologies. This will support the democratization of information and, consequently, the regional farmer-driven development (down top approach).

Politics: CDA, such as any technological development, could bring risk for the agri-food ecosystem and different players. It seems that between different players, farmers are the most vulnerable one in terms of the risk of adopting new technologies[34] and this should be managed at the macro-level while the solution would be more politically, Governments would find a solution for it. CDA will help countries with unsuitable and poor conditions to employ technology that could guaranty minimum food security of different regions, and this would be important in a difficult situation such as COVID-19 while the logistics and supply chains are not working properly. It is also important to understand how to support small farms vs. dominant giant agri-food companies and avoid worsening of the farmer debt/income crisis, which could exclude small, peasant farmers from the Agri-food production network [35], [36]. CDA will help governments to have access to dynamic data from the Agri-food process in detail, which could give them power for estimation of demand & supply, supporting clean business against the black market in the Agri-food industry.

Legal: Using emerging technology, including intelligent systems and robotics, is challenging and could raise legal issues[37], specifically when the data would have a major role in the future of the Agri-food industry. The nature of collaboration on a large-scale causes' problems. For instance, CDA could cause a question of responsibility as in case of any problem in the quality of the farms' product, it would create confusion about who will take responsibility and how the potential support by governments could be managed. Technology providers, technology enablers, and farmers are all in the process, which makes the judgment very difficult. The crystal process in FVC could also bring advantages and disadvantages simultaneously, which could lead to a legal fight!

Ethics: CDA could make confusion in terms of “Data Justice” for farmers, and it should be cleared and guaranteed fairness and social justice into digital agriculture to protect the most vulnerable in the agri-food industry. CDA is based on new emerging technology, while data is the most valuable asset. This would raise concerns about the privacy and cyber security issue, which could be seen from the perspective of practical ethics of digital agriculture and should be addressed in any technological development project dealing with agri-food, including the food supply chain. Fair Trade is also a critical issue as it supports the right of the people, including invisible agri-food workers. CDA will create a traceable digital passport among collaborators that could increase the level of fair trade in different aspects, from resource to market, including laborers and their rights.

2.3 Agri-food Industry Internal

Alongside external components in the agri-food industry, here are important concerns in the internal agri-food ecosystem. Below some of them are introduced while two crucial components of the *Business Model* and *Technology Architecture* would be discussed in separate sections following section two.

Culture: The Agri-food industry has a particular culture with specific characteristics. The number of invisible staff, seasonal workers, and low-skill persons are among these characteristics. Comparing with other sectors, the penetration rate of technology is low, and in most countries, it is still a family business. It is claimed that

although women have an essential role, especially in rural agriculture and in developing and underdeveloped countries[38], they are not visible, and they do not have normal rights such as insurance or retirement benefits[39]. CDA hopes to change the agri-food industrial culture dramatically, including the working environment. It will help to attract more intelligent and high qualified people in this industry and make it a prestigious cluster to work for high tech companies and talented people. Technology will change the types of needed skills as well as the visibility, models of collaboration, and responsibility, which means a new working environment for Agri-food stakeholders and players.

Technology Acceptance and Adoption: One of the main challenges of CDA is the problem of real cases and the rate of penetration. The acceptance of technology is more than just the technology itself and how it is advanced, but it's about successful technology deployment, which needs a strategy. Many papers are discussing the barriers to justify the lack of technology in the agri-food industry(e.g. [40]–[43]), but most of them are focusing on the traditional criteria. Interviewing different FVC chain players shows us that the main problem is the collaboration model. Most of the other factors are derived from weak Collaborative Networks (CNs). Analysing the agri-food industry as an ecosystem from the point of view of CN, the main causes such as inappropriate typology of the network, lack of synergy, and weak cooperation to share the resources and increase productivity and finally, lack some critical nodes of the supply chain are recognized. Also, the vertical development to connect the process from farm to fork is not yet fully supported by existing technology.

Human Resources & Literacy: Agri-food-tech businesses are aware that the technical and soft skills of their employees directly influence business performance and, consequently, improving these skills will enhance the effectiveness, efficiency, and sustainability of their business[44]. They also are informed that the lack of knowledge, lack of technical skills for working with new technologies, lack of awareness, and social ignorance about new methods, technologies, and processes are some of the most critical adapting barriers of their products and services by consumers, market and society which cause resistance. In this regard, Literacy is not just crucial to agri-food-tech businesses, but vital[45]. One main issue which would be a crucial challenge that should be addressed in any technological project in the agri-food industry is the level of technology literacy of stakeholders, mainly farmers and the leading agriculture field players[46]. This would be one of the primary and critical issues to guaranty the use, manage, understand, and assess technology.

