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D3.8 Guidelines for a data-driven CRFS management platform



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Abstract	This deliverable provides some guidelines to create a blockchain-based digital system (within WP6) and encompassing precise information on possible pathways considering sustainable CRFS developments. In order to guide the development of the S2CP (Single-Click CRFS Platform) technological platform foreseen in the WP6 of the CITIES2030 project, in this task a work Focus Group is constituted whose objective is to guarantee the impact of said platform. In order to guarantee the impact, this task generates two different results. On the one hand, a set of recommendations regarding the functionalities and design that the platform should follow, and on the other hand, a set of indicators that should monitor the programming and implementation process of the different components, detecting whether they meet the expected impact or if improvement and correction actions are necessary. Carrying out an exhaustive quantitative survey of both internal and external interested agents reported highly relevant information: (i) in general aspects on the use of information technologies by the different agents integrated in the CRFS, (ii) on specific issues of previously identified technologies (blockchain and artificial intelligence), (iii) on concerns detected in the initial questionnaire such as cybersecurity or data governance. As a result of the work, the Focus Group proposed a set of up to 4 high-level functionalities and a framework of KPIs with 14 elements.
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Deliverable D3.8 Guidelines for a data-driven CRFS management platform

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Abbreviations

Abbreviation	Description
5G	Fifth Generation Mobile Networks
AI	Artificial Intelligence
AIDC	Automatic Identification and Data Capture
AIOTI	Alliance for IoT Innovation
CAP	Common Agricultural Policy
CBD	Convention on Biological Diversity
CIAB	Cities2030 Advisory Board
CICES	Common International Classification of Ecosystem Services
CFRS	Cities Regions Food Systems
DL	Deep Learning
EC	European Commission
EU	European Union
EU-U11NUA	EU, UN's SDG 11 and New Urban Agenda
EVM	Ethereum Virtual Machine
ExeCom	Executive Committee, composed by all WP leaders and co-leaders
FAO	Food and Agriculture Organization
GFAR	Global Forum on Agricultural Research and Innovation
GHG	Greenhouse Gas
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile communications
HSNC	Healthy Sustainable Nutritious and Culturally appropriate
ICT	Information and Communication Technologies
IEEE	Institute of Electrical and Electronics Engineers
IoT	Internet of Things
IoT-A	Internet of Things Architecture
ISO	International Standards Organization
ITU	International Telecommunication Union
KPI	Key Performance Indicators
LoRaWAN	Long Range Wide Area Network
M2M	Machine-to-Machine (Communications)
ML	Machine Learning
NFC	Near Field Communications
PMO	Project Management office

PoS	Proof of Stake
PoW	Proof of Work
RFID	Radio Frequency Identification
S2CP	Single-Click CRFS Platform
SCADA	Supervisory Control and Data Acquisition
UA	Urban Agriculture
UAV	Unmanned aircraft/aerial vehicles
UFSE	Urban food systems and ecosystems
UN	United Nations
WoS	Web of Science
WP	Work package
WSN	Wireless Sensor Network

1 Introduction

In this first Section, the context and global overview of Task 3.7 is described, with a special focus on document D3.8, which is the final outcome from the WP3 Focus Group; whose main objective was to collect the most important guidelines, recommendations and KPI for the future Cities2030 platform to be developed in WP6.

1.1 Short description of the CITIES 2030 project

The main goal of CITIES2030 is to create a future proof and effective UFSE via a connected structure centered in the citizen, built on trust, with partners encompassing the entire UFSE. CITIES2030 commit to work towards the transformation and restructuring of the way systems produce, transport and supply, recycle and reuse food in the 21st century. CITIES2030 vision is to connect short food supply chains, gathering cities and regions, consumers, strategic and complement industry partners, the civil society, promising start-ups and enterprises, innovators and visionary thinkers, leading universities and research across the vast diversity of disciplines addressing UFSE, including food science, social science and big data.

1.2 Short description of the WP3 Package

WP3 generates an actionable blueprint to create sustainable CRFS, and incorporates detailed plans of action and methodologies, outlined in a structured form, to provide all agents of the food system arena an interactive approach for food supply chain planning, production, monitoring and improvement, to meet the EU-U11NUA (EU, UN's SDG 11 and New Urban Agenda) objectives. WP3 aims to identify, engage and activate agents and stakeholders of the food system arena to establish the "CRFS Alliance". Activities will characterize and assemble sound evidence on current needs (vulnerabilities, obstacles) to sustainable CRFS implementation and development. This provides conditions to examine current solutions from a broad spectrum of sources with a special attention to cities signatories of the MUFPP, the citizen science and start-up sphere. WP3 generates instruments to facilitate co-creation and participatory processes, and intelligence.

1.3 Purpose of D3.8 Report

The objective of document D3.8 is to collect and present in a coherent way all discussions carried out in the context of the WP3 Focus Group and its conclusions. This document describes the analysis methodology and the different meetings and actions that were organized. In this document, however, they are only presented the final version of all the products and discussions.

1.4 Relation of the D3.8 Report with other WPs and deliverables

This deliverable has a direct relationship with WP6 and in particular with task T6.1 "Requirements and reference architecture" which will provide the CITIES2030 technical architecture, based on the experiences of participants from previous project platforms and compatible with other already established ecosystems.

The link between tasks T3.7 "Data-driven CRFS management system ideation" and T6.1 is the establishment of final user requirements and development guidelines that will become technical requirements to be taken into account in the development of the architecture and that will determine the tentative list of components to be developed, following a co-creation methodology with WP4 and WP5.

In relation to WP3, there are many tasks related to this report. In terms of stakeholder identification, this deliverable is fed by the work being carried out in T3.1 “Engage agents and stakeholders of the food system arena”, where it is intended to design and implement engagement activities to gather insight from agents from the food system arena, including the unorganized public (consumers) to better understand the related landscape, and initiate the project's synergies action plan.

In relation to the study of technologies, this deliverable offers other subsequent deliverables the study carried out in such detail. Task T3.6 “Examination of the innovation landscape and living lab prototype” will be able to take advantage of all this insight for screening and mapping technological trends (food processing technologies, equipment and ICT-based systems) in novel and in all applicable sphere of the food system sand.

Finally, the requirements of the stakeholders and the use they would like for the future data-driven CRFS management platform have been provided thanks to the relationship of this task with the WP4 and WP5 work packages. WP4, in this sense WP4 explores policy-framed and technology-based scenarios, build competences at city level, and deploy policies at regional level towards compliance with the aforementioned policy framework.

In the case of WP5, it structures and accelerates innovation processes incorporating the design, pilot, validation and deployment of cutting-edge food-related technology. The synergy of WP5 with this deliverable is clear, since the innovations that WP5 reports will be facilitated by the use of the data-driven CRFS management platform whose requirements we are collecting in this report.

1.5 D3.8 structure

The document is organized as follows.

Section 2 describes the composition, roles, and work methodology of the Focus Group, according to the requirements of task 3.7.

Section 3 presents the results of the first phase of the proposed work methodology, consisting of a review of the state of the art on information and communication technologies (ICT). The review criterion for this section is the relevance of the technologies in the research world in the last five years.

Section 4 describes the second part the referred ICT review, concluding the first phase of the methodology, but from a different point of view. In this case the technologies employed in different application scenarios are analyzed, considering as potential applications the pillars identified by FAO for CRFS.

Section 5 presents the results for the stakeholder analysis. In this section all stakeholders for the future S2CP platform, including internal agents to the project (partners) and external agents are identified. In that way, the second phase of the work methodology is introduced.

Section 6 describes the data capture methodology and the results for an initial questionnaire, answered by a small group of stakeholders with the higher participation and commitment with Cities2030. With this information the Focus Group was able to advance in the work methodology and propose a quantitative survey for capturing the users' needs and requirements.

Section 7, finally, describes the data capture methodology and the results for quantitative survey. The analysis includes a statistical evaluation of the results, and some initial ideas about the design guidelines the Focus Group should propose to the WP6 partners, considering the responses of the stakeholders. This is the last step of the second phase in the work methodology.

Section 8 presents the first result of the Focus Group discussions: the design guidelines for the S2CP platform. The objective of these guidelines is to guarantee the impact of the proposed platform. The guidelines are

presented as general functionalities, which are later decomposed into low level functional recommendations, so a roadmap for the S2CP platform implementation is defined.

Section 9 describes the second and last product of the Focus Group discussions: a KPI framework. This framework should guarantee the envisioned impact for the S2CP platform is actually reached. This framework includes both technological and domain-based KPI. This framework is dynamic and will evolve as the use cases, users' needs, etc. will do.

Section 10 concludes the document.

1.6 Roles and responsibilities

Lead partner role: UPM (P21) coordinates the activities, provide guidance, steer implementation and secure alignment, implement activities to deliver planned outcomes.

The rest of task participants: IAAD (P5), INVE (P9), VEJLE (P10), TTZ (P16), BIOZ(P17), WIT(P21), AGFT (P27), ARFI (P29), ITC (P30), PRIM (37) develop the task simultaneously at EU level and beyond and contribute in the focus group.

2 Focus group

The WP3 Focus Group is composed by more than fifteen participants, with the roles of technology enablers, industry, social entities and final users.

The objective of this Focus Group is to propose some design guidelines for the S2CP platform that ensure its impact at the social and end-user level. These design lines must be adjusted to the current state of the art of technology and to the needs of the users in the CRFS, in order to guarantee the aforementioned impact. In addition, this Focus Group is also responsible for determining a framework of indicators that allows monitoring of the achievement of said impact by the S2CP platform, in the terms provided in the above-mentioned recommendations. All these instruments should allow WP6 to implement a platform of great impact and utility.

In this section we will explain the composition of this Focus Group and its work methodology, which should allow capturing all the relevant information to build the design guidelines and recommendations, as well as to define indicators that are of interest and relevance.

2.1 Composition, members and roles

Any design line or recommendation whose objective is to guarantee the impact of the final product comes from 2 main sources of information: **the state of the art of current technology**, and the **needs and expectations of the end users**. The composition of this Focus Group must therefore reflect this duality, and it will therefore be necessary to incorporate both technological agents and end users.

For this reason and in view of the internal structure of the Cities2030 project, this Focus Group had members mainly participating in 2 work packages: the fifth work package, in which the end users (cities, industrial agents, etc.) will implement improvement policies in the different CRFS; and the sixth package, dedicated to strictly technical and programming tasks.

On the other hand, in order to achieve an agile work group, the number of members should not exceed twenty in any case. To maintain a balanced composition, 8 invitations were sent among the members of the WP6 (technology members), and another 8 among the members and end users who were working on it WP5.

Finally, after accepting the corresponding invitations, those partners considered their participation appropriate, the composition of the Focus Group was established as reflected in the following table:

Technological partners	CRFS-focused partners
UPM (P20), WIT(P21), AGFT (P27), ITC (P30), PRIM (37)	IAAD (P5), VEJLE (P10), INVE (P9), TTZ (P16), BIOZ (P17), AGFT (P27), ARFI (P29)

While the role of technology partners within the Focus Group is to collect all the information related to the current state of technology, to inform the rest of the partners about it and allow the group as a whole to make decisions and prepare the corresponding recommendations and indicators; the role of the CRFS-focused partners is to serve as a link with the group of interested users (inside and outside the project), from which it is necessary to extract information about their interests and preferences (which is essential information to guarantee the impact of the recommendations and indicators, and therefore of the future S2CP platform).

2.2 Work methodology

The final objective of this Focus Group, as has been said, is to generate a set of recommendations and design lines for the S2CP platform that guarantee its impact both in technological terms and in terms of the end user. To monitor the achievement of said impact, the Focus Group will also provide a Key Performance Indicator framework.

To achieve these objectives, we have proceeded according to the following methodology:

- 1- In a first phase, the technology partners conducted a review of the state of the art of current technology according to two main criteria. The first (the result of which can be seen in section 3) was based on identifying those enabling technologies that had shown the greatest scientific relevance in the last 5 years. After a first bibliographic review, 5 basic enabling technologies were identified that were studied from the point of view of their applications, their benefits and drawbacks, and their potential use in the context of the S2CP platform. The second criterion (the result of which can be seen in section 4) reviewed the information and communication technologies according to their use in different application scenarios. In particular, given the use of the S2CP platform in the context of CRFS, the Focus Group decided that the application scenarios should be the pillars identified by FAO for CRFS.
- 2- In the second phase, information was captured regarding the needs and expectations of the end users. For this, in a first phase, all those potentially interested in the use of the S2CP platform were identified. Both internal agents to the project (partners) and external agents were considered. To locate these external agents, the networks established by the CRFS-focused partners integrated in the Focus Group in their corresponding CRFS were used. Other partners with the ability to identify potential external stakeholders also contributed information to the contact list. Section 5 shows the result of this stakeholder identification. Since the capture of information from end users requires their active participation, the process is more complex than in the case of the bibliographic review of the state-of-the-art technology. For this reason, an information capture methodology was designed in several steps.
 - a. In order to capture information of the greatest possible relevance, before carrying out a quantitative and exhaustive survey about the preferences and needs of users, the Focus Group considered it appropriate to carry out a first qualitative questionnaire of only 5 questions to a selected subgroup of among the interested parties. The objective is to capture

some first ideas about the interest that users may have in the use of a platform such as S2CP, in such a way that in the final quantitative survey the questions can be oriented towards these needs, avoiding very general questions of less added value. The analysis of this questionnaire was planned to be heuristic, given the small number of expected responses and its qualitative nature. Section 6 is dedicated to the detailed presentation of this initial questionnaire.

- b. Based on the needs, ideas and expectations shown by the end users in the initial questionnaire, a comprehensive quantitative survey was designed in a second sub-phase to capture all the relevant information about those interested in the S2CP platform. This survey took into account both the technologies identified in the first phase technological review, as well as the information provided by the users in the initial questionnaire. In order to facilitate its subsequent analysis, and to simplify the response mechanism (which was expected to increase the number of valid responses to the survey), it was based on the Likert scale. The results of said survey was analyzed using statistical techniques, and the results were discussed in the context of the Focus Group to be considered in the design of the recommendations and indicators. In order to maximize the impact of the platform, both the recommendations and the indicators must be aligned with the expectations and needs of the users expressed in this survey. Section 7 is dedicated to the detailed presentation of the survey procedure and its results.
- 3- Finally, and in view of the state of the art of technology and the needs and expectations of users expressed through the quantitative survey, the Focus Group debated, generated and validated two results whose objective will be to guarantee the impact of the S2CP platform, and monitor the achievement of said impact (through a framework of KPIs). These results are:
 - a. Design guides that must be fully aligned with the state of the art of technology and with the needs and expectations of users. The use of innovative technologies is an essential condition to maximize impact. While the integration of the needs of the users will allow to maximize the number of applications, the design recommendations will be concrete, and will focus on the identification of those final functionalities and enabling components that are of great interest to the Cities2030 project and to the European Society in general. Section 8 is dedicated to presenting the technology guides finally approved for the Focus Group.
 - b. A framework of indicators that allows the dynamic monitoring of the development of the platform, in order to guarantee the achievement of the expected impact at the time of design and proposal of the recommendations (for which the aforementioned recommendations will be taken into account). These indicators should reflect the duality of the Focus Group and its work, monitoring both technological innovation and the proper adjustment to the needs and expectations of users. These indicators must be included in a dynamic document that can be updated in WP6, and can at the same time be controlled by the project management bodies. Section 9 of this document is finally dedicated to the presentation of the indicators approved by the Focus Group.

To coordinate all the work carried out by the Focus Group, the official coordination platform of the Cities2030 project was used: Correlate. This platform contains all the documentation related to the discussions of the Focus Group, as well as the agendas, minutes, presentations and videos of the different meetings that were held throughout the development of the work.

In order to guarantee the agility and the successful achievement of the objectives of the Focus Group, this group met regularly and constantly every two weeks. However, at specific moments of critical work (specifically in the design of the quantitative survey and at the time of approving the final version of the indicators), extraordinary meetings were called in addition to the periodic fortnightly ones.

Deliverable D3.8 Guidelines for a data-driven CRFS management platform

Prepared by P20 | Edited by P5, P9, P10, P16, P17, P20, P21, P27, P29, P30, P37 | Checked and reviewed by EX COMM | Approved by P1

Rev 1.9 – 12th July, 2021

The following table shows a list of the most important meetings held throughout the different months and up to the time of delivery of the deliverable, as the main objective discussed in said meeting.