3 Reference Architecture Model

The proposed digital ecosystem for CDA focuses on delivering an autonomous and fully interoperable environment taking advantage of the European investments on platforms such as FIWARE and Arrowhead tools, intending to optimize the agri-food chain (from farming to processing and distribution) in a modular and open way. This is possible with the aid of core technologies and proved tested through pilot demonstrators that embed within real environments. The proposed reference model for CDA shows in Figure 2.

The CDA ecosystem addresses the combination of robotics at scale with IoT devices, big data, and AI applications to bring added value into the agri-food chain across its different phases, following the Farm-to-Fork vision represented by the yellow arrow in Figure 2. This implies that several of the actors are transversal to the lifecycle, with the context of their intervention changing depending on the phase in question from *farming* to *processing*, *distribution*, and finally, the *consumer*.

Throughout the different phases, the key for the interoperability of the ecosystem is the CDA middleware, built on top of the FIWARE platform. First, a multiagent-based IoT layer is responsible for the interaction and acquisition of data from the field level, namely interacting with existing legacy equipment (using appropriate adaptors) and the CDA robotic systems, as well as external data sources such as the Copernicus observation satellites and state of the art ground data sensors (Humidity, geo-localization) or meteorology services. This layer interacts with the FIWARE Orion Context Broker following the Next Generation Services Interface (NGSI) specification, managing, and facilitating the access to the information flowing through the platform. This allows the management of the entire lifecycle of context information (including updates, queries, registrations, and subscriptions), using an NGSI v2 interface. The adoption of FIWARE will be leveraged to speed-up the design and implementation of the ecosystem, as it offers a catalogue of components known as Generic Enablers, along with a set of reference implementations that allow the instantiation of functionalities such as Big Data analysis, development of context-aware applications, connection with different IoT devices or external systems.

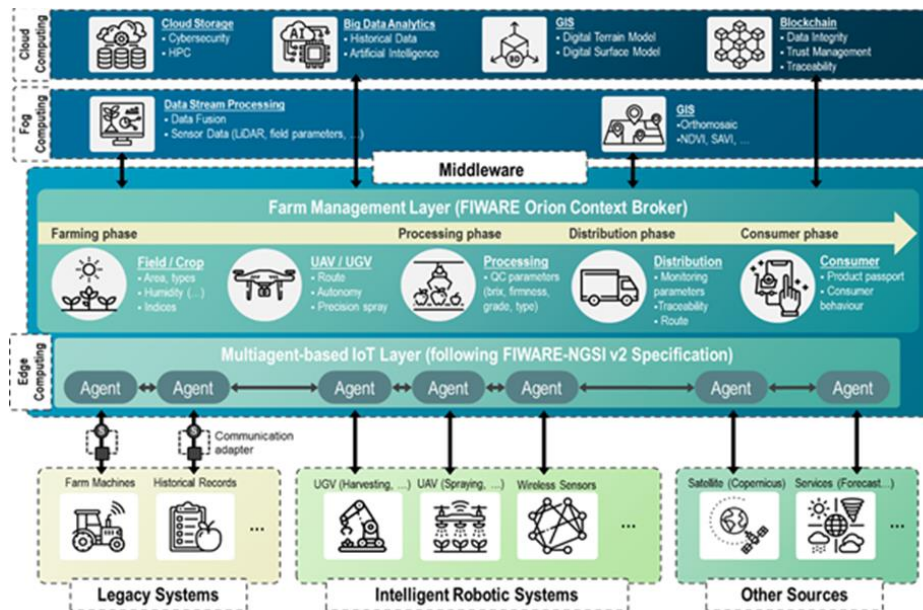


Fig. 2. A Conceptual Architecture for the CDA Ecosystem

On top of this, several applications can be plugged at different levels to bring added functionality and value to the ecosystem. A fundamental characteristic of the CDA ecosystem is the low-code approach for the configuration of the information flow and interaction with the platform. The advantages of such an approach are two-fold, firstly it ensures that stakeholders, particularly farmers, do not require expert knowledge to interact with the platform. Secondly, it facilitates the rapid configuration and deployment of intelligent robotic solutions using the CDA ecosystem in different scenarios. Also, while FIWARE will be regarded as a core enabling technology, CDA will exploit the connections within the consortium to maximize compatibility and compliance with other major platforms as part of the development cycle of the modular software applications. One such case will be the connection to the Arrowhead Framework through the mutual STM partner, which is being actively developed and exploited across multiple EU projects for building IoT-based systems-of-systems.