#ID	# ATTENDEES	MAIN OBJECTIVE OF THE FOCUS GROUP MEETING
1	16	Focus group definition: workplan and roles D3.8 presentation and organization Next deadlines: ICT review and surveys
2	11	D3.8 deadline D3.8 organization (first iteration) Technological guidelines and first stakeholders' responses Next deadlines: ICT review and surveys
3	17	D3.8 administrative information D3.8 status Quantitative surveys
4	17	D3.8 status Quantitative surveys Proposed data collection methodology
5	17	D3.8 status Quantitative surveys: final version Data collection process
6	16	D3.8 status Quantitative surveys: final version Data collection process
7	13	D3.8 status Quantitative surveys: data collection process Technological KPI Next meetings
8	15	D3.8 status Quantitative surveys: data analysis KPI framework Next meetings
9	11	D3.8 status and final steps KPI framework Next meetings

The following figure graphically reflects the proposed work methodology, which has been described in this section:

Deliverable D3.8 Guidelines for a data-driven CRFS management platform

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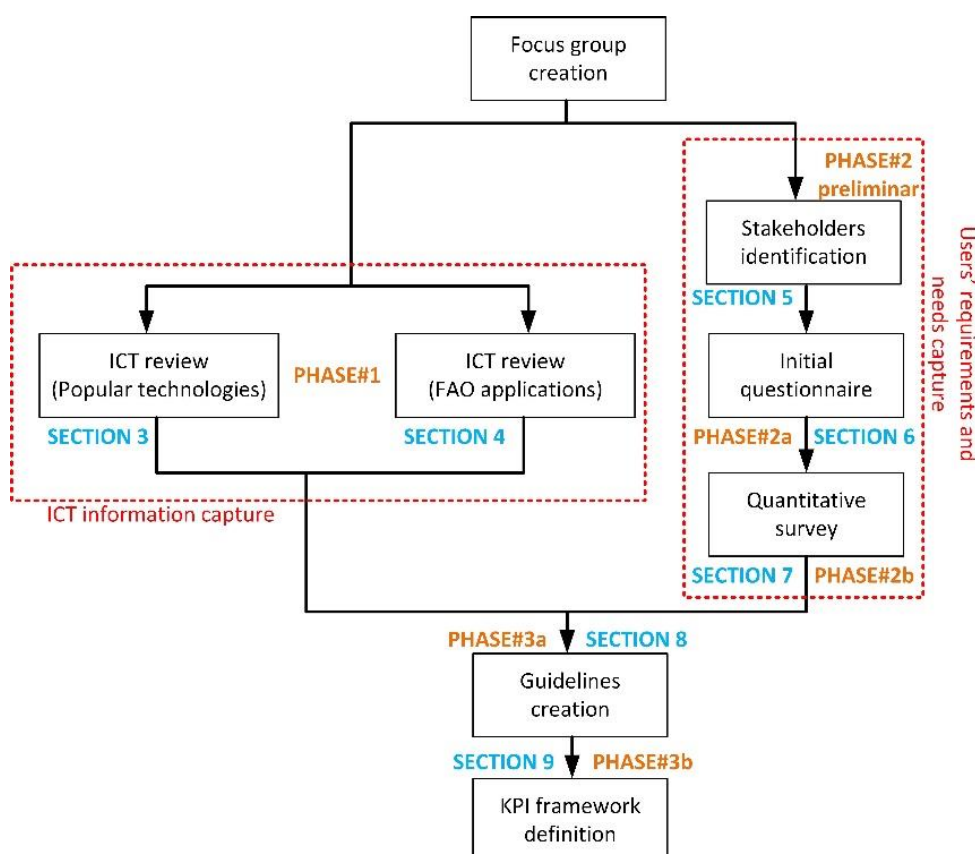


Figure 1 – Work methodology in Task 3.7

3 ICT enabling technologies for a data-driven CRFS management platform: from farm to fork. A review

In this third section, and according to the proposed work methodology, the results of the analysis of the current state of technology carried out by the technology partners during the first phase of the work are presented, according to the first of the chosen criteria (enabling technologies with the greatest impact in the scientific world in the last 5 years).

For the selection of the technologies that are going to be treated in this section, the main scientific databases (WoS and Scopus) have been consulted, looking for those words that have been repeated the most in the titles of the articles of the journals belonging to the technology categories in the last 5 years.

The technologies finally identified are 4: Internet of Things, Blockchain, Artificial Intelligence, Big Data.

Big data analytics and artificial intelligence, paired with blockchain technology, the Internet of Things, and other emerging technologies, are poised to revolutionize urban management. With massive amounts of data collected from citizens, devices, and traditional sources such as routine and well-established censuses, urban areas across the world have – for the first time in history – the opportunity to monitor and manage their

urban infrastructure in real-time.⁴ This simultaneously provides previously unimaginable opportunities to shape the future of cities, but also gives rise to new ethical challenges. This section intends to provide a synthesis of technology developments, opportunities and challenges to apply ICT enabling technologies for transformation of non-digital CRF management systems to data-driven CRF management systems. Once available technologies are screened it will be possible to map these technologies to the landscape of data-driven urban management systems, considering food systems as the relevant particularization. In Section 4 these and other technologies will be related to the technological components present in the main areas of CRFS, according to the FAO classification.

3.1 Internet of Things: Introduction and architectures

The Internet of Things (IoT) is a concept and, implicitly, a model built on the assumption of the omnipresence of a multitude of objects which, through wireless or cabled connections and unique addressing schemes, can interact and collaborate with other objects, creating new services and applications aimed at reaching a common goal. Many application areas have been studied in the literature highlighting the area of food supply chains is addressed most frequently, followed by arable farming. The frequency of references for fishery and aquaculture, food consumption, open air horticulture and livestock farming are relatively low.

On the global level, services offered by the IoT and Machine-to-Machine Communication (M2M) connections have increased by almost three times, from 4.9 billion in 2015 to 12.2 billion until 2020, representing almost half (46%) of the total number of connected devices. Apart from, for example, IoT medical services (showing a fast evolution from 144 million connections in 2015, to 729 million in 2020) the IoT is also expected to make a significant contribution in the related fields of food and consumer safety⁵. The total installed base of Internet of Things (IoT) connected devices worldwide is projected to amount to 30.9 billion units by 2025, a sharp jump from the 13.8 billion units that are expected in 2021.

There are several initiatives working toward standardized architectures to overcome fragmentation in IoT development⁶. The Internet of Things—Architecture (IoT-A) provides a detailed view of IoT's information technology aspects⁷. The International Telecoms Unions (ITU) has developed an IoT Reference Model which provides a high-level capability view of an IoT infrastructure⁸. The Alliance for IoT Innovation (AIOTI) has defined a High Level IoT Architecture to achieve IoT semantic interoperability⁹.

Most of these architectures define an IoT infrastructure through three layers: Perception, Network and Application layers¹⁰.

⁴ <https://discovery.ucl.ac.uk/id/eprint/10088791/>

⁵ <https://www.mdpi.com/2073-8994/11/3/374/pdf>

⁶ M. Weyrich, C. Ebert. Reference architectures for the Internet of Things. IEEE Softw., 33 (1) (2016), pp. 112-116

⁷ J. Gubbi, R. Buyya, S. Marusic, M. Palaniswami. Internet of Things (IoT): a vision, architectural elements, and future directions

⁸ Recommendation ITU-T Y.2060, IoT Reference Model, Overview of the Internet of Things. Telecommunication Standardization sector of ITU. <http://www.itu.int/itu-t/recommendations/rec.aspx?rec=Y.2060>.

⁹ AIOTI, 2018. High Level Architecture (HLA) Release 2.1. Alliance for Internet of Things Innovation WG03, pp. 20. https://aioti.eu/wp-content/uploads/2017/03/AIOTI-WG3-IoT-High-Level-Architecture-Release_2_1.pdf

¹⁰

https://www.researchgate.net/publication/347182626_A_Review_of_the_Applications_of_the_Internet_of_Things_IoT_for_Agricultural_Automation

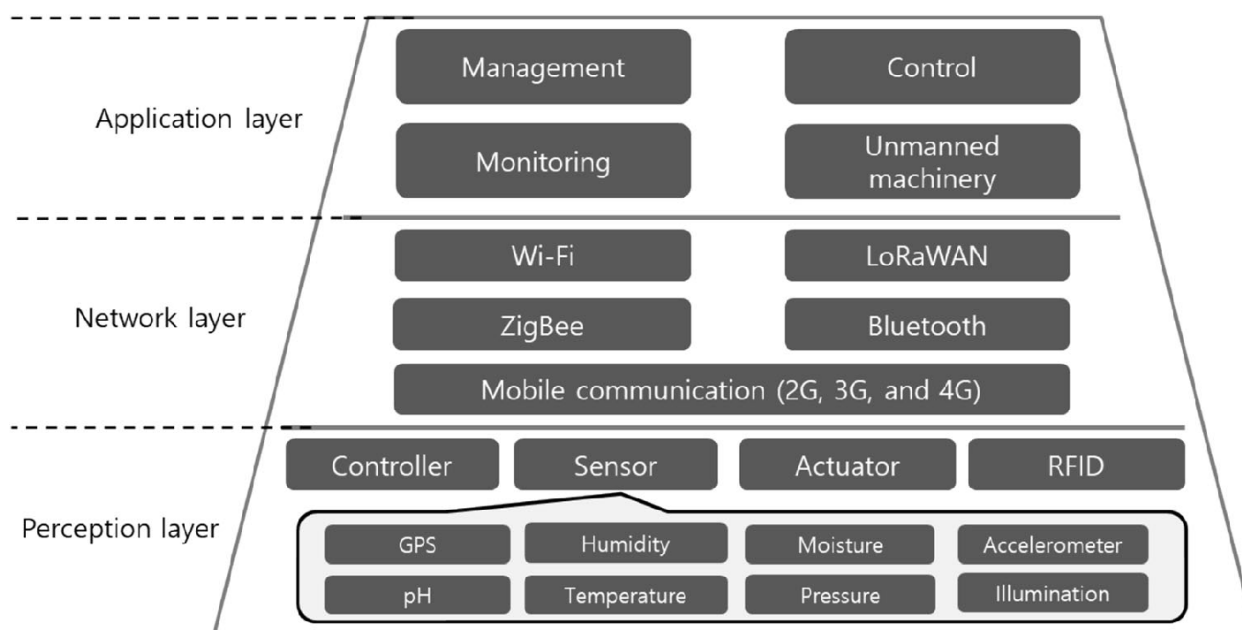


Figure 2 – Common architecture of IoT infrastructure

The perception layer as a medium between the digital and real world. In the IoT architecture layers, this perception layer has the main function of transforming analog signals into the digital form and vice versa. Elements such as sensors (small devices or systems built to understand and detect the change in their environment and further streamline information to their system), actuators (represent a part of the machine that allows an electrical signal to be transformed into physical actions) and other machines and devices (as groups of sensors and actuators).

- In the network layer communication takes center stage between the physical layer of devices and IoT architecture. In addition, there are several media to transport data, such as 3G/4G/5G, Wi-Fi, Bluetooth, IEEE-802.11, NFC, global system for mobile communications (GSM), ZigBee, and general packet radio service (GPRS).
- Finally, the application layer defines all applications that use the IoT technology or in which IoT has deployed. This layer includes various intelligent systems, such as managing data across agriculture; monitoring and controlling plants, animals, machinery, and farms; early warning and diagnosing infections of diseases and infestations of pests; and running autonomous machinery.

This structure has been particularized for the agrifood sector through various works. One of the most recent and successful applications is the architecture of the IoF2020 project, which follows the descriptions of ISO/IEC42010¹¹, separating the diagrams into multiple so-called architecture views each of which describes an architecture according to specific stakeholders' concerns. The IoT view, which is the most relevant for this study, classifies IoT functionalities into different technical layers ranging from device layer until application layer, as such it provides an overview of the technical architecture and allows to identify suitable technology providers; this viewpoint is based on the ITU-T Y.2060 IoT Reference Model mentioned in the previous paragraph.

In addition to the three layers mentioned above, this architecture includes an intermediate layer of "Service support and Application Support layer" with generic services such as cloud data storage, or context broker, which allows us to integrate generic and specific capabilities of real-time processing, data storage and data

¹¹ ISO/IEC/IEEE, 2011. ISO/IEC/IEEE 42010:2011 Systems and software engineering -- Architecture description. <https://www.iso.org/standard/50508.html>

fusion. Finally, two layers are incorporated offering transversal functionalities: (i) Management capabilities: cross-layer capabilities related to an IoT network, e.g., device management, traffic and congestion management; and (ii) Security capabilities: cross-layer capabilities at application, network and device layer. Below, a particularized IoT architecture design is described for a specific Smart farming scenario.

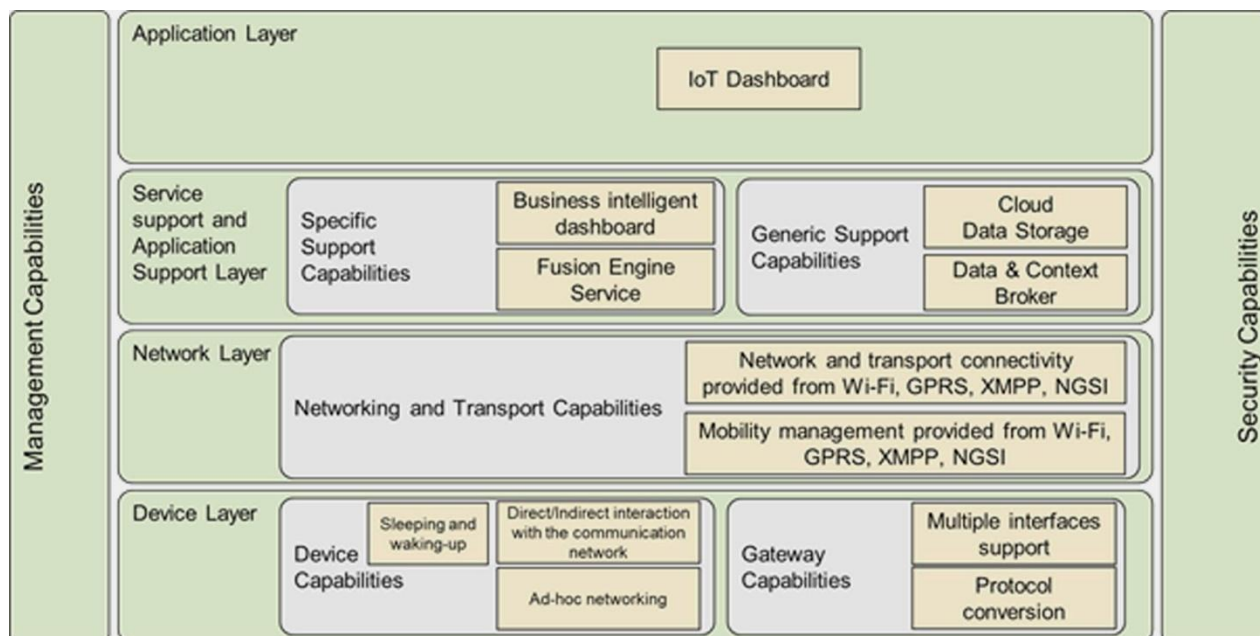


Figure 3 – Customized architecture for Smart farming scenario¹²

In the following sections we particularize the study on the perception/device, network and application levels.

3.2 Internet of things: device, network and application approaches

As we have seen, the device layer provides capabilities for (i) automatic identification (AutoID), (ii) sensing and (iii) actuating physical objects i.e. the real-life things that are to be virtualized (e.g. plant, parcel, animal, stable, box, pallet, truck).

Identification technologies play an important role in urban food systems. The most popular technology that we find in this field is RFID, which has become a common practice in animal identification¹³, but it also has been used in the food chain for traceability control¹⁴. In addition to identification systems, a large multitude of sensors are used to measure the dynamic properties of objects or living beings such as temperature, humidity, lighting, moisture, CO₂, ammonia, pH value.

Another important aspect collected through sensorization devices is the location. Sensing equipment (mainly based on GPS) and remote sensing technologies (satellite and aerial image processing, small unmanned aerial

¹² Cor Verdouw, Harald Sundmaeker, Bedir Tekinerdogan, Davide Conzon, Teodoro Montanaro, Architecture framework of IoT-based food and farm systems: A multiple case study, Computers and Electronics in Agriculture, Volume 165, 2019, 104939, ISSN 0168-1699, <https://doi.org/10.1016/j.compag.2019.104939>.

¹³ Scalera, A., et al. From animal monitoring to early warning systems through the Internet of Things. In Precision Livestock Farming - ECPLF 2013.

¹⁴ Zhao, G., et al., Applied research of IOT and RFID technology in agricultural product traceability system, in IFIP Advances in Information and Communication Technology, D. Li and Y. Chen, Editors. 2015, Springer New York LLC. p. 506-514

systems) are very necessary for applications such as precision farming, tracking and tracing and food security and safety aspects.

Finally, actuators are also present to remotely operate objects such as tractors, other processing machinery, belonging to the Industry 4.0 paradigm, climate control, irrigation, aquaculture control systems.

Regarding network approaches, and given the characteristics of this type of environment, the family of wireless transmission technologies has developed rapidly as the predominant one to support the network level in IoT architectures for food systems. Many types of Wireless communication technologies are available, including Wi-Fi, LoRaWAN, mobile communication (e.g., 2G, 3G, 4G, and the upcoming 5G), ZigBee, and Bluetooth).

These communication technologies enable the automation of the entire cycle of agriculture, thus facilitating highly convenient and highly efficient agriculture. ZigBee and Bluetooth consume minimal power and cost little, so they are widely used in agricultural IoT. ZigBee is an integrated, standard short-range wireless communication technology that consumes minimal power, costs little, and is versatile, and among various communication technologies, ZigBee is widely used for IoT implementation in agriculture¹⁵.

Various types of wireless networks have different characteristics, such as frequency, power consumption, communication ranges, and data transfer limits. The transmission range of the data is an important indicator for selecting which communication technology to apply to a particular type of agriculture, which is related to cost. Therefore, farmers should select a communication technology with an appropriate data transmission range according to the required agricultural characteristics. Table 4 shows the characteristics of different types of wireless networks. Most WSNs used in agriculture need to cost little, use minimal power, and have low data¹⁶.

Table 1 - Characteristics of the wireless technologies used in agri-food systems (modified from (Farooq et al. 2019))

Network protocols	Standard	Frequency band	Data rates	Transmission range	Power consumption
Wi-Fi	IEEE 802.11 a/c/b/d/g/n	5–60 GHz	1 Mb/s–7 Gb/s	20–100 m	High
LoRaWAN	LoRaWAN R1.0	868/915 MHz	0.3~50 kb/s	< 30 km	Very low
Mobile communications	2G (GSM), 2.5G (GPRS), 3G (UMTS, CDMA2000), 4G (LTE)	865 MHz, 2.4 GHz	2G:50–100 kb/s, 3G: 200 kb/s, 4G:0.1–1 Gb/s	Entire cellular area	Medium
Next-gen communication	5G	450 MHz to 6 GHz	Up to 20 Gb/s	Smaller cellular areas	Medium-High
ZigBee	IEEE 802.15.4	2.4 GHz	20–250 Kb/s	10–20 m	Low

¹⁵ Farooq, M. S., Riaz, S., Abid, A., Abid, K., & Naeem, M. A. (2019). A survey on the role of IoT in agriculture for the implementation of smart farming. *IEEE Access*, 7, 156237–156271. <https://doi.org/10.1109/access.2019.2949703>.

¹⁶ Kang, H., & Chen, C. (2020). Fast implementation of real-time fruit detection in apple orchards using deep learning. *Computers and Electronics in Agriculture*, 168, 105108. <https://doi.org/10.1016/j.compag.2019.105108>

Bluetooth	IEEE 802.15.1	2.4 GHz	1–24 Mbps	8–10 m	Very low
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Highlight from this graph of upcoming 5G technology, which presents the following qualitative advantages over the previous generations¹⁷:

- Centralized users provide 24x7 device connectivity, smooth user experience with uninterrupted services.
- A Centralized service provider delivering intelligent transport systems, critical monitoring services, sensors, vehicular roadside services.
- Centralized network operator provides scalability, energy efficiency, and secure infrastructure communication.

Due to these characteristics and the improvement in data rates and network latency, 5G technology can be seen as a means of transformation for innovation in agriculture, supply chain and food production, among others. In relation to agriculture, 5G will make connectivity between devices a lot faster, while facilitating more devices to connect to a single cell tower. The farmers, who are already using 4G will embrace 5G. 4G operates at 100 Mbps, while 5G runs at 10Gbps, with very low latency. This can facilitate the interconnection of countless devices that are beginning to be used in the field of Smart farming, such as Autonomous tractors sowing the seeds, drones with sensors monitoring the crops, and small robots taking samples to calculate what fertilizers and pesticides need to be applied and where.

In the field of food traceability, 5G networks have the potential to enable dynamic, end-to-end food traceability – thanks to an ability to connect to many low-power devices, like embedded Internet of Things sensors at the same time. As a result, the food supply chain will be able to further modernize its practices and processes, becoming super-interconnected and better equipped to leverage technologies like blockchain and AI. 5G-enabled IoT devices can go with the food products and report their condition, temperature, safety, humidity level and other related factors in real-time. That will increase accountability of food businesses in the event of foodborne illness outbreaks, help organizations better mitigate food safety risk and streamline costs for companies and, in turn, consumers.

Finally, in terms of food manufacturing, increasing the level of automation is key to making the food manufacturing process and supply chain more flexible and responsive to the latest changes in demand. Operational efficiency and cost reductions are key aspects, and 5G-enabled processing systems and equipment will facilitate the industry to manage food products' journey from the farm via the factory to the consumer. Incorporating 5G could take this control to a whole new level, and at the same time could potentially provide greater quality and safety measures.

3.2.1 Internet of things: device, network and application approaches

According to the different uses that we can make of the functionalities of the Internet of Things platforms, we can break down their use in different use cases, which we have called application approaches. In the following, we describe the use cases studied in relation to Urban Food Systems.

In relation to autonomous harvesting, the agri-food domain is a challenging domain from IoT-point of view, as things are often living and perishable objects such as animal and food products. This means that IoT devices (eg, microprocessors, sensors, antennas) cannot be easily embedded in products themselves, and have to operate in harsh environments (open air, cold storage, hot cleaning treatments, etc.) and remote

¹⁷ K. Shafique, B. A. Khawaja, F. Sabir, S. Qazi and M. Mustaqim, "Internet of Things (IoT) for Next-Generation Smart Systems: A Review of Current Challenges, Future Trends and Prospects for Emerging 5G-IoT Scenarios," in IEEE Access, vol. 8, pp. 23022-23040, 2020, doi: 10.1109/ACCESS.2020.2970118.

areas (fields, stables, etc.). Therefore, they not only have the requirements to be autonomous, but, due to the long times of food growth, it is necessary that they be operational for months and years.

This approach also enables farmers to perform a comprehensive analysis of soil, such as the temperature, acidity, nutrient status, and other properties¹⁸. In 2017, for the first time, the 5G Rural First project successfully planted and harvested a crop using autonomous tractors to sow seeds, drones to monitor crops, and machines to apply water, fertilizer, and pesticides. The whole process was performed without any laborers stepping into the field¹⁹. In 2018, another project titled Hands-Free Hectare reported a successful harvest.

In relation to land management recently, the use of drone technology, farms and agricultural enterprises can increase crop yields, save time, and make land management decisions that maximize long-term performance. Drones employing several types of sensors, such as multispectral imaging, thermal infrared imaging, hyperspectral, and lidar, are used to scan a vast area for 3D mapping; counting plants; computing vegetation indices such as NDVI, CCCI, NDRE, MCARI, and CWSI; and capturing the health of the plants, soil temperature, and water levels²⁰.

Another very relevant application in food systems is virtual consultation, as domain experts or consultation services can attend to the needs of food producers through virtual consultation using high-definition (HD) streaming without the need for a physical meeting in the comfort of home. In addition to normal video conferencing, domain experts or consultation services can directly pull a live feed from real-time monitoring sensors or agricultural drones to obtain detailed insight into the situation and provide necessary solutions to farmers for the betterment of agricultural practice on time. With this, the farmer is informed about any upcoming issue and any failing parts based on feedback from different 5G-enabled sensors, allowing repairs to be scheduled in a timely manner and without halting any operation²¹.

In addition to the field of agriculture, we can also find applications of the IoT paradigm in other processes of food systems such as packaging and nutrition services. In relation to food packaging, gas sensors are mainly used to monitor the correct preservation of food, which enable the appearance of mobile olfaction technologies, monitoring the gas level, the humidity level and the temperature of, for example, vacuum - packed foods. These technologies have a greater impact on intelligent food feature extraction, and have become important fields of research in recent years. Robots capable of localizing odor sources have also been developed today.

A wireless electronic nose (WEN) developed for fruit quality control and classification was demonstrated in the work of Deshmukh et al.²². The electronic nose system was based on wireless data transmission using ZigBee, a series of gas sensors, and a LabVIEW Graphic User Interface, and it was tested with green and yellow mango samples.

¹⁸ P. Placidi, L. Gasperini, A. Grassi, M. Cecconi, A. Scorzoni. Characterization of Low-Cost Capacitive Soil Moisture Sensors for IoT Networks

¹⁹ Yu Tang, Sathian Dananjayan, Chaojun Hou, Qiwei Guo, Shaoming Luo, Yong He, A survey on the 5G network and its impact on agriculture: Challenges and opportunities, Computers and Electronics in Agriculture, Volume 180, 2021, 105895, ISSN 0168-1699, <https://doi.org/10.1016/j.compag.2020.105895>

²⁰ Y. Ampatzidis, V. Partel, L. Costa. Agroview: Cloud-based application to process, analyze and visualize UAV-collected data for precision agriculture applications utilizing artificial intelligence. Comput. Electron. Agric., 174 (2020), p. 105457, 10.1016/j.compag.2020.105457

²¹ M. Compare, P. Baraldi, E. Zio. Challenges to IoT-Enabled Predictive Maintenance for Industry 4.0. IEEE Internet Things J., 7 (5) (2020), pp. 4585-4597, 10.1109/JIOT.2019.2957029

²² Deshmukh, L.P.; Kasbe, M.S.; Mujawar, T.H.; Mule, S.S.; Shaligram, A.D. A wireless electronic nose (WEN) for the detection and classification of fruits: A case study. In Proceedings of the 2016 International Symposium on Electronics and Smart Devices (ISESD), Bandung, Indonesia, 29–30 November 2016

Future smart packaging developments will focus on food safety (detecting microbial growth, oxidation, and improved tamper visibility), food quality (sensing volatile flavors and aromas), shelf-life tracking, authentication, convenience, and sustainability of food products²³.

In relation to nutrition, there are IoT solutions for food nutrition quantification. In²⁴ authors developed a consumer electronics product consisting of WiFi-enabled sensors for food nutrition quantification, and a smartphone application that collects nutritional facts of the food ingredients. The experimental results are based on the analysis of 8172 items for 1000 types of foods. With this data, the system provided suggestions to decrease the risk of imbalanced diets with 98.6% classification accuracy.

3.3 Privacy and trust for all: Blockchain

Distributed Ledger technologies (DLT) (and blockchain in particular) have revolutionized many business sectors in recent years including food systems. These technologies' popularity is largely due to the removal of the dependence on a central technology whilst maintaining a verifiable and irrefutable set of transactions. In essence, a set of distributed nodes independently agree upon (via consensus) and record transactions to maintain the integrity of the ledger. Blockchain is a particular type of DLT where data is grouped together in blocks which are linked and secured using cryptography. Common applications of blockchain technology are crypto-currencies and smart contracts. A recent comprehensive state of the art of blockchain and its applications and challenges is provided by Sanka et al.²⁵.

3.3.1 Blockchain examples

Bitcoin

The Bitcoin crypto currency is probably the most well-known use of blockchain technology today. Started in 2009, Bitcoin uses Nakamoto Consensus model where miners solve a puzzle to generate new blocks. To maintain state, Bitcoin deploys an Unspent Transaction Output (UTXO). A UTXO is the unspent amount of digital currency after a transaction has occurred.

Ethereum

Ethereum is an open-source platform utilizing blockchain theory in the generation of smart contracts. Ethereum operates through a set of decentralised Ethereum Virtual Machines (EVMs). Ethereum 2.0 moved to a Proof of Stake (PoS) consensus mechanism from the previous Proof of Work (PoW). Another difference of Ethereum as compared to Bitcoin is that it uses a more traditional type of Account/Balance model for state maintenance.

Hyperledger Fabric

²³ Kuswandi, B.; Wicaksono, Y.; Abdullah, A.; Heng, L.Y.; Ahmad, M. Smart packaging: Sensors for monitoring of food quality and safety. *Sens. Instrum. Food Qual. Saf.* 2011, 5, 137–146.

²⁴ P. Sundaravadivel, K. Kesavan, L. Kesavan, S. P. Mohanty and E. Kougianos, "Smart-Log: A Deep-Learning Based Automated Nutrition Monitoring System in the IoT," in *IEEE Transactions on Consumer Electronics*, vol. 64, no. 3, pp. 390-398, Aug. 2018, doi: 10.1109/TCE.2018.2867802.

²⁵ Abdurrashid Ibrahim Sanka, Muhammad Irfan, Ian Huang, Ray C.C. Cheung, A survey of breakthrough in blockchain technology: Adoptions, applications, challenges and future research, *Computer Communications*,

Volume 169, 2021, Pages 179-201, ISSN 0140-3664, <https://doi.org/10.1016/j.comcom.2020.12.028>.

Hyperledger Fabric is a permissioned distributed ledger platform that utilizes a plug & play modular approach. This allows for individual deployments to use modular components for consensus and membership management. The focus is on performance and flexibility with its modular approach lending itself to a wide range of enterprise level applications depending on the trust requirements of the specific application.

EOSIO

EOSIO is a blockchain platform launched by block.one in 2018. EOSIO smart contract users do not pay transaction fees (unlike Bitcoin and Ethereum). EOSIO claims millions of transactions per second. Due to these features this platform has become very popular in a short timeframe.

3.3.2 Blockchain and privacy

There are several ways in which blockchain technology enables privacy. Firstly, by the use of public and private keys, the identity of users is obfuscated. Secondly, the decentralized nature of these platforms means that no one central authority holds user details. Thirdly, consensus protocols ensure that no information about transactions is revealed. Usually, the sender and receiver addresses and the amount sent is what is revealed in a blockchain transaction.

Following the introduction of the “right to be forgotten” in the GDPR concerning transactions between, or pertaining to, EU citizens, concerns about the legal aspects of the blockchain have emerged. Once blocks are generated, they cannot be deleted, meaning that a user cannot request for their data to be erased.

3.3.3 Blockchain in food systems

Blockchain is useful for recording transactions of a chain of events in much the same way as food systems operate and as such is a suitable technology for managing food systems and its inherent supply chain. A good overview of blockchain in food systems is given in ²⁶.

Below we describe the use of blockchain technologies applied to various aspects of the food industry.

Digitalization of the agri-food sector

The ever-increasing integration of digital technologies in the agri-food sector brings great opportunities in the management and control of food systems. Kamilaris et al.²⁷ analyze how blockchain can support this digitalization trend in the sector and provide a discussion on how blockchain is being applied to several challenges in agriculture and food systems, namely food security, food safety, food integrity, waste management, support for small farmers and improved management of the supply chain.

Traceability

The ever-increasing emergence of IoT technologies in the agri-food sector has brought with it the potential for complete farm-to-fork traceability. Most of the traditional systems for traceability in the agri-food supply chain rely on centralized solutions which bring potential pitfalls for complete and reliable traceability guarantees, namely single points of failure, data integrity issues and lack of transparency. Blockchain features lend themselves well to solving these issues as they provide transparency, immutability and remove the

²⁶ Understanding blockchain in the food industry, Sam Mehmet, <https://www.newfoodmagazine.com/article/104104/understanding-blockchain-in-the-food-industry/>

²⁷ Andreas Kamilaris, Agusti Fonts, Francesc X. Prenafeta-Boldó, The rise of blockchain technology in agriculture and food supply chains, Trends in Food Science & Technology, Volume 91, 2019, Pages 640-652, ISSN 0924-2244, <https://doi.org/10.1016/j.tifs.2019.07.034>.

single point of failure issue. Caro et al²⁸ describe the application of blockchain to the traceability issues in the agri-food sector and provide farm-fork use cases and implementations using both Ethereum and Hyperledger and a technical analysis of each of the deployments. Galvez et al²⁹ recognize the suitability of blockchain in the application of traceability in the agri-food supply chain but also identify some challenges including regulatory issues, a lack of uniform requirements, and different traceability processes in different sub-sectors.

Table 2 - Selected applications of blockchain technology in the agricultural and farming food-supply chain. (Source: Galvez et al)

Food	Goal	Advantage	Result
Fish	Auditable system	Reduce transaction costs and increase transaction capacity	Certifications
Wine	Increase performance, revenue, accountability and security	Most reliable and secure global transactions	Management
Agri-food	Allow quality and digital identity to be certified	Especially for "bio" and DOCG products	Quality
Agri-food	Trusted information throughout the agri-food supply chain	Guarantee of food safety, by sharing the authentic data in production, processing, warehousing, distribution, etc.	Trust
Fruits	Public, immutable, ordered ledger of records	Decreased variance of mining rewards	Fairness
Pork	Brand protection and security through transparency	Enhancing consumer loyalty	Reduced risk
Large enterprises	Food tracking project	Integration with existing systems used by retailers, wholesalers and food manufacturers	Traceability
Fresh food	Enabling data transparency and transfer from farm to fork	Information on product origin including sensor data	Transparency

3.3.4 Challenges

Despite the rising popularity of blockchain across many industrial sectors, there remain challenges that need to be addressed. The challenges can be categorized as technical and non-technical. A comprehensive discussion of the current challenges in blockchain is available at Sanka et al. and is summarized below.

Technical challenges

Scalability: Probably the greatest technical challenge in public blockchains is the issue of scalability. There is a tradeoff between the block size and the block interval in obtaining optimal throughput. Also there is a storage issue particularly with IoT devices where storage is a scarce resource.

Security: Security threats have been identified in public blockchains. Commonly reported threats include scams, malware attacks, denial of service attacks. Loss of private keys is another potential security weakness. Private blockchains are less prone to security threats due to their controlled access.

Privacy: Despite being pseudonymous, it has been shown that the physical identity of a user can be revealed through analysis of transactions on a specific node. There also exists the GDPR issue around the right to be forgotten mentioned above.

Usability: Swan³⁰ believes that blockchain APIs are not easy for developers to use. There remains a need to increase usability for developers.

²⁸ M. P. Caro, M. S. Ali, M. Vecchio and R. Giaffreda, "Blockchain-based traceability in Agri-Food supply chain management: A practical implementation," 2018 IoT Vertical and Topical Summit on Agriculture - Tuscany (IOT Tuscany), 2018, pp. 1-4, doi: 10.1109/IOT-TUSCANY.2018.8373021.

²⁹ Juan F. Galvez, J.C. Mejuto, J. Simal-Gandara, Future challenges on the use of blockchain for food traceability analysis, TrAC Trends in Analytical Chemistry, Volume 107, 2018, Pages 222-232, ISSN 0165-9936, <https://doi.org/10.1016/j.trac.2018.08.011>.

³⁰ Swan M., Blockchain: Blueprint for a New Economy (first ed.), O'Reilly Media, Incorporated, Cambridge (2015), p. 129, URL <https://ebookcentral.proquest.com/lib/cityuhk/detail.action?docID=1929181>

Quantum Computing: As most blockchains use the elliptic curve digital signature (ECDSA) there is a future threat from the emergence of quantum computing which can be used to break this signature.

Non-technical challenges

Regulatory Issues: Lack of regulation around blockchain technologies is probably the greatest non-technical barrier to blockchain adoption in commercial environments. There is a perception around cryptocurrencies being used largely for criminal transactions and as such governments are slow to legalize these currencies.

Lack of understanding: There is a lack of understanding of blockchain technologies among non-technical users and this is manifested through a lack of trust in the technology and thus a slowness in adoption.

Skill shortage: There is a recognized skill shortage among software developers with adequate skills for blockchain application development.