Three distinct levels of computation are considered across the lifecycle, namely edge, fog, and cloud computing. At the edge level, the multiagent IoT layer ensures that not only the data acquisition takes place, but also that some computation can be performed to address the real-time requirements, with the added flexibility of such an approach (i.e., plug and play deployment of smart drop-in sensors). At the fog level (for instance at IoT gateways) some stream processing can be performed, along with the fusion of data from the different sources at the field level and computations that can be too heavy to perform at the edge, but do not necessarily require the computational power of cloud resources (e.g., calculation of varied indexes). Finally, several services can be made available at the cloud level, including robust and secure data storage, big data analytics, and blockchain services to ensure the traceability and integrity of all transactions being carried out. The lifecycle addressed in CDA is shown in figure 3 and expected to flow as follows:

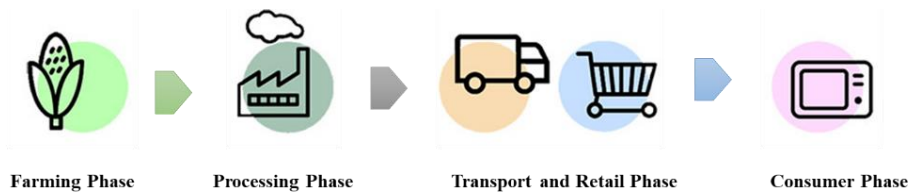


Fig. 3. The FVC Phases in the CDA Ecosystem

Farming Phase: During the “Farming Phase”, the harvesting of various types of agricultural products, which can be either manual or automated, takes place. This phase also encompasses the management of the fields and crops with the use of different farming practices, such as the precision spraying case. The geo-reference data acquired by the robotic system is then made available for the subsequent phases through the CDA middleware. Besides, traceability of all products is enabled through the employment of a new type of blockchain technology, ensuring that a complete, contextualized digital passport is provided at all stages of the product lifecycle.

Processing Phase: Afterwards, in the “Processing Phase”, an improved resource allocation strategy is made possible due to all the newly available data, with CDA

supporting decision-making based on the analysis of historical data and forecasting applications. Harvested products are then submitted to automated, non-destructive quality control during grading, as opposed to the current manual and more subjective approach, which is often tedious and error prone. To achieve this, data from the different phases can be combined and processed by a data analytics module which can either be embedded onto the flexible robotic platform in an in-door setting or onto quality control checkpoint stations. In the case of the former, the AGV can navigate from pallet to pallet as they arrive at the processing facility, performing the quality assessment with the assistance of a mounted manipulator and the embedded AI application. In both scenarios, the emphasis is on sustainability, as the approach reduces the amount of wasted product due to its non-destructive nature, whilst reducing the time required for testing (in some instances manual testing can currently take up to a few hours) and thus increasing the number of items that can be tested to improve the overall process. Moreover, in contrast to destructive methods, this solution enables products to be tested multiple times, including for instance both before and after storage, hence providing a better indication of the evolution or possible degradation of the associated quality.

Retail Phase: Then, during the “Retail Phase”, once more products can be monitored enroute to retail through the IoT layer, ensuring that appropriate conditions are maintained during transportation with data being recorded into the passport of the product, increasing the transparency, and promoting trust along the value chain.

Consumer Phase: Finally, at the “Consumer Phase”, CDA aims to tackle one of the big challenges being currently faced in the agri-food sector, which is the lack of visibility at this stage, which contributes heavily to the problem of food waste and loss. This will be addressed with the employment of gamification strategies to promote the engagement of consumers with the CDA ecosystem. On the one hand, it will create the means for consumers to provide feedback on the perceived product quality and safety, contributing to the continuous improvement of the automated processes in the previous phases. On the other, it will contribute directly to the mitigation of the food loss and waste problem, by rewarding users for logging their consumer behaviour, fully consuming products before their expiration date, and providing suggestions to better manage their inventory at home.

These different phases are perfectly aligned with the Farm to Fork strategy, from sustainable food production to processing, distribution, and consumption, promoting responsible behaviour towards the reduction of food loss and waste.