Blockchain challenges in the agri-food sector

The general blockchain challenges described above manifest themselves in the agri-food sector. A good overview of how these challenges occur in the sector is provided by Kamilaris et al and is summarized in the following Table:

Table 3 - Potential benefits and existing barriers for the use of blockchain in agriculture (Source Kamilaris et al)

Opportunities and potential benefits	Challenges and barriers
Traceability in value chains	SME have difficulties in adopting the technology
Support for small farmers	Information infrastructure might prevent access to markets for new users
Finance and insurance of rural farmers	Lack of expertise by small SME
Facilitation of financial transactions in developing countries	High uncertainties and market volatility
Fairer pricing through the whole value chain	Limited education and training platforms
A useful platform in emission reduction efforts	No regulations in place
Consumer awareness and empowerment	Lack of understanding among policy makers and technical experts
More informed consumer purchasing decisions	Open technical questions and scalability issues (e.g. latency of transactions)
Increased sustainability and reduction of waste	Digital divide among developed and developing world
Reduced transaction fees and less dependence on intermediaries	Decline of cryptocurrencies in market share and high volatility (reputation issues)
More transparent transactions and less frauds	Cost of computing/IoT equipment required
Better quality of products, lower probability for foodborne diseases	Design decisions might reduce overall flexibility
	Privacy issues
	Some quality parameters of food products cannot be monitored by objective analytical methods, especially environmental indicators

3.4 Big Data and other data management and processing technologies

Agriculture and food-chain are well-known areas in which empirical knowledge is exhaustively established and historically documented. The old perspective of farming, far away from big data and information systems, is by no means found in modern farming practices which are intensely data-driven. The agricultural sector has already been active in digital innovation for decades, with the advances in Precision Agriculture, remote sensing, robots, farm management information systems, and (agronomic) decision support systems paving the way for a broad digital transformation in farming and food. The digital transformation of current societies has led to a new era in industry, which can be described as "Industry 4.0", or, in this particular case food-systems has been coined Agro-Food 4.0, based on the technological concepts and architecture which facilitates the development of "smart"-entities. One of the core principles is data management, from collection to analysis, and the integration of information technologies, manufacturing and operation systems as a way to acquire data in a more timely, rapid and flexible manner. Big data, its related methods and tools form one of the pillars supporting this transformation.

Big data is usually characterized through the prism of its four pillars³¹, the 4 'V's: 'Volume', 'Velocity', 'Variety' and 'Value', which are joined by a fifth one: 'Veracity', representing the uncertainty in the target datasets. Managing such a massive amount of information cannot be done using the traditional approaches of SQL queries, since the datasets become very volatile, with large complexity, without uniform information and most of the time, geographical distribution³². Big data management has been sub-categorized into big data science and big data infrastructure³³. The former deals with acquisition, conditioning and evaluation, management, analysis, visualization and exploiting informative knowledge from several datasets. The infrastructure enables the processing, optimization of large amounts of data in distributed environments across computational clusters.

Big data management has been characterized in three main activities³⁴:

1. transformation of data from original format to standard formats;
2. application of big data operations;
3. decision making based on the outcomes of 1 and 2.

It is a well-known problem that the data coming from several sources may be heterogeneous, incomplete or inconsistent³⁵. A simple example is IoT sensors that may measure different parameters, or due to buffering, only chunks of data arrive at the database, introducing the volatilization of data and non-uniformity. This issue is typically treated at the pre-processing mathematical modeling already at the management activities. Network management starts with transmission of raw information to a data storage infrastructure, often to a data center, object storage system or distributed cloud storage, for subsequent processing³⁶. This process can be categorized as IP backbone transmission, which provides a high-capacity pipe for big data transmission from data source to data center and as data center transmission, which entails transferring big data within a

³¹ Prableen Kaur and Manik Sharma and Mamta Mittal, *Procedia Computer Science* Volume 132, 2018, Pages 1049-1059.

³² Han R., Lu X., Xu J. (2014) On Big Data Benchmarking. In: Zhan J., Han R., Weng C. (eds) *Big Data Benchmarks, Performance Optimization, and Emerging Hardware*. BPOE 2014. Lecture Notes in Computer Science, vol 8807.

³³ Mohamed Ahzam Amanullah and Riyaz Ahamed Ariyaluran Habeeb and Fariza Hanum Nasaruddin and Abdullah Gani and Ejaz Ahmed and Abdul Salam Mohamed Nainar and Nazihah Md Akim and Muhammad Imran, *Computer Communications* Volume 151, 1 February 2020, Pages 495-517

³⁴ S. Sagioglu and D. Sinanc, "Big data: A review," 2013 International Conference on Collaboration Technologies and Systems (CTS), 2013, pp. 42-47

³⁵ Bautista Villalpando, L.E., April, A., Abran, A., 2014. DIPAR: a framework for implementing big data science in organizations. In: Mahmood, Z. (Ed.), *Continued Rise of the Cloud*. Springer, London, pp. 177-194.

³⁶ Wu, Xindong, et al. "Data mining with big data." *IEEE transactions on knowledge and data engineering* 26.1 (2013): 97-107.

data center for other pre-processing activities³⁷. This type of transmission mostly involves the data center's network architecture as well as the transportation protocol.

A critical issue of the big data center is data storage, which allows the high availability of data and should be massively scalable³⁸. New technologies like cloud computing services reveal a shift to a new computing paradigm, and it has become increasingly challenging to assure consistency in managing such large-scale data in cloud storage³⁹. Data management procedures should avoid filter out and waste data, as it may contribute to future decision-making processes⁴⁰. The complexity, dimensionality and dynamic growth of data derive a need for such a storage management system that can keep sufficient data, optimizing its availability to processing sites and improving retrieval efficiency⁴¹.

The process of managing storage for big data involves performing activities in parallel to optimize the storage process⁴². Data clustering, replication and indexing are activities which are considered significant for accomplishing the storage phase⁴³. Traditionally, the clustering algorithms decompose the data into multi-layer matrices, improved with iteratives merging and classification to avoid duplication of records. Other algorithms like the MapReduce framework and K-mean are being applied to food-chain databases. To reduce the operational storage space, replication has been used to have data consistently accessible and available to users⁴⁴.

The main purpose of storing data is to efficiently utilize it in future for decision-making so that an instant value is obtained. In big data storage management, it is challenging to obtain optimized query execution results when a large volume data is allocated to distributed sites. While preserving space resources, the indexing process improves performance and future efficient retrieval of stored data should also be guaranteed by storage management. For large datasets it is unacceptably time consuming to retrieve required data items; thus, in developing a suitable mechanism it is challenging to obtain high indexing throughput and efficient data lookup⁴⁵. Furthermore, multivariable and multi-site searching, performing different types of queries and numerical data search optimization are challenges faced in big data management from an indexing perspective⁴⁶.

³⁷ Taleb, Ikbali, Rachida Dssouli, and Mohamed Adel Serhani. "Big data pre-processing: A quality framework." 2015 IEEE international congress on big data. IEEE, 2015.

³⁸ G. Putnik, A. Sluga, H. ElMaraghy, R. Teti, Y. Koren, T. Tolio, B. Hon, CIRP Annals 62, 751-774 (2013).

³⁹ Buza, K., Nagy, G.I., Nanopoulos, A., 2014. Storage-optimizing clustering algorithms for high-dimensional tick data. Expert Syst. Appl. 41 (9), 4148–4157.

⁴⁰ Duan, Yanqing, John S. Edwards, and Yogesh K. Dwivedi. "Artificial intelligence for decision making in the era of Big Data—evolution, challenges and research agenda." International Journal of Information Management 48 (2019): 63-71.

⁴¹ Siddiqua, Aisha, Ahmad Karim, and Abdullah Gani. "Big data storage technologies: a survey." Frontiers of Information Technology & Electronic Engineering 18.8 (2017): 1040-1070.

⁴² Hammad, Khalid Adam Ismail, et al. "Big data analysis and storage." International Conference on Operations Excellence and Service Engineering. 2015.

⁴³ Jain, Priyank, Manasi Gyanchandani, and Nilay Khare. "Big data privacy: a technological perspective and review." Journal of Big Data 3.1 (2016): 1-25.

⁴⁴ Mtshali, Mxolisi, et al. "K-Means Based on Resource Clustering for Smart Farming Problem in Fog Computing." 2019 IEEE AFRICON. IEEE, 2019.

⁴⁵ Schmidt, Bertil, and Andreas Hildebrandt. "Next-generation sequencing: big data meets high performance computing." Drug discovery today 22.4 (2017): 712-717.

⁴⁶ Li, Xin, and Vladan Babovic. "Multi-site multivariate downscaling of global climate model outputs: an integrated framework combining quantile mapping, stochastic weather generator and Empirical Copula approaches." Climate Dynamics 52.9 (2019): 5775-5799.

Quality decisions need quality data. One of the main problems following the process of big data system assimilation is the “sanity of data”⁴⁷. Data pre-processing is a mean of transforming raw data, which can be incomplete or inconsistent and have many errors or unusable parts, into an understandable format that is ready for a more efficient analysis process. Pre-processing data prepares raw data for further processing and entails transforming data into such a format that processing becomes more efficient. The different steps in data pre-processing⁴⁸ include:

- Data cleansing: The process of identifying and removing inaccuracies, incompleteness, and inconsistencies of data.
- Data transformation: Additional pre-processing steps, i.e. normalization and aggregation. Transformation significantly enhances the data mining process.
- Data integration: To provide a single view of the data distributed over different sources, data integration combines the data views.
- Data transmission: A method in which raw data is transferred to a data storage infrastructure, commonly a data center, objects storage system or distributed cloud storage for subsequent processing.
- Data reduction: large datasets are reduced in size for use by nearly all real-time applications.
- Data discretization: An essential pre-processing step of decision tree learning, it refers to increasing the continuous attribute intervals such that the obtained values will be reduced.

The ability to process huge amounts of data can assist an organization to deal with abundant information that could impact the business. Nevertheless, data processing has been a challenge for many applications, due to the complexity of the data that needs to be processed and the scalability of the underlying algorithms that support such processes. Begoli and Horey⁴⁹ proposed three principles that make flexible data processing. The first principle is that its architecture should support a large variety of analysis methods, for example statistical analysis, machine learning, data mining and visual analysis. The second principle is that all data cannot fill one type of storage place, so the storage mechanisms and also data processing should be different. Classification is a data mining method used to classify objects into different groups or classes⁵⁰. Data mining assists many business communities with IT requirements to discover hidden insight from large amounts of data. Data mining has successfully been adopted in many applications⁵¹ for science, medicine, business, engineering, etc. Moreover, extracting meaningful and valuable information from huge datasets is important for providing attractive new services and boosting quality. Big data not only brings large amounts of data together, but it also contains a variety of data formats like structured and unstructured⁵², which have not been considered before in mining data sources.

⁴⁷ Leros, Jefferson L., and Mia V. Villarica. "Pattern extraction of water quality prediction using machine learning algorithms of water reservoir." *International Journal of Mechanical Engineering and Robotics Research* 8.6 (2019): 992-997.

⁴⁸ Jarolímek, Jan, et al. "Data Pre-processing for Agricultural Simulations." *Agris on-line Papers in Economics and Informatics* 11.01 (2019): 49-53

⁴⁹ Begoli, E., Horey, J., 2012. Design principles for effective knowledge discovery from big data. In: *Proceedings of the IEEE 2012 Joint Working IEEE/IFIP Conference on Software Architecture (WICSA) and European Conference on Software Architecture (ECSA)*.

⁵⁰ Bansal, Arpit, Mayur Sharma, and Shalini Goel. "Improved K-mean clustering algorithm for prediction analysis using classification technique in data mining." *International Journal of Computer Applications* 157.6 (2017): 0975-8887.

⁵¹ Amani, Farzaneh A., and Adam M. Fadlalla. "Data mining applications in accounting: A review of the literature and organizing framework." *International Journal of Accounting Information Systems* 24 (2017): 32-58

⁵² Cauteruccio, F., Giudice, P. L., Musarella, L., Terracina, G., Ursino, D., & Virgili, L. (2020). A Lightweight Approach to Extract Interschema Properties from Structured, Semi-Structured and Unstructured Sources in a Big Data Scenario. *International Journal of Information Technology & Decision Making*, 19(03), 849-889.

Finding unknown and homogeneous patterns for analysis was done using traditional data mining algorithms, which generally consider only structured data formats. However, the data being collected today has different formats, which introduces a new challenge in data mining. Big data analysis is performed using compute-intensive data mining algorithms that require high-performance CPU and memory to accomplish the tasks. Cloud computing serves as an effective platform for addressing storage and computing needs of big data analysis⁵³. Cloud computing enables organizations to implement big data technology in order to reduce organizational resource consumption. Several major data mining techniques have been developed and applied in data mining projects⁵⁴.

Choosing a proper data analysis technique is one of the most critical and difficult tasks in big data management. The need to develop and implement large-scale machine learning algorithms is vital⁵⁵.

Unstructured data is stored in a distributed database such as Hbase, Cassandra or simpleDB⁵⁶. The data is then processed using data mining techniques and algorithms before analysis. Mathematical methods are employed in many classification techniques such as decision trees, statistics, linear programming and neural networks⁵⁷. Traditionally, statistical methods have been used for analyzing massive data. Data analysis is considered an important guide in discovering new insights for large amounts of data. Big data analysis is considered an analysis technique for a special kind of data, so many traditional data analysis methods may still be utilized in big data analysis.

A final note regarding some already developed databases, relying on big data strategies. For example, Monsanto⁵⁸ is a well-established company with a track record on chemicals and seeds production. Recently they proposed a new big data for precision agriculture that encompasses, in-situ measurements, earth observation imagery and services, climate variables, drones based-data and many other inputs. The objectives are:

- resource productivity;
- developing unmanned agricultural machinery;
- implementing computer vision techniques to model pattern recognition;
- cattle breeding and milking;
- effective algorithmic planning and improved knowledge for better decision-making.

This database is also related with the data coming from John-Deere. John Deere uses sensors added to their equipment to help farmers manage their fleet and to decrease downtime of their tractors as well as to save fuel. The information is combined with historical and real-time weather data, soil conditions, crop features and many other data sets.

⁵³ Ning, H., Li, Y., Shi, F., & Yang, L. T. (2020). Heterogeneous edge computing open platforms and tools for internet of things. *Future Generation Computer Systems*, 106, 67-76.

⁵⁴ Selamat, Siti Aishah Mohd, Simant Prakoonwit, and Wajid Khan. "A review of data mining in knowledge management: applications/findings for transportation of small and medium enterprises." *SN Applied Sciences* 2.5 (2020): 1-15.

⁵⁵ Lwakatare, L. E., Raj, A., Crnkovic, I., Bosch, J., & Olsson, H. H. (2020). Large-scale machine learning systems in real-world industrial settings: A review of challenges and solutions. *Information and Software Technology*, 127, 106368.

⁵⁶ Malik, A., Burney, A., & Ahmed, F. (2020). A Comparative Study of Unstructured Data with SQL and NO-SQL Database Management Systems. *Journal of Computer and Communications*, 8(4), 59-71.

⁵⁷ Al-Tashi, Q., Rais, H. M., Abdulkadir, S. J., Mirjalili, S., & Alhussian, H. (2020). A review of grey wolf optimizer-based feature selection methods for classification. *Evolutionary Machine Learning Techniques*, 273-286

⁵⁸ <https://www.cropsience.bayer.com/innovations/data-science>

Additional food-chain partners are also using big data⁵⁹:

1. The Cheesecake Factory utilizes a Big Data-driven software to process and analyze enormous data sets from 175 locations in the U.S.
2. FreshDirect uses sensors, processing, and analyzing data to monitor product status and environmental conditions during transportation.
3. Connecterra has designed a predictive analytics-based tool to aid farmers in determining cattle health problems.
4. The Yield company has developed the solution to monitor planting beds and the whole agricultural ecosystem and foresee any arising issues.
5. The all-known restaurant KFC uses Big Data to analyze customer feedback and food preferences, which comes up with better customer experience and sales.

3.5 Artificial Intelligence and Smart Systems

3.5.1 Digitalization and digital transition

We are in the age of the fourth industrial revolution 'Industry 4.0' which involves sensors and smart data capture systems. Though, the digitalization and computing systems have reached to the most minuscule daily activities of human life, still there is a need for a systematic synthesis of knowledge extraction with the use of such system to build a sustainable ecosystem in long term. Artificial Intelligence (AI) is transforming almost every industry segment that we can think of, and food systems and regional development are no exceptions. It is reaching all parts of food systems in ways that indicate transformative system changes needed to move to sustainable food systems are possible.

Food and Agriculture Organization (FAO) of the United Nations⁶⁰ has estimated that 70 percent more food will be needed by 2050. Meanwhile, water's receding and the land is not getting richer in the natural nutrients. Never before have we had so few resources to produce so much.

Authors in⁶¹ identify and inform that AI has the disruptive potential that can fill the gaps and needs to build a sustainable food system (SFS) within sustainable and ethical boundaries, and human values at its core. They identify that there is a need to build transdisciplinary approaches that assess possible scenarios, future visions that is balanced across the social technical and environmental realms. Authors here conclude that there is a strong need of an AI-powered solution developed by utilizing interdisciplinary system and design thinking process consisting of a diversity of stakeholders is key for transitioning to sustainable food systems. Further, the COVID-19⁶² pandemic has highlighted and added to the concerns of food wastage, spoilage, logistics etc., and have brought them to the fore: the disease has disrupted supply chains and demand, perversely increasing the amount of food waste in farms and fields while threatening food security for many. The pandemic has shown the need of innovation, advancement and application of technologies such as AI that could make a powerful contribution to secure and sustainable food production. For example, AI and sensors could help food processors sort better and slash waste, and other smart technologies could identify

⁵⁹ <https://www.mckinsey.com/business-functions/mckinsey-digital/our-insights/how-big-data-will-revolutionize-the-global-food-chain>

⁶⁰ <http://www.fao.org/news/story/en/item/35571/icode/>

⁶¹ Camar  na, St  phanie. "Artificial Intelligence in the design of transition to Sustainable Food Systems." *Journal of Cleaner Production* (2020): 122574 <https://doi.org/10.1016/j.jclepro.2020.122574>.

(<https://www.sciencedirect.com/science/article/pii/S0959652620326214>)

⁶² <https://www.oecd.org/coronavirus/policy-responses/covid-19-and-global-food-systems-aeb1434b/>

inedible by-products for reprocessing. Data and advanced analytics also could help authorities better monitor and manage, leading to improved practices with sustainability at its core. Agriculture is a traditional industry, but its quest for tech-enabled sustainability offers valuable lessons.

One must consider logistics in getting fresh produce and goods from warmer climates to colder climates. Going to be able to predict supply and demand trends across the globe, not only in normal times, but within a global pandemic. Food must be carefully monitored during the journey within cold storage and at retail to prevent spoilage, and of course, food safety is paramount.

In the journey from farm to fork, the connected continuum of IoT devices, combined with intelligent systems can help ensure safe, resilient, and efficient distribution. Ensuring the safe, resilient, and efficient delivery of food to the consumer is a Herculean endeavor, and AI-based digitalized systems can help us achieve that.

3.5.2 Problems and challenges

The application of the Internet of Things (IoT) coupled with AI⁶³ to food systems and agriculture is widely talked about, however in most real-world deployments it is limited to single-provider solutions focused on a limited use case. The result⁶⁴ of this is that if one solution (say on a farm) wishes to address multiple issues there is large degree of duplication in the solutions, and limited ability to link data between solutions. Furthermore, the solutions remain relatively expensive, and ignore the capabilities of AI to provide insight into the collected data. To overcome the disadvantages of closed, vendor lock-in solutions, authors⁶⁵ identify the need to build platform(s) that is capable of gathering and transforming data collected from devices, as an input to other system components such as AI models or cloud services. Such digitized systems⁶⁶ need to have a modular and service-oriented approach that allows easy extension of the platform for new types of devices, protocols and data processing tools.

Besides, by adding AI and ML techniques, critical problems for e.g. of knowing when to plant, fertilize, treat, and harvest crops can be addressed by providing data insights using the latest AI modelling coupled analytical system, with multi-parameter analysis by using inexpensive devices and simplified procedures, with access to data and processed data remotely from anywhere at any time for the farmers, so that even small regions and farmers in remote areas could optimize their assessment system, with strong increase in quality and consistency of the products.

Enabling technologies such as IoT and AI, even if technically viable, may be hampered by “soft” barriers, such as social acceptance or legal restrictions. Thus, social and cultural barriers should also be taken into consideration while building such solutions.

- Commercial or mature technologies that are already deployed and integrated in industry:

Computer vision and AI are setting the stage for industry 4.0 revolution in the field of agriculture and food industry. On a Global scale, increased population has significant influence on the aspects such as government policies and services. The major concern regarding this issue is balancing the demand and supply of the food

⁶³ H. Cao, M. Wachowicz, C. Renso and E. Carlini, "Analytics Everywhere: Generating Insights from the Internet of Things," in IEEE Access, vol. 7, pp. 71749-71769, 2019, doi: 10.1109/ACCESS.2019.2919514.

⁶⁴ G. Alfian, M. Syafrudin, N. L. Fitriyani, J. Rhee, M. R. Ma'arif and I. Riadi, "Traceability system using IoT and forecasting model for food supply chain," 2020 International Conference on Decision Aid Sciences and Application (DASA), 2020, pp. 903-907, doi: 10.1109/DASA51403.2020.9317011.

⁶⁵ M. Taneja, N. Jalodia, J. Byabazaire, A. Davy, and C. Olariu. "SmartHerd Management: A Microservices Based Fog Computing Assisted IoT Platform towards Data Driven Smart Dairy Farming". In: Software: Practice and Experience 49.7 (2019), pp. 1055–1078. doi: 10.1002/spe.2704. url: <https://onlinelibrary.wiley.com/doi/abs/10.1002/spe.2704>.

⁶⁶ Tseng, Ming-Lang, Anthony SF Chiu, Chen-Fu Chien, and Raymond R. Tan. "Pathways and barriers to circularity in food systems." *Resources, Conservation and Recycling* 143 (2019): 236-237.

in developing countries with increasing population. The relative increase in technological progress paves a way for the better economic status of any country, with this factor as basis-governments and private investors⁶⁷ are working on inducing AI and computer vision technologies into sectors such as food industry and agriculture for solving specific problems and increasing productivity. There has been significant growth in AgTech investments over the past few years. With the increase of AI startups annually, the advancements in industries throughout the public and private sector will grow at rapid pace in the coming decade leading towards better productivity and sustainable food supply^{68,69}. An illustrative end-to-end use-case example of AI and computer vision driven food industry has been presented in the following Figure^{70,34}:



Figure 4 – AI and computer vision driven food industry (harvesting, picking, quality control and sorting)

Machine learning technologies and computer vision techniques are being exploited by various companies and startups which are distributed in various portfolios such as agriculture, food processing, livestock etc. AgTech startups using AI and computer vision technologies are comprehensively illustrated in the following Figure (Table adaptation as figures from⁷¹)

⁶⁷ <https://myfarmlife.com/equipment/infographic-to-share-ag-tech-on-the-rise/>

⁶⁸ McKinsey & Company, M. Chui, Artificial Intelligence the Next Digital Frontier? vol.47 McKinsey and Company Global Institute, 2017, pp. 3–6.

⁶⁹ McKinsey & Company, Feeding the world sustainably, McKinsey Quarterly, June 2020, <https://www.mckinsey.com/business-functions/sustainability/our-insights/feeding-the-world-sustainably>

⁷⁰ Stemmer, Vision technology for the food and beverage industry, URL, <https://www.stemmer-imaging.com/media/uploads/general/sis/20/2018-03-Market-Brochure-Food-en-WEB.pdf>

⁷¹ Kakani, V., Nguyen, V.H., Kumar, B.P., Kim, H. and Pasupuleti, V.R., 2020. A critical review on computer vision and artificial intelligence in food industry. *Journal of Agriculture and Food Research*, 2, p.100033.

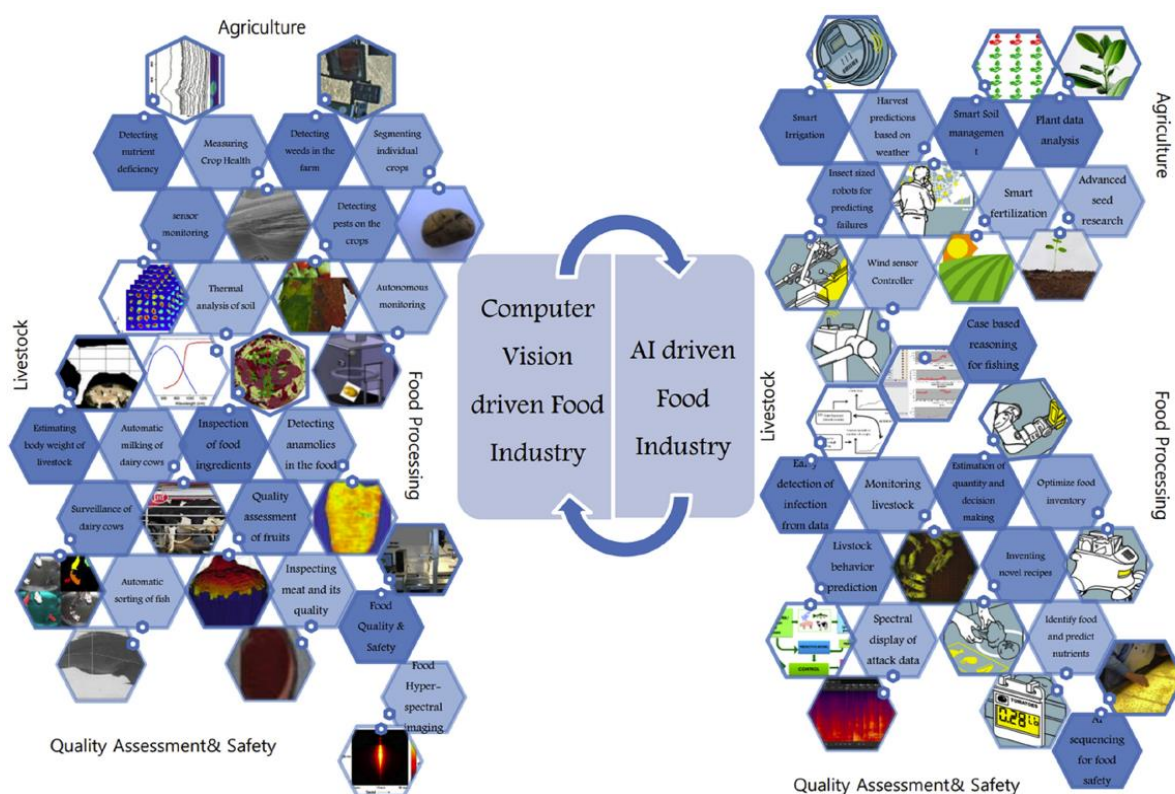


Figure 5 – AgTech startups using AI and computer vision technologies

Further large pilot projects such as IoF2020⁷² (H2020: 2017 -2021) accelerate adoption of technologies such as IoT and AI for securing sufficient, safe, and healthy food and to strengthen competitiveness of farming and food chains in the *agri* ecosystem. It enables a symbiotic ecosystem of farmers, food industry, technology providers and research institutes.

⁷²Internet of Food and Farm 2020: <https://cordis.europa.eu/project/id/731884>

Table 4 – AgTech startups using AI and computer vision technologies

Technology	Entity	Details	Use-cases	Investors
Robotics, Drones	Ceres Imaging	Founded in 2014, Oakland, California, USA	Identify nutrient deficiencies, establish management zones, enable variable rate applications and water stress imaging	ImagineH2O, Lemnos Labs, Silicon Badia
Robotics, Drones	Sky Squirrel Technologies	Founded in 2012, Halifax, Canada	Identification of crop health using drone imaging	InNOVAcorp
Robotics, Drones	Blue River Technology	Founded in 2011, Sunnyvale, CA, USA	Herbicide resistant weed control Robotic vehicle and cloud analytics for improved yields	Data Collective, Innovation Endeavors
Sensors	Centaur Analytics	Founded in 2014, Greater Los Angeles, USA	Using sensors to monitor each crop and reduce unnecessary usage of chemicals	OurCrowd, PJ Tech Catalyst
Sensors	Spensa Technologies	Founded in 2009, Great Lakes, USA	Smart sensors for weed detection, prediction of pests	Emerging Innovations
Sensors	Sencrop	Founded in 2016, Lille France	Employing sensors such as wind gauge, rain gauge to precise and efficient prediction	Breega Capital, Emertec Gestion
Precision Agriculture and Predictive Analysis	MyAgData	Founded in 2012, Great Lakes, USA	Using strategies to develop precise agricultural data to fill the bridge between data created and used by farmers, data required crop insurance companies	Adams Street Partners, Alpha Capital Partners, Don Walsworth, Early Investments
Precision Agriculture and Predictive Analysis	Agrilyst	Founded in 2015, Brooklyn, New York, USA	Forecasting harvest periods and guided sowing cycles. Using data-driven systems that leads to good yields	Brooklyn Bridge Ventures, Metamorphic Ventures
Precision Agriculture and Predictive Analysis	Agribile	Founded in 2012, Great Lakes, USA	Uses data systems to help growers find value in the supply chain and make proprietary crop models that can help growers streamline operations	Archer Daniels Midland Company, Flyover Capital, Serra Ventures
Plant Data Analysis	Trace Genomics	Founded in 2015, San Francisco Bay Area, USA	Uses machine learning to learn the metadata from the farm soil	Illumina Ventures, Fall Line Capital, Refactor Capital
Plant Data Analysis	Benson Hill Biosystems	Founded in 2012, St Louis, Missouri, USA	Uses plant biology, big data analytics and cloud computing through predictive learning engine for better crops	BioGenerator, iSelect Fund, Lewis and Clark Ventures
Plant Data Analysis	CiBO Technologies	Founded in 2015, Cambridge, Massachusetts, USA	Tracking real-time resource needs of the plant and customizing queries by crops	BFlagship Pioneering
Smart Irrigation	AquaSpy	Founded in 1998, Adelaide, South Australia, Australia	Tracking crop behavior of both water and nutrients through profiling modeled using predicted parameters of soil moisture	Alpina Partners, Centre for Energy and Greenhouse Technologies
Smart Irrigation	HydroPoint Data Systems	Founded in 2002, Petaluma, California, USA	Leak detection, smart irrigation solutions, evapotranspiration technology	Chrysalix Global Network
Smart Irrigation	Alesca Life	Founded in 2013, Beijing, China	Fresh onsite production of hard to procure microgreens, wheatgrass through data driven and vision systems	Bits x Bites, The Pearse Lyons Accelerator

3.5.3 Applications to specific domains such as agriculture

Agriculture domain has seen an increasing application of IoT and AI in recent years. Agriculture automation is the main concern and emerging subject for every country. The world population is increasing at a very fast rate and with increase in population the need for food increases briskly. Traditional methods used by farmers aren't sufficient enough to serve the increasing demand and thus there is a need to develop solution that can assist farmers and the agri ecosystem to meet those demands in a sustainable way⁷³.

Authors in ⁷⁴ proposed a fuzz-logic based model to detect abnormalities in dairy cows based on variability in milk properties. GHG emission being a critical issue in the subject-field, authors in ⁷⁵ proposed a regression

⁷³ Jha, K., Doshi, A., Patel, P. and Shah, M., 2019. A comprehensive review on automation in agriculture using artificial intelligence. *Artificial Intelligence in Agriculture*, 2, pp.1-12.

⁷⁴ K. Hempstalk, S. McParland, and D. P. Berry. Machine learning algorithms for the prediction of conception success to a given insemination in lactating dairy cows. *Dairy Science*, 98(8):5262–5273, 2015 <https://doi.org/10.3168/jds.2014-8984>

⁷⁵ G. Jaurena, J. M. Cantet, J. I. Arroquy, R. A. Palladino, M. Wawrzekiewicz, and D. Colombatto. Prediction of the ym factor for livestock from on-farm accessible data. *Livestock Science*, 77, 2015 DOI : [10.1016/j.livsci.2015.04.009](https://doi.org/10.1016/j.livsci.2015.04.009)

model to predict methane emissions. Further, multiple linear regression, adaptive-neuro fuzzy inference system has also been proposed to estimate the dairy grassland biomass⁷⁶. In recent times, use of Deep Learning (DL) methods for complex data analytics has shown great potential compared to the ML models mentioned above, although their commercial application and adoption in farms is still limited⁷⁷.

Computer vision systems are already widely employed in different segments of agricultural production and industrial food production. They can be used in grading systems for a variety of fruits and. Its use is justifiable due to the benefits obtained. The use of such systems provides a simple and objective analysis of the samples, producing accurate descriptive data. Through these systems it is possible to automate laborious tasks, in a non-destructive way, producing adequate data for future analysis. Authors in⁷⁸ identified that there are gaps to be filled with the development of intelligent devices that use computer vision and artificial intelligence for automation of tasks in the field, as well as their integration with agricultural machines and drones.

Finally, AI has an important role to play in transforming food systems and helping to address food and nutrition insecurity. In the agricultural sectors, it can do so in several ways, including optimizing or even carrying out some human activities, such as planting and harvesting, thus increasing productivity, improving working conditions - by reducing the amount of time and toil - and using natural resources more efficiently, including through better knowledge management and planning.⁷⁹

4 State of the art on data-driven urban management systems. A focus on a CRFS management platform

Continuing with the results corresponding to the first phase of the work methodology, in this section we focus on the study of the State of the art of information and communication technologies, but classified according to the application scenarios identified in the pillars from FAO. Within the Focus Group, these application scenarios have been considered to be the most interesting given that they are specifically defined for the CRFS on which the Cities2030 project is focused.

The study of the ICT arena of section 3 was done to screen available technologies so that it is possible to map these technologies to the landscape of data-driven urban management systems, considering food systems as the relevant particularization. In this new section we relate these technologies with the technological components present in the main areas of CRFS, which we present in this section according to the FAO classification⁸⁰, which we also incorporate in this deliverable to guide the development of the study:

⁷⁶ I. Ali, F. Cawkwell, E. Dwyer, and S. Green. Modeling managed grassland biomass estimation by using multitemporal remote sensing data - a machine learning approach. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, 10(7):3254–3264, July 2017. doi: 10.1109/JSTARS.2016.2561618

⁷⁷ M. J. O'Grady and G. M. P. O'Hare. Modelling the smart farm. *Information Processing in Agriculture*, 4:179–187, 2017. <https://doi.org/10.1016/j.inpa.2017.05.001>

⁷⁸ Patrício, D.I. and Rieder, R., 2018. Computer vision and artificial intelligence in precision agriculture for grain crops: A systematic review. *Computers and electronics in agriculture*, 153, pp.69-81.

⁷⁹ <http://www.fao.org/news/story/en/item/1309630/icode/>

⁸⁰ <http://www.fao.org/in-action/food-for-cities-programme/overview/crfs/en/>



Figure 6 – Main areas of CRFS according to FAO

A City Region Food System is defined as “all the actors, processes and relationships that are involved in food production, processing, distribution and consumption in a given city region”.

Additionally, city region food systems are connected to many other rural and urban sectors (e.g. food security, economic development, water and waste management, energy, transport, health, climate change, governance and spatial planning, etc.). By taking this into account, economic, social, and environmental sustainability linkages can be acknowledged.

Adopting a City Region Food Systems (CRFS) approach offers concrete policy and program opportunities where urban developmental issues can be addressed and rural and urban communities can be directly linked. Improved city region food systems improve economic, social and environmental conditions in both urban and nearby rural areas.

Apart from the involvement of local governments and other actors - the development of a resilient and sustainable city region food system also requires political will, the use of available policy and planning instruments (infrastructure and logistics, public procurement, licenses, land use planning), multi-level and cross-sectional government involvement, (local and provincial) actors from the civil society and the private sector.

According to FAO classification, main areas of CRFS are described as: production, processing and manufacturing, distribution, markets, consumption, food waste, social inclusion, environmental and ecosystem services, livelihoods and economic development, and food security and nutrition⁸¹. All these fields are represented in this study in emphasis of now ICT technologies can contribute to improve current practices.

⁸¹ CRFS Tools and Examples: <http://www.fao.org/3/i9255en/I9255EN.pdf>

4.1 Production data-driven solutions

4.1.1 Digital technologies for agriculture and precision agriculture (a focus on data)

The importance of data

In order for the CRFS to become more productive, sustainable and competitive it must be driven by data and information handling. Data is the key component in producing quality and safe food in one agricultural value chain while reducing the environmental impacts and tackling climate change.