4 Business Model

The sharing Economy paradigm has changed the principles of business, and it helps technology providers to commercialize their technology. In different ecosystems, the most successfully implemented technology uses the business layer, which is called "Service Enabler." They are a group of entities that could connect supply and demand in the market and give the right service to potential clients without involving them in the complicated world of technology. Despite the success of technology providers in terms of implementation and usage, in the agri-food industry, sophisticated

technologies have not yet found their market. Technology literacy, price, and cost, economy scale, permanent use due to the seasonal process, and other criteria lead us to the fact that it would be challenging to connect suppliers to the final user of technology in the agri-food value chain. In this regard, connecting the providers of these services to the targeted consumers, including smallholder farmers through a service enabler platform, is vital. This platform includes a network of organizations and businesses involved in the delivery of specific agri-food technology-related services through a technology-based platform. Due to the absence of this platform and its framework in the agri-food sector, in the first place, proposing a framework for such a network is fundamental. This platform would be based on the sharing economy model, which is an economic model defined as a peer-to-peer (P2P) based activity of acquiring, providing, or sharing access to goods and services that is often facilitated by a community-based online platform. Figure 4 shows the business model of Collaborative Digital Agriculture.

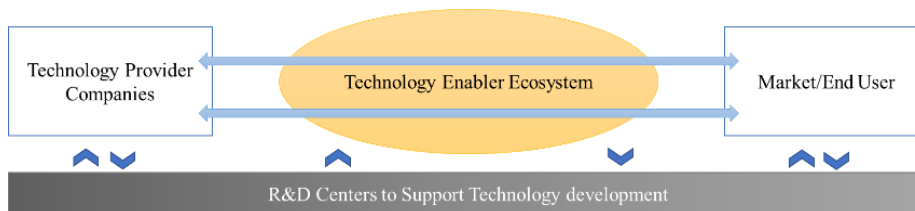


Fig. 4. Technology Enabler as a key chain in CDA Business Model

As it could be seen, CDA as a collaborative network includes different players, and here the roles and categories are described: i) **Technology Providers:** Technology is the trigger of CDA. This group includes companies that are developing and selling technologies using different models. ii) **Technology R&D Partners:** The R&D units are the engine of innovation and work with the value chain to support the R&D needs. iii) **Technology Enabler:** Technology enablers are the heart of this business, which is missing in the Agri-food industry now. One of the main concerns in CDA should be developing a “Technology Enabler Ecosystem”. This ecosystem is vital for the successful implementation of any strategy related to Smart Agriculture, including CDA. iv) **Technology User / Market:** Any technology at the end needs to have an end-user, and the users are not just companies working in any specific part of the agri-food industry, but the entities involved in the value chain and from farm to fork, including farmers, transporting companies, distribution, and retailers and so on. Technology users are the final client whose needs must be addressed and their challenges to be met.

Table 1 is the initial Canvas model as a general framework to understand the business side of CDA:

Table 1. Canvas Model for CDA as a Business

Key Partners -Agri-food associations -Local Governors and mayors -Big retailers	Key Activities - Developing Technology - Develop standards for Agri-food technology - Develop Technology Enabler ecosystem for the Agri-food industry	Value Proposition CDA will propose a cooperative network using emerging technologies	Customer Relationship Technology enabler system will develop Agri-food technology Club to make an international network of stakeholders	Customer Segments Agri-food Industry
	Key Resources - Knowledgeable and experienced team both in technology and Agri-food industry - Partnership with relevant entities	This will support the Agri-food value chain from farm to fork.	Channels The services and technologies would employ usual strategies such as social media, website, etc, but mainly will approach its target group by being active in related fairs, arranging workshops, and events. Also, policymakers at state and national levels who are looking for new technology in Agri-food are the potential target to catch and present the work.	
Cost Structure Cost of business includes: - Technology Development - Service Customization & Project Implementation - Hi qualified HR			Revenue Streams The revenue streams would be different for different partners in this ecosystem, but the main revenue stream would be based on Technology as a service (TaaS).	

In Table 2, SWOT analysis of future potential business according to the information from the Portuguese team working in SFColab and the initial investigation is presented. The SWOT table shows the main strategies which could be similar for many entities looking to this business to develop a CDA ecosystem.