Almost everything that is happening within the value chain, from food production to the end consumption could be transformed in data. Different devices and technologies such as IoTs, satellites and drones can provide valuable data that can be later used in order to improve the value chain in a more ecological and sophisticated manner.

Computers today compute large amounts of data in a very short time. The results of processing different kinds of data will help the farmers and every stakeholder included in the CRFS to have information about the trends, patterns and association between various factors in one agro-food value chain.

At a farmer level, the available data from the soil analysis and the generated data from satellite imagery will provide sufficient insight for different kinds of algorithms in order to implement precision technologies, such as Variable Rate Technology, and improve their production while reducing the inputs (seeds, fertilizers, pesticides).

At a logistic and warehouse level, the IoTs undoubtedly will have enormous impact on monitoring workers productivity, tracking refilling inventory, monitoring and controlling different parameters such as temperature and humidity, tracking product locations and many other implementations. While having this type of data in one CRFS, the improvement of the system can be easily achieved based on more informed decisions.

At a consumer level, the availability of different kinds of information will influence their buying decisions. With traceability of the food there is improved transparency and the final consumer would be able to choose different products based on their preferences.

To sum up, the importance of data is from a great value for each stakeholder in the CRFS for enabling different kinds of production technologies, improving and optimizing production processes, optimization of resources and achieving better transparency.

Data streams in agricultural production

In the report *"Digital and Data-Driven Agriculture: Harnessing the Power of Data for Smallholders"* from the Global Forum on Agricultural Research and Innovation (GFAR)⁸², 4 streams of data are defined:

⁸² Maru, Ajit & Berne, Dan & de Beer, Jeremy & Ballantyne, Peter & Pesce, Valeria & Kalyesubula, Stephen & Fourie, Nicolene & Addison, Chris & Collett, Anneliza & Chaves, Juanita. (2018). Digital and Data-Driven Agriculture: Harnessing the Power of Data for Smallholders.

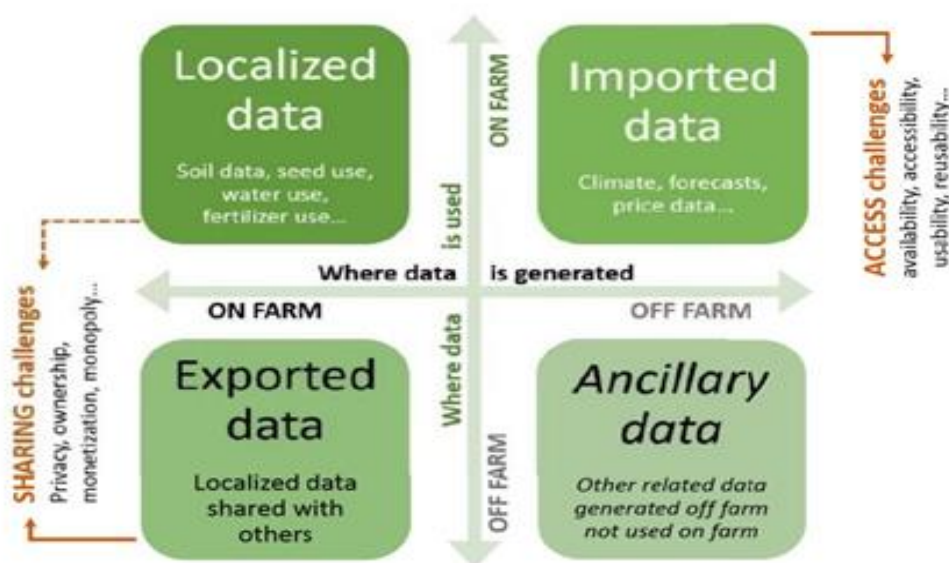


Figure 7 – Defined streams of data according to GFAR

“Localized” data, and includes: soil data (soil form, soil depth, nutrient composition); seed and fertilizer use; date of sowing; production practices; water use. It is mainly used by the farmers or advisors.

“Imported” data. It is owned, managed and controlled by a third party and made available for the farmers and their representatives. Farmers do not own this data, unless they have purchased it or they have permission to exploit it. Common examples are climatic data, and data for market prices that have been pre-interpreted and customized for on-farm use.

“Exported” data is usually processed, aggregated or combined with other data and information generated elsewhere. It is intended to be used by various actors and stakeholders, such as governments or private companies. Whilst this data may be collected from farmers (using sophisticated tools such as drones or remote sensing), a third party usually owns this data.

“Ancillary” data. A large proportion of agricultural data, such as government statistical and research data, are generated using various data sources in other value chains. While this data may initially appear to have little direct on-farm application, various policies and policy changes may lead to indirect on-farm influences that were not previously foreseen.

The challenges with farming data

The complexity of the recorded data in one agricultural system is enormous. We have financial data, crop science data, meteorological data up to policy and demographics data. In order to process the data in a seamless and logical way, the industry needs to offer specialized processes and tools. These processes and tools need to integrate the data, as well as to compute it and give results or reports that will help the farmers in the decision-making process.

The process of data integration needs to solve several problems. The most crucial problem is the privacy of the data, respectively to ensure that the users of the data are the one that need to use it. Another problem is the process of homogenization of the data or convergence of different sources into meaningful and valuable information. After solving the privacy and the convergence of the data there is a need for an interpretation in a form that can give the farmers and other users' correct directions, trends and bottlenecks of the desired operation in the agricultural production.

On other hand, along with the integration of different kinds of data formats, the industry must seek standardization of the data to be used on different platforms and machinery. This process is more

complicated than it seems because the agro-sector is more complex than other businesses or industries. Beside the complexity, it is of great importance to mention the readiness for accepting these kinds of changes, especially among the producers with smaller capacities.

Finally, the industry must provide interoperability of data and accessibility of the data in different language variants.⁸³

4.1.2 Data sources

This chapter will focus on the different types of data sources that can be found in one agricultural production system. In order to measure the different types of data sources there is a need for implementation of specific technologies which are going to be described complementary with the data formats that they are sensing.

In the 21st century the evolution and the implementation of digital technologies has progressed exponentially and is expecting to be an inseparable part in the process of food production.

Soil particles have capabilities to conduct or accumulate electrical charge and with the help of **electromagnetic sensors** we can transform these properties into data. The concept is to apply electrical current into the soil and measure the intensity of the signal in a data logger. The electromagnetic properties are influenced by soil texture, organic and moisture content, as well as salinity. When the soil conditions are changing in one field, for example: one part of the field is sandy and the other part is more clayish, the signal is affected almost immediately and the recorded changes after processing and calibration can give the data that we need. The data is later used for delineating management zones for implementation of Variable Rate Technology (VRT) in application of fertilizers, pesticides, seeds, and water.



Figure 8 – Example of electromagnetic sensor: Veris EC sensor⁸⁴

Via **electrochemical sensors** we can measure the soil nutrient levels and pH of the soil. In recent times, the industry is focused in creating tools with this kind of sensors for testing the soil on-site, although the accuracy will not be the same as testing the properties in the laboratory, it will give farmers the right directions and the accuracy will improve with the ability to perform more samples over one field.

Also, **electric permittivity sensors** are used to measure the soil water status and can be particularly beneficial in regions with high salinity. The most used sensors are Frequency-domain reflectometry (FDR) sensors that

⁸³ Mareš, František & Jarolímek, Jan & Vaněk, Jiří & Kubata, Karel. (2021). Data integration in agriculture.

⁸⁴ <https://www.veristech.com/the-sensors/v3100>

measure the soil's dielectric permittivity spectrum – a measure of the soil's electrical capacitance – and its salinity index showing the soil water electrical conductivity value.



Figure 9 – Examples of electrochemical (ph-electrode, left) and electric permittivity sensors (FDR sensor, right)

Mechanical sensors are used to measure the mechanical properties of the soil, which later can be used for assessment of the compaction and other structural properties to improve the existing practices, achieving optimization of resources and minimize the economic and environmental impacts. The industry has provided already available products such as electric penetrometers and soil cutting resistance sensors.



Figure 10 – Example of mechanical sensor: Soil cutting resistance sensor⁸⁵

The **weather sensing technology** generally is mostly presented as one product, the weather station. By combining the sensors and collecting real time environmental data there is a precise historical overview of the environmental effect on the soil and the crops which later can be used for creating climate condition maps, informed decisions, improvement of crop capacity and achieving maximum possible yields. Additionally, the data generated from the weather stations can be used for modeling the evapotranspiration processes, as well as to improve the disease and pest management processes through disease and pest models. Weather sensing technology considers air temperature and relative humidity sensors, wind sensors, rain sensors, etc.

The general application for the **crop sensing technology** is nutrition management and improving plant health. These sensors are using light as a source, and they can be active and passive. Active sensors are using their own artificial light and the passive sensors are using the light from the sun. Nevertheless, the light is used for determining the plant development and photosynthetic activity. Photosynthetically active radiation defines the type of light needed to support photosynthesis. To achieve successful photosynthesis plants primarily use wavelengths between 400 and 700 nanometers. The light within this range is called photosynthetic active radiation. The Photosynthetic photon flux represents the measurement of all the photons in this range. By measuring the photons or the fluorescence we are determining the plant stress that can be caused by biotic

⁸⁵ <https://www.veristech.com/the-sensors/v3100>

or abiotic factors. The data obtained from this type of sensor gives directions to the farmers if there is a need for correcting the environment of the plants or in the process of improvement of the yield.

Considering **digital technologies for sensing in live-stock production**, livestock can be monitored in two ways: in a group (flocks, herds) or individually. The technology that is used for sensing different parameters in livestock production can differ depending on what kind of data is needed. For counting the number of animals that are grazing or monitoring activity on larger areas, farmers often use drones to record or capture images. Different software automatically tags the animals, generating automatic reports and alarming when there is inconsistency in numbers. On the other hand, there are plenty of sensors that work on different principles (accelerometers, electronic identification, thermal camera etc.) that are monitoring the behavior on an individual level (eating, ruminating, resting etc.). The data obtained from the sensors is of a great value for the farmers supporting the process of decision making. The benefits from obtaining such data ranges from the improved well-being of the animals, minimizing antibiotic use or diseases, to increase profitability.

The most utilized high-tech gadgets in agriculture are the **Unmanned aircraft vehicles (UAVs)** or popularly called drones. In comparison with the older methods of recording geospatial data, like the use of airplanes, this is a relatively inexpensive tool that helps the farmers in the assessment of crop health, creating 3-D topography maps and many other applications that are going to contribute to the process of decision making. The drones (multicopters and the fixed wing drones) are often a carrier or platforms for equipping them with various drone-mounted sensors that can collect data in real time. The drone-mounted sensors are mostly optical sensors that can capture RGB, Infrared and/or Multispectral images.

The produced data can help in the assessment of crop health and different soil conditions, the result of different agricultural operations, counting of plans and determination of population, determination of the damages that are induced by different environmental hazards.

Satellite imagery has become an essential tool in precision agriculture, because it can deliver accurate and reliable data over large areas, thus helping the decision support process for various operations. The most common operations that are supported by the satellite imagery are planning of farming activities and comparison of the actual state with historical data.

The European Union has developed an observation program called Copernicus for monitoring the environment. Under the Copernicus program until now 7 satellites were launched (Sentinel) that can generate different kinds of accurate, reliable and high-quality data. Every 3-4 days the satellites are orbiting the planet and providing information daily. The most useful satellite for agriculture from the Copernicus program is Sentinel-2 providing high-resolution imagery in the visible and infrared part of the spectrum aiming to support the monitoring of vegetation, soil and water cover, inland waterways and coastal areas. Additionally, from the satellite images we can calculate and visualize different indexes such as NDVI (Normalized difference vegetation index), NIR (Near-Infrared spectroscopy), SWIR (Short-wavelength infrared), NDWI (Normalized difference water index) and Moisture index.

The information obtained from the satellite can help to improve and simplify the Common Agricultural Policy (CAP) in the areas of environment, agrobiodiversity, climate and sustainability.

Finally, we study the impact of **Global Positioning System (GPS)** and **Yield mapping** over current production systems. The Global Positioning System (GPS) represents a navigation system used to determine the position of an object through use of satellites. GPS has widespread use in almost every economic sector and nowadays many of existing devices that improve processes cannot function without a GPS signal. In agriculture this system is used in field mapping, soil sampling, guidance of tractors and implements, scouting, implementation of VRT, yield mapping etc.

In the CRFS, GPS is widely implemented, but it can be further improved in order to reduce the level of human error, costs for transport and inputs, and the operators' fatigue. The data obtained from the GPS can be utilized in order to improve the traceability in CRFS.

Yield mapping is possible by combining GPS and grain flow sensors. GPS is actively recording and generating data of combine field passes, while the sensors are measuring the flow of the grain when the combine is actively harvesting. This results in quantitative data for yield on a given location in the field. The importance of yield mapping in one agricultural production is enormous. It shows how the vegetation responds to applied management methods, helps identifying causes of yield changes, assists in planning the nutritional management for the next season, and provides accurate information about variabilities within the field.

4.1.3 Contribution to Precision Agriculture

By combining the types of data described above (drone and satellite imagery, soil, and crop sensing technologies) and soil maps created in decision support software, we can create prescriptions maps that are going to be used in different operations with agricultural mechanization. The use of prescription maps in operations like fertilizing, seeding and crop protection allows farmers to control the amount of input they apply in a specific location.

By controlling the inputs, the farmers can homogenize the soil in one specific field by making it more uniform in aspect of the available nutrients, apply fewer mineral fertilizers and pesticides. Considering the data fusion coming from these data sources it is possible to provide the following benefits: improving biodiversity, lowering the levels of nitrogen leaching into the subsoil and ground water, minimizing phytotoxicity, promoting life of beneficial soil microorganisms and fungi, improving soil structure, lowering the costs of production per hectare, establishing more transparent traceability, etc.

Precision Agriculture (PA) is a farming management concept based on observing, measuring and responding to inter and intra-field variability in crops. By implementation and fulfillment of the objective of PA in the CRFS the concept of PA will serve as a catalyst for implementing sustainable intensification and sustainable crop production intensification. Additionally, the created data can be utilized in order to create effective methods for shortening the supply chain, forming circular economies, boosting sustainability and improving the process of traceability.

For what concerns technologies, GPS is now widely used in many farms for tasks related to geo-positioning (e.g. auto-steer systems) and production of geo-reference information (e.g. Yield mapping). GPS has enabled the expansion of machinery guidance, auto-steering and controlled traffic farming (CTF) systems. Another significant element is the use of Variable Rate Technology (VRT) that allows precise seeding, optimization on planting density and improved application rate efficiency of herbicides, pesticides and nutrients, resulting in cost reduction and reducing environmental impact.

The data sources that are explained in the sections above are designed to capture data both in-situ and on-the-go. Measuring the status of soils, such as apparent electrical conductivity (ECa) sensors and soil moisture devices, while others can capture weather information or micro-climate data (thermometer, hygrometer, etc.). Particular importance is given to sensors developed to quantify the physiological status of crops (e.g. Nitrogen sensors). Additionally, the UAVs are also enabling the nitrogen assessment from generation of very-high resolution (2 to 10 cm) farm-level imagery. Availability from satellite platforms is generally at lower resolution (0.5 to 10 m) and is generally more costly.⁸⁶

⁸⁶ Joint Research Centre (JRC) of the European Commission (2014): Precision agriculture - An opportunity for EU farmers - Potential support with the CAP 2014-2020

4.1.4 Digital technologies for decision support in agriculture

Decision support tools⁸⁷ are designed to help users make more effective decisions by leading them through clear decision stages and presenting the likelihood of various outcomes resulting from different options. These can be dynamic software tools, whose recommendations vary according to the user's inputs, and they may suggest an optimal decision path⁸⁸. For farmers, and their advisers, software tools can facilitate effective farm management by recording data efficiently, analyzing it, and generating a series of evidence-based recommendations⁸⁹.

Stakeholders and farmers may encounter difficulties in making proper decisions about agricultural management with the explosive amount of information (e.g. environmental, crop-related, and economic data). Because it is challenging for them to transfer this data into practical knowledge. Thus, platforms like decision support systems are needed in order to assist them in making evidence-based and precise decisions.

An agricultural decision support system (ADSS) can be defined as a human-computer system which utilizes data from various sources, aiming at providing farmers with a list of advice for supporting their decision-making under different circumstances. One of the most representative characteristics of an ADSS is that it does not give direct instructions or commands to farmers. Because farmers are in the position of taking the final decisions.

The following list contains examples of ADSSs and in some cases feedback from users of such systems.

- **Watson Decision Platform for Agriculture:** based on combining the power of Artificial Intelligence, analytics, and predictive insights with unique agricultural IoT data. The Watson Decision Platform for Agriculture also automates data handoffs between stakeholders across functions, creating a more transparent, connected ecosystem and driving value for non-growers in roles such as:
 1. food producers: Integrated supply chains with greater harvest timing and volume predictability;
 2. Commodities traders: Custom predictive queries using multi-layer geospatial analysis to encourage price stability for growers;
 3. Lenders: Lower-friction loans for growers by validating yield performance versus potential;
 4. Insurance: Smarter rates for growers by using validated EFR data to improve risk insight and claims processing;
 5. Governments: Improved food independence strategies by giving growers and agencies a common set of tools.
- **Granular:** Managing operations by organizing data in one system for clear, field-level profitability, making the most of every input. Make faster and better decisions for business with integrated operational, financial and agronomic data for your whole team. Based on farmers upload data already collected and integration through the John Deere Ops Center, Corteva On Farm, and simple data uploads from 10+ other manufacturers.

Disadvantages:

1. programs contain so much information, so it is sometimes difficult to know where to go to get the data or analysis you are looking for, being overwhelming to learn.

⁸⁷ Grêt-Regamey, A., Sirén, E., Brunner, S. H., & Weibel, B. (2017). Review of decision support tools to operationalize the ecosystem services concept. *Ecosystem Services*, 26, 306-315.

⁸⁸ Kumar, A., Sah, B., Singh, A. R., Deng, Y., He, X., Kumar, P., & Bansal, R. C. (2017). A review of multi criteria decision making (MCDM) towards sustainable renewable energy development. *Renewable and Sustainable Energy Reviews*, 69, 596-609

⁸⁹ Kukar, M., Vračar, P., Košir, D., Pevec, D., & Bosnić, Z. (2019). AgroDSS: A decision support system for agriculture and farming. *Computers and Electronics in Agriculture*, 161, 260-271.

- **Cropio:** Cropio is a satellite crop health management and vegetation control platform that facilitates remote monitoring of agricultural land and enables its users to efficiently plan and carry out agricultural operations. Cropio provides real-time updates on current field and crop conditions, determines vegetation levels and pinpoints problem areas, delivers precise weather forecasts and an actual overview of the soft commodity market.
Disadvantages:
 1. too many functions for small business, so it was a little confusing to use at first until people honed in on what they needed and learned to ignore the rest.
 2. Quality of the satellite images but even higher quality ones add little value to business at present, also the language availability is limited.
- **Agro Pal,** is a Free Farming Assistance Android App backed by Artificial Intelligence. Salient features include Crop Details Assistance, AI backed Plant Disease Detection, Weather Prediction, Aggregation of useful Agro Information Web links, Forum support to enable community discussion.
Disadvantages: Main dislike is centered with the AI modules that do not refresh often.
- **Farmers Business Network:** Global Agtech company focused on helping family farmers maximize their farm's profit potential. Their platform leverages technology to help reducing the cost of production, maximizing the value of crops and make confident decisions to improve farmer's business.
- **AgriSupport II system:** Adopting the latest advances in decision support systems to fulfill the needs of agricultural production processes. The overall objective of this system is to provide farmers with sufficient agricultural decision-making suggestions like farm operation scheduling, detailed operation cost, resources usage, and profitability analysis. Two main issues are mentioned in their requirement analysis. The decision-making process in the AgriSupport II system is computed by a farm planning model algorithm. This algorithm is designed to identify which work units are suitable for performing what tasks.
- **Graincast:** Using simple local paddock information, high-resolution satellite and sensor data sources and CSIRO's innovative analytics, CSIRO's free Graincast™ app helps growers with their crop decision-making instincts. It uses weather and soils information to forecast soil moisture and yield for the grain crops planted. During times of drought, it can assist farmers to maximise the profitability of their farming operation by informing input application decisions – resulting in increased returns or minimised expenses.

Some major features and challenges that must be taken into account in the decision-making platform, and directly applied to our project, can be summarized as follows:

1. **Accessibility:** The major complaint by the users of decision-making platforms are related to how the information is shown. The graphical user interface of an ADSS allows a simple analysis by the user. Generally, graphical visualization can (should) hide the complexity of ADSSs, enabling farmers to manage agricultural activities more easily and efficiently. Furthermore, the GUIs provided by current ADSSs sometimes display the computation processes and require complex text inputs, leading to noise and confusion for farmers.
2. **Scalability:** Capability of ADSSs to process the growing number of missions and extendibility of the platform, for example, extra components can be added into an ADSS for enriching its functionality.
3. **Interoperability:** Integrating functions and knowledge from heterogeneous components into a single ADSS means it can work with other external components or systems. This is crucial, since after pre-processing, data formats of product types, quantity, delivery routes, and transportation modes must be unified, for example. Heterogeneous components will share a common understanding for the collected information.

4. **Uncertainty and dynamic factors:** Uncertainty and dynamic factors may cause unexpected results. The ADSS must account for such factors in its AI modules, in particular for dynamical variables such as weather. The system should not recommend irrigation of a field based only on solid analysis but also on the amount of rain that is expected and recorded instantaneously.
5. **Re-planning:** Unexpected failures may occur when performing agricultural activities. The re-planning mechanism is supposed to enhance the robustness of decision support by adjusting current strategies or generating new ones.
6. **Expert knowledge:** Knowledge from experienced experts is highly valuable for ADSSs when generating feasible decision supports (Poch et al., 2004). Moreover, experts can adjust inappropriate strategies. Due to the limitations of computation time and complexity of agricultural problems, an ADSS may provide users with inaccurate decision supports, sometimes even wrong advice. Therefore, it is worth considering adopting knowledge from experienced users and domain experts. However, current ADSSs remain to be improved in this aspect.
7. **Prediction and forecast:** Predictions of productivity, market fluctuations, and costs (Patel et al., 2018) may enable ADSSs to generate more accurate decision supports, while forecasts of meteorological information (Pham and Kamei, 2012) are especially helpful when planning agricultural activities.
8. **Analysis on historical information:** Historical data and strategies contain valuable information which can improve the quality of future decision support (Poczeta et al., 2018). Ignoring historical information not only loses successful experiences, but also failure cases. Current agricultural activities can be performed by referring to the solutions for past cases, which had been successfully dealt with before.

4.2 Data-driven food manufacturing and processing solutions

One of the most important processes that have a place in urban food systems is that of food processing and manufacturing. In this subsection we will explain the concepts that we are going to use in the study of data-driven food manufacturing and processing solutions, the challenges of creating a CRFS management platform, how some very specific characteristics of this environment are handled, such as quality control, and finally, new challenges related to COVID-19 era. We end this subsection with some conclusions.

4.2.1 Concepts

According to the General Principles of Food Law (Regulation (EC) No 178/2002⁹⁰), 'food' is defined as 'any substance or product, whether processed, partially processed or unprocessed, intended to be, or reasonably intended to be ingested by humans. It also includes any substance, including water, intentionally incorporated into the food during its manufacture, preparation or treatment'.

The processing and manufacturing⁹¹ stage of the food supply chain encompasses all processes intended to transform raw food materials into products suitable for consumption, cooking or sale. This stage in the supply chain includes the processes that turn raw agricultural products into saleable goods, which often move to retail, wholesale, distribution or food service institutions. It also includes packaging of processed goods.

⁹⁰ https://www.fsai.ie/legislation/food_legislation/general_principles_of_food_law.html

⁹¹ <http://www.cec.org/flwm/sector/processing-and-manufacturing>

Some authors suggest distinctions between these two terms. For example, Fintan Clear⁹² considers food processing as the natural actions taken to preserve foodstuffs (e.g. drying, salting, pickling), but also industrial procedures such as bottling, canning, freezing, freeze-drying, chilling and dehydration. However, it uses manufacturing as a broader concept: transforming raw materials in semi-finished products. This requires the provision of manufacturing plant, machinery, and labor, and of course also includes other more transversal aspects such as the transport of materials, through and out of the plant, and other processes including goods receipt, packaging, storage and dispatch. Other such as Aptean Food & Beverage considers processing as a first level manufacturing⁹³ (e.g. turning raw tomatoes into tomato paste, and packaging into cans) whereas manufacturer is focused on creating a more complex product (e.g. purchasing the paste and turning into a more complex elaboration such as spaghetti sauce). In this chapter we will use the previous definition of the Commission for Environmental Cooperation, so we will use “food processing” and “food manufacturing” interchangeably.

Information technology and information systems can be used in several spheres in food processing and manufacturing (as implied above), such as controlling manufacturing processes, managing material flows, receiving data from suppliers, sending data to customers, and maintaining an audit on production activity for process conformance and product traceability. In this section, information systems and their role in serving manufacturing processes is examined.

4.2.2 Challenges towards CRFS management platform

Increasing the level of automation is key to making the food manufacturing process and supply chain more flexible and responsive to the latest changes in demand. Operational efficiency and cost reductions are industry lifelines. In fact, McKinsey found⁹⁴ that the food processing and handling equipment sector grew more rapidly than almost any industrial market through 2018, providing the processing systems and equipment that enable the industry to manage food products' journey from the farm via the factory to the consumer. Incorporating 5G could take this control to a whole new level, and at the same time could potentially provide greater quality and safety measures.

5G in that sense, could provide a medium for integrated data collection and control, beginning with smart tags assigned at the farm that would store all the relevant data about produce, for example. Information such as harvest date, the identity and history of an animal used for meat and so on could be included and tracked. Sensors in the truck could then relay logistics information over a nationwide 5G network, noting departure times, anticipated arrival at the factory, onboard temperature, and humidity and more, all of which would be saved to the data records of that batch of ingredients. If problems emerge down the line, products could be traced back to their exact source and time of dispatch.

The technological concept whose implementation seems most beneficial for manufacturing systems is the arrival of the technological support of Industry 4.0, where technologies studied in this deliverable such as Internet of Things, Robotics and Smart Systems are combined. According to this paradigm of Industry 4.0, we consider a factory floor with smart machinery or robots responsible for food manufacturing processes such as cutting, blending, heating, sorting, etc., and which will rely on embedded information technology including sensors, actuators (that perform some mechanical action such as starting and stopping a machine, making adjustments to settings, etc.) and a programmable logic controller by which the machine is controlled⁹⁵. Such

⁹² Clear, F. (2011). Food and Drink Manufacturing and the Role of ICT. Intelligent Agrifood Chains and Networks, 7–25. doi:10.1002/9781444339895.ch2

⁹³ <https://www.bcfooderp.com/food-processing-software-vs-food-manufacturing-software/>

⁹⁴ <https://www.mckinsey.com/industries/advanced-electronics/our-insights/whats-ahead-for-food-processing-and-handling>

⁹⁵ <https://onlinelibrary.wiley.com/doi/pdf/10.1002/9781444339895.ch2>

machinery may incorporate a digital control system (DCS) with the possibility of being operated remotely, which will allow human operators to manually interact with it and take reports.

This data-driven digital control system generally connects to supervisory control and data acquisition (SCADA) systems, which a series of different machines (and hence a production line) might be monitored and controlled. To complete the integration, SCADA systems can be linked with ERP systems that can have an oversight over production activities. The ERP system and its functional modules may sit on increasingly powerful computers or cloud services. In terms of the underlying logic, the information systems described here could be applied to almost any manufacturing facility, whatever the industry sector. Key aspects that will differentiate food manufacturing from other industries in broad terms are traceability and food security, which will be analyzed in other subsections.

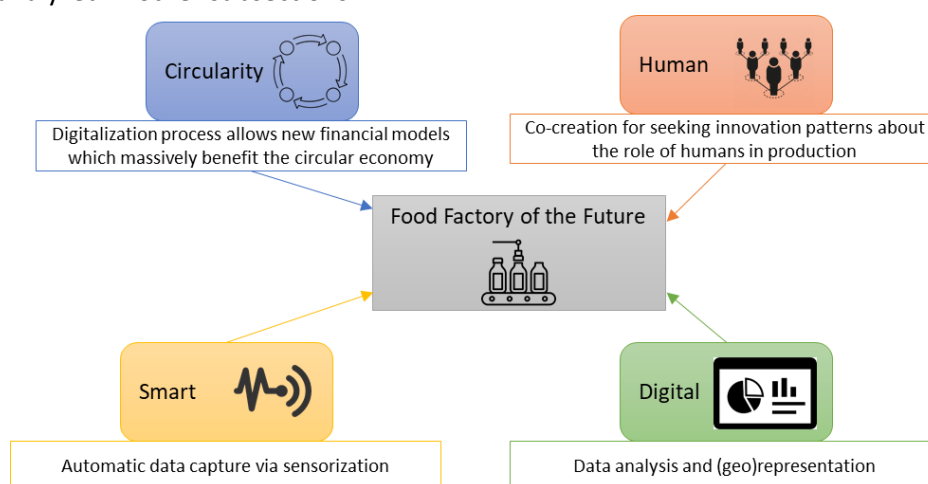


Figure 11 – Data-driven CRFS platform from food processing and manufacturing perspective

4.2.3 Quality control

An element also related to food manufacturing that can be improved thanks to new technologies is food hygiene (of food contamination). In this sense, ERP systems can also be used to monitor that the production process meets the appropriate quality standards, for example the handling that has been applied, or the product batch identifiers used to offer traceability in case of notification of defective products.

Big Data is of crucial importance when it comes to food quality control. A spectacular example here is a cold supply chain during transportation. Temperature-sensitive products like vegetables, fruits, milk, ice-cream demand accurate environmental conditions and can get damaged in case of temperature fluctuations.

Specific IoT-driven sensors, which process, analyze, and transfer the data to all parties in real-time, providing the ability to monitor the full supply chain cycle is the perfect solution here. While using Big Data, it is possible to timely replace the damaged products with new ones or perform preventive measures. Big Data-powered software and hardware can also be adopted and used along with production processes, scanning the quality of incoming materials and final products.

Protecting the brand from negative feedback caused by insufficient food quality has long-term outcomes rather than the short-term.

In 2019, the U.S. Food and Drug Administration (FDA) announced they “New Era of Smarter Food Safety” initiative⁹⁶, outlining plans to use technology to “create a more digital, traceable and safer food system,” including leveraging the Internet of Things (IoT) and artificial intelligence (AI)⁹⁷. The blueprint builds on the Food Safety Modernization Act (FSMA), which mandated controls on food allergens, sanitation and other controls, in addition to process control of parameters such as product formulation and temperature during manufacturing operations.

In a future where ingredient could be automatically assessed for quality and compliance, a pneumatic production environment, thanks to technologies such as IoT, 5G or Artificial Intelligence could deliver ingredients to production lines at the time they are required, by using autonomous vehicles, and ensuring the appropriate quantities of ingredients are used and recorded correctly on product packaging and labeling, documenting all the key process data and preserving traceability.

4.2.4 New challenges in COVID-19-era

In addition to all this, the manufacturing processes in cities have changed with the passage of COVID-19. In the latest EIT Food report of December 2020⁹⁸, it has been reported that European consumers are also spending more time in the kitchen with over a third (36%) reporting that they have enjoyed spending time cooking during the lockdown. Also, nearly a third of consumers said it will be more important to have time to cook home-made meals (27%) and to continue eating more varied foods (30%) after the pandemic.

Related to that, an article published by Easter⁹⁹ suggests that citizens are asking for more frozen food, and no processing, than restaurants, during the lockdown period and beyond. Therefore, there are new challenges in how processing companies have to adapt to the type of demand and better control of the packaging and type of conservation of their products, when they are destined directly to a final consumer instead of to a supermarket or restaurant.

4.2.5 Conclusions:

Consumers are now much more aware of the quality of food and ingredients (e.g. fat, sugar, salt, etc.) in terms of healthy living and are becoming more demanding in their requirements. In a food supply chain of links and interdependencies that takes in primary producers, manufacturers, wholesalers, retailers, agents, logistics providers and shippers, and which runs from ‘farm to fork’, manufacturers occupy a central role as the processors of raw materials into the finished goods that will ultimately be consumed by the public.

Considering the landscape of the ICT adoption in the food manufacturing industry, we believe that there are already a large number of technologies that are being used to improve food transformation processes, such as industrial automation and highly sensorized environments. The current challenges are in line with making the DCS and ERP management systems more open and connected with the rest of the links in the supply chain, so that the food quality control indicators can be controlled having a global vision of the chain, where additional calculations can be performed such as the calculation of carbon footprint, which affects other scopes of the CRF Systems such as environmental sustainability.

As valuable characteristics for the design of a data-driven CRFS management platform are the monitoring of indicators generated in real time, such as the status of production, or the arrival of events produced by a process change and the presentation of these indicators in display systems.

⁹⁶ <https://www.fda.gov/media/131682/download>

⁹⁷ <https://www.forbes.com/sites/tmobile/2020/07/13/5g-possibilities-for-a-more-nimble-and-data-driven-food-industry/>

⁹⁸ <https://eit.europa.eu/news-events/news/eit-food-report-reveals-impact-covid-19-pandemic-european-food-behaviours>

⁹⁹ <https://www.eater.com/2020/3/24/21192437/suppliers-sell-direct-to-consumer-as-restaurants-close-coronavirus-delivery-pickup>

4.3 Distribution: traceability solutions and regional food systems

4.3.1 The concept of traceability

Traceability as a process is present in any supply chain management or quality/safety control system. Very often it is described as the ability to track various products (food, feed, substances etc.) through all stages of production, processing and distribution across the agricultural value chains. According to the World Economic Forum (2019) the benefits of implementing traceability are the following:

- satisfying consumer requirements for transparent food production
- increased ability to identify, respond to and prevent food safety issues
- supply chain optimization and food loss reduction
- validation of sourcing claims to meet sustainability goals

One traceability system should support identification of ingredients and product, country of origin, species, as well as detailed information about the batches and the links between participants in the supply chain.

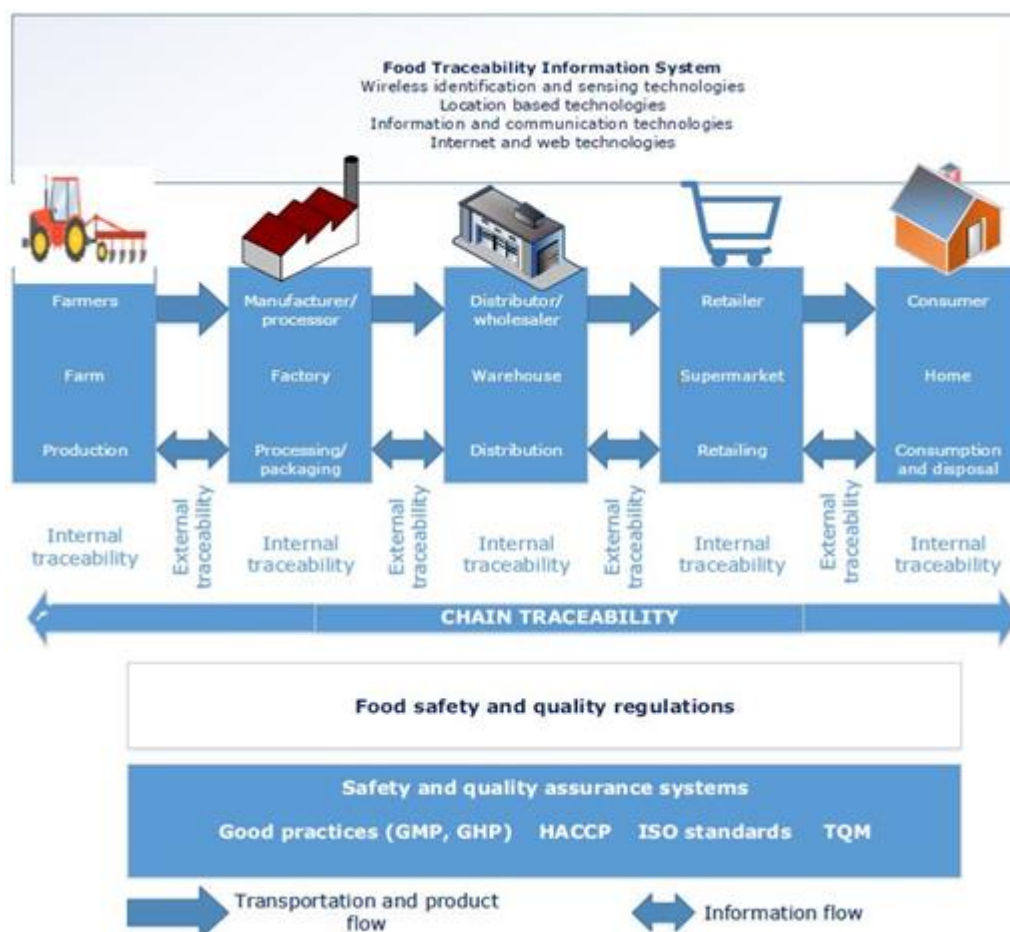


Figure 12 - "Traceability in a food supply chain: Safety and quality perspectives," by M.M. Aung and Y.S. Chang, 2014, *Food Control*, 39, p. 180

4.3.2 Key issues for implementing traceability in CRFS

According to Aung & Chang (2014) the key aspects of successful management in the process of implementation of traceability are divided into three groups: technical, managerial and environmental. Each

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of the group is consisted of a combination of activities that create cost streams that need to be managed in order to create a holistic approach in effective utilizing and maintaining the traceability concept in one agro-food value chain.

Technical	Internet & Web technologies (online tracking, monitoring, information exchange and retrieval over web etc.)
	Location based technologies (e.g., GPS, RS, RTLS etc.)
	Sensing technologies (e.g., WSN, TTI, Electronic Nose etc.)
	Identification technologies (e.g., Bar code, RFID etc.)
	Information and Communication technologies (e.g. Information systems, computers and mobile networks)
Managerial	Product, time, location and quality traceability, Monitoring, surveillance, recording and control, Inspections
	Identify risks and apply safety & quality assurance schemes (i.e., ISO, HACCP, TQM, etc.)
	Follow regulations, Standards and Standard Operating Procedures (SOPs)
	Routing decisions and recall strategies
	Traceability data management (to collect, to keep and to share)
	Implement coordination among supply chain actors
	Transparency, authenticity and access of information
Environmental	Evaluation on carbon footprint of food and labelling
	Use of eco-friendly packaging materials and processing methods
	Waste and water management
	Recycling food and food related materials
	Protect odours, pollutants, contamination
	To inspect the use of fertilizers, pesticides with regard to chemical residue

Figure 13 – Key issues for implementing traceability, from "Traceability in a food supply chain: Safety and quality perspectives," by M.M. Aung and Y.S. Chang, 2014, *Food Control*, 39, p. 180

4.3.3 Digital solutions for traceability

In order to provide the relevant information that every traceability system must have we need implementation of technologies that can identify the product, describe the process of transport, conduct automatic analysis for available storage capacity, and overall connectivity and data integration from all involved stakeholders in the CRFS traceability systems.

These technologies include Automatic Identification and Data Capture (AIDC) technology, connectivity technology, and business intelligence on traceability (e.g., online analytical processing, analytics, data mining, process mining, complex event processing, business performance management, benchmarking, text mining, predictive analytics, and prescriptive analytics) (Scholten et al., 2016).¹⁰⁰

To create a successful traceability system, the process of identification of the products it is a must. Identification can be accomplished in many ways by labelling the products. The labeling can be done manually or by implementing advanced technologies such as AIDC technologies. The most useful and exploited AIDC technologies are the barcodes, radio frequency identification (RFID), Near-field communication (NFC), and blockchain technology.

¹⁰⁰ Scholten, H., Verdouw, C., Beulens, A., & van der Vorst, J. (2016). Defining and Analyzing Traceability Systems in Food Supply Chains. In *Advances in Food Traceability Techniques and Technologies*.

- AIDC technologies

This technology refers to the methods of automatically identifying objects, simultaneously collecting the previous data and automatically incorporating the data and ID into computer systems. All of the mentioned methods are done without human involvement. The technology is widespread used in different industries (asset tracking, Automotive, Beverage, Chemical, Consumer goods, Electronics, Food, Healthcare, Library, Manufacturing, Medical devices and equipment, Paper, Pharmaceutical, Plastics, Point of sale, Retail, Transportation and logistics, Warehousing and distribution etc.).

The most utilized AIDC technologies today are the barcodes, RFIDs and NFC (Scholten et al., 2016). A **barcode** is a standardized code formed by a pattern of parallel lines of varying widths that can be read automatically by barcode scanners. The bar code standards of GS1 are internationally common practice. Some of the improved barcode standards like quick response QR codes can have additional information such as best before dates, batch number and weight (Scholten et al., 2016).

The **RFID technology** uses radio frequency as a data transmission intermediary. It can be classified by the frequency band the RFID system adopts since different frequencies will result in different physical attributes.

The **Near Field Communication (NFC)** extends the RFID technology, and utilizes the particular radio frequency to communicate and exchange data between devices which are in close proximity (less than 10cm) to each other.

Lately, the involvement of **blockchain technology** is considered in becoming the optimal solution for improving food traceability systems.¹⁰¹ Blockchain technology is a growing list of records, called blocks, which are linked using cryptography. Each block contains so called hash (cryptographic hash functions) a mathematical one-way algorithm, a timestamp and transaction data.

4.3.4 Factors for effective traceability

The most critical factor in creating a successful traceability process is the identification of the products. This factor can be solved by implementing AIDC technologies such as RFID, barcodes and QR codes. AIDC technologies will enable identification of the product (collecting and entering data into computer systems) without the need of human intervention.

The transparency of the destination between the actors in the traceability process, as well as the transparency of the final destination is also a critical factor in creating a resilient traceability system in the CRFS. The data format for stating the destination needs to be the same for all involved actors in order to easily measure the effectiveness of the system, assessing the consumers' behavioral trends and to comply with different market regulations (food safety standards, customs, regulations, business cultures) in the CRFS.

Additional factors that largely influence on the cost-effectiveness of the system is knowing the structure and the organization of the supply chain. Good understanding of the state of the structure of the supply chain and the way it is organized determine the scope of the traceability system, the approach of implementation and the level of effectiveness translated into economic benefits.

Moreover, one of the main ideas of the CRFS is shortening the value chain among the actors. With a short value chain the number of actors would be smaller, and respectively the achieving of internal and external traceability would be a much easier process than the existing value chains that can consist of a large number of actors among different parts of the country or even different countries.

¹⁰¹ Burke, T. (2019). Blockchain in Food Traceability. In J. McEntire & A. W. Kennedy (Eds.), *Food Traceability: From Binders to Blockchain*. Springer International Publishing. <https://doi.org/10.1007/978-3-030-10902-8>

4.4 Markets and consumption: a data-driven perspective

Consumption of goods and services is a defining feature of our modern lives. In particular, food consumption enables a range of social relationships and interactions where population characteristics such as needs, satisfactions, or the roles of status and reputation¹⁰².

Some authors have indicated how there is a great correlation between what we eat and our social identities¹⁰³, but also how income and education affect food consumption, so for instance to abide to a healthy lifestyle and follow nutritional recommendations would be the result of a higher socioeconomic status¹⁰⁴.

Technology has an enormous influence on the consumption habits of citizens. The traditional path of sell and purchase have been completely rewritten thanks to the personalization technology that combines data on health and nutrition to provide dietary recommendations (not only tracking fitness and health levels but recommending nutrition options to help citizens maximize their goals).

In that sense, The IT field has proven to be a leading sector in this area of study, taking up the challenge of addressing current issues such as local consumption and healthy eating¹⁰⁵. Many state-of-the-art works have focused on how digital technologies can strengthen the urban-regional links by eliminating the middlemen and allowing for a direct contact between producers and consumers, which is usually more difficult to achieve in urban contexts.

Food consumption in CRFS settings presents many different points of view, reflected by the different habits that citizens have. Although the shift from home consumption to eating out has existed for a couple of decades, there is also a new paradigm of individualization of food, as a hallmark of the citizen, where new trends appear such as greening and sustainability.

As for the place of consumption, we also must make a distinction between mass-attended dining places, such as diners or fast-food, and the so-called 'fine-dining', since the products offered by the industrial actors here proposed provide for two different needs: one is mass-production, popular and cheap meals; and the other is artisanal, highly skilled production, elitist and expensive meals, a highly contradicting category. Even considering all this diversity of places, types of consumption and social profiles, it seems that there is no clear separation between the innovative technologies destined to household and those to professionals, so we have decided to consider the product purchase process together with that of consumption of the product by the citizen within the same section.

Robotization: Professionalization of Home Cooking

The evolution that kitchens have had in terms of the introduction of professional appliances in traditional consumption systems is noteworthy in this desk research. More and more sophisticated equipment is used from those that facilitate the task of cooking such as kitchen robots to those dedicated to food preservation such as refrigeration and freezing, dehydration, fermentation, acidification, smoking, etc.

In relation to kitchen robots and other automation devices, many of them work with Internet connectivity, through which you can update their software, download recipes and connect with other personal services such as those that could track consumers' diets. Connectivity with other users will enable bi-directional share

¹⁰² Piatti C., Khajehei F. (2019) Food Consumption and Technologies. In: Piatti C., Graeff-Hönniger S., Khajehei F. (eds) Food Tech Transitions. Springer, Cham. https://doi.org/10.1007/978-3-030-21059-5_7

¹⁰³ Diner, H. (2001). *Hungering for America: Italian, Irish and Jewish Foodways in the age of migration*. Cambridge, MA: Harvard Univ. Press.

¹⁰⁴ Harrington, J., Fitzgerald, A. P., Layte, R., Lutomski, J., Molcho, M., & Perry, I. J. (2011). Sociodemographic, health and lifestyle predictors of poor diets. *Public Health Nutrition*, 14(12), 2166–2175.

¹⁰⁵ Samoggia, A.; Monticone, F.; Bertazzoli, A. Innovative Digital Technologies for Purchasing and Consumption in Urban and Regional Agro-Food Systems: A Systematic Review. *Foods* 2021, 10, 208. <https://doi.org/10.3390/foods10020208>

of information, recipes and entire cooking patterns, which links to the online user communities around shopping experience and nutrition that we describe in a later subsection.

Following the trends explained above in which food consumption is individualized and the use of robotic systems frequently used in the retail sector is transferred to home consumption (although still designed for very particular consumer segments), we can find it in use from ultrasound food processor, such as Sonicprep¹⁰⁶, a tool which emits ultrasonic sound waves to 'extract, infuse, homogenize, emulsify, suspend, de-gas or even rapidly create barrel-aged flavor'. Composed of a generator, converter, probe and sound box, this tool applies low heat vibrations of sound energy, therefore avoiding the transformations given by heat, preserving colors, aromas and nutrients.

Consumption in Smart Systems

A transition from product-centric to service-centric with focus on consumer is undergoing, driven by the desire for convenience. New routes to the market such as subscription services have become more common, as takeout and ordered food has boomed.

Smart systems, enabled by paradigms such as the Internet of Things, offer us the possibility of having consumer electronics devices that facilitate purchasing processes, such as Smart fridges that can help keeping track of food inventory and manage shopping lists. Artificial intelligence also plays its role in the processing of this data, since it has the potential to answer questions so common in the daily life of citizens such as what is for dinner today, or what would be missing to buy to be able to use my favorite recipe.

Also companies like Walmart¹⁰⁷ have merged the concepts of home delivery with home automation control systems, achieving the automatic delivery of groceries all the way to the fridge. The procedure is as follows: (i) Walmart employees select produce and other household items ordered by a customer online. (ii) They then deliver the items right into the shopper's kitchen or garage using smart technology that gives them a one-time code to enter. (iii) The homeowner will be able to watch the delivery through their smartphone. The Walmart employee wears a camera that will livestream the delivery; if it doesn't turn on, the door at the customer's home won't unlock.

Technologies for the facilitation of food purchase

In the last decade, technologies have proliferated that allow a better in-store experience, driving the customer through the store to their shopping list products, or providing loyalty mechanisms such as promotions, digital loyalty cards, etc.

For instance, famous sharing-economy transport service Uber has recently launched into food delivering under the name Uber-Eats¹⁰⁸[RPAG7]. Customers will now receive "personalised" menu recommendations for every restaurant. So instead of scrolling through an entire menu, the app floats what it thinks your favorite dish options will be up to the top of the page.

The customization is based on what UberEats calls a "taste profile." The taste profile is an Artificial Intelligence-based algorithm that learns your preferences based on factors like your previous orders and what restaurants you've browsed through.

Creation of online communities around shopping experience and nutrition

The creation of an online community has proven crucial in enhancing networking among consumers and between them and farmers, radically changing the food shopping experience from both sides. While not

¹⁰⁶ The PolyScience Sonicprep ultrasonic homogenizer. Polyscienceculinary, <https://polyscienceculinary.com/products/the-sonicprep-ultrasonic-homogenizer>

¹⁰⁷ Walmart skips the front porch and delivers right to your refrigerator starting today. Usa Today, 2019. <https://eu.usatoday.com/story/money/2019/10/15/walmart-takes-amazon-starts-deliveries-right-your-fridge/3983426002/>

¹⁰⁸ UberEats is going to let you order food from 'virtual restaurants' that don't exist IRL, 2017. <https://mashable.com/2017/11/09/ubereats-virtual-restaurants>

being a substitute for in person exchanges, online interactions help create a sense of community through sharing food choices and food shopping experiences. Digital technologies, through mapping and reviews, have made it easier for consumers to find local producers and restaurants. They also help maintain these new habits by providing further information and a service that is easy to use and fits with consumers' busy lifestyles. Mobile phone Apps are particularly fitting for this as they are able to target consumers and farmers, helping the former with sustainable consumption and the latter with farm marketing.

In this review, digital technologies were proven crucial in addressing the issues of asymmetry of information along the food supply chain and of consumers' detachment towards the food they eat. These are the focuses of the recently published European Green Deal, which aims at using digitalisation as a tool for improving communications of products characteristics to consumers¹⁰⁹. How to do this at best, could be the topic of further research.

Nutrition is central for understanding the recent trends for both production and processing. The (re)discovery of crops estimated to be highly healthy has produced a change in agricultural production, and subsequently an adaptation in the global supply chain to ensure demand. At present, and thanks to the technologies that allow multi-skate holder communication, communities have been established in terms of food consumption such as Superfoods, plant-based products (HappyCow¹¹⁰), Plantpure Communities¹¹¹, or Impossible Foods¹¹²). Data tells us that in 2018 in general plant-based food sales rose 20% over the previous year reaching \$3.3 billion¹¹³, among which some innovative products stand out. Interestingly cow-milk and cow-milk based products are down, whereas plant-based milk (as it is referred to) gains some positions. Mainly plant-based substitute employ plants because of their characteristics such as less saturated fats, more fibers and Omega-3s, and help with vitamins-income and to reduce blood pressure.

Conclusions and challenges

The main revolution of technology applications comes from synergies of digitalization and AI technologies, as it has been highlighted when talking about full connectivity.

This allows interaction of equipment, voice assistants and chatbots helping with the cooking process. This presupposes that adopters know how to use these technologies, which have been rendered more accessible on the basis of the 'user-friendly' rule. The outcome makes an observer think at a digital kitchen in which little human participation is necessary, as the instruction set for our appliances make the content becoming dynamic, atomized and personalized depending on our personal preferences and the context of our current day, meal plan, and food inventory.

The creation of digital communities that support trends in ethical eating, health concern, environmental issues are at the forefront, but adoption of new technologies are to be measured against disposable income and education / food and tech literacy, two of the main barriers common to many of the categories proposed. Digital technologies transformation potential is in the hands of the users: the issue of access to digital technologies, as pointed out by FAO, needs to be addressed. Unequal access to digital technologies could cause long-term disparities hindering the economic development of rural areas worldwide. That is why FAO

¹⁰⁹ European Commission. A Smart and Sustainable Digital Future for European Agriculture and Rural Areas. 2019. Available online: <https://ec.europa.eu/digital-single-market/en/news/eu-member-states-join-forces-digitalisation-european-agriculture-and-rural-areas>

¹¹⁰ HappyCow website: <https://www.happycow.net/>

¹¹¹ Plantpure Communities: <https://plantpurecommunities.org/>

¹¹² Impossible Foods: <https://impossiblefoods.com/>

¹¹³ Plant based foods association: <https://www.plantbasedfoods.org/wp-content/uploads/2018/07/PBFA-Release-on-Nielsen-Data-7.30.18.pdf>

Digital Council committed to a considerable effort in an even access to basic ICT tools for rural communities¹¹⁴.

In these conclusions we would like to highlight two challenges that are important to address in the future. On the one hand, the massive use of apps and related technology means that data is collected and used by the industry behind it, raising questions over their use¹¹⁵. This starts to concern users, on the issues of data ownership and invasion of privacy, considering that the information must be protected by the GDPR. Much of the personal data collected in personalized nutrition offerings or used for research qualifies as 'special data' under the GDPR because it relates to the health of individuals or consists of genetic information. The concept