Table 2. SWOT Analysis to identify strategies of CDA as a Business

SWOT Strategies	Strength a) Presence of High qualified teams in this area b) Developing a new business model based on technology that would be unique and competitive c) Knowing types of merging technologies and working with agricultural entities d) Diversity of the team to make sure all aspects and needs are covered	Weaknesses a) Lack of collaboration with different entities in this scale b) lack of Financial strength comparison with American companies in the industry
Opportunities 1. Very large and committed potential market 2. Support of European Commission for the renovation of Agri-food industry 3. The rising importance of the local Agri-food industry as a national security 4. The decreasing trend of Technology-based solutions in the Agri-food industry 5. Technology as a recognized solution to deal with the challenge of radical change in the world population and its consequences (Food, water ...) 6. EU is one of the world's leading producers and exporters of agricultural products	SO 1. Working on R&D projects and use potential resources from universities including professors, researchers, and students 2. Develop different platform of collaboration to Keep the team 3. Protect the technology and CDA know-how by using strategies such as patent registration	WO 1. Using financial instruments of EC to leverage the work and continue developing the technology 2. Target countries with the non-suitable situation for agriculture using the high-level European delegation to penetrate their market
Threats 1. The agri-food industry is a price-sensitive industry in which costs of new expensive technologies will not be readily accepted 2. Lack of standardization in the Agri-food industry 3. Lack of Technology Enablers in the Agri-food industry 4. Nature of Agri-food industry with an unbalanced load of work in the year 5. Variety of processes to be covered in the Agri-food value chain 6. The dominant position of Political economy in the Agri-food industry	ST 1. Finding a supplier for different modules in the solution to have a competitive price 2. Develop a Start-up ecosystem 3. Develop a Technology enabler system in the Agri-food Industry 4. Increasing our mobility and agility to meet the unbalanced seasonal business of Agri-food	WT 1. Negotiating with investors and financial organizations to have financial support for the competition 2. Work with the European Commission to develop the international market using a unified approach 3. Negotiate with the standard organizations/ Companies and related authority in European Commission to establish standards of Technologies in Agri-food Industry

As it could be seen, all the aspects of the business are promising. Potentially it shows that the investment in CDA is a very wise and smart move not only in terms of business but to guaranty, the future of the agri-food industry in Europe aligns with the CDGs of the United Nations and to increases the share of European entities, worldwide in the agri-food industry.

5 Impacts

In this section, the main idea is to understand the impact of a CDA solution based on SDGs that meet the urgent social, environmental, political, and economic challenges facing our world. Social and Environmental Impact is the effect on people, communities, and environments that happens as a result of an action or inaction, an activity, project, program, or policy. Investigating social and environmental impact in any activities, such as technological development, business activities, social movement, etc., is a priority to help to achieve the mission of that activity, attracting additional funding, ensuring avoiding from any environmental harm, improving society, improving effective communication, demonstrating value for money, understanding better the strengths and weaknesses of the activity, and improving the activity.



Fig. 5. CDA Potential impact on UN-SDGs

The advantage of the proposed model called "Collaborative Digital Agriculture" was discussed in the previous section, and here the aim is investigating the expected impact of CDA outcomes on 17 UN-SDGs. To do that, questionnaires were designed and distributed between large-scale potential clients in different FVC processes and asked them to justify the impact of CDA based on their existing businesses and situation by giving a number from 0 to 10. Fig 5 shows the result of aggregated data after collecting

the questionnaires, merging different potential implementation cases to analyse the data.

According to Figure 5, the six most significant impacts will be on the Partnerships for the goals, Industry, Innovation, and Infrastructure, Zero Hunger, Good Health and Well-being, Decent Work and Economic Growth, and No poverty. CDA outcomes will have the lowest impact on Life Below Water, Peace, Justice, and Strong Institutions, Reduced Inequalities, Life on the Land, and Gender Equality. The CDA application outcomes will have a positive impact on Climate Action.

6 Discussion & Conclusion

New emerging technologies will boost effectiveness and reduce risks of the agri-food industry. This would be a shifting paradigm in this sector, which will dramatically change farms and food processing industries. The increasing demand for food, which is estimated to be doubled by 2050 due to population growth and the rising importance of food security pushing the agri-food industry to increase its productivity. This will be impossible without employing new technologies and creating different ways of managing the FVC. Considering all challenges and dilemmas, "Collaborative Digital Agriculture" seems the most promising model to achieve this goal. In this paper, CDA was discussed as a multidisciplinary concept, and the main challenges from various points of view were brought up. Then two crucial issues, the business model to tackle exiting barriers and the technical architecture to develop the core technology, were introduced separately as a framework of CDA. On the other side, dealing with SDGs and social impact is the driver in the sector, and the impact of CDA on SDGs was evaluated. The main output of this paper could be listed as below: i) "Technology Enabler" is an essential missing ring in the food value chain to employ emerging technologies and make it feasible and attainable. ii) The success of CDA depends on the alignment of the Micro and Macro strategy to tackle challenges and dilemmas. iii) The appropriate Technology architecture is proposed to be used in the framework of CDA.

The article is the first step to shape the new strategy, which could support the shift of the agri-food industry to the new paradigm. Still, it needs further research to understand the operational barriers, the role of local ecosystems as well as developing the typology of the collaborative network to have a better picture of this new paradigm of agriculture align with the Farm to Fork strategy.

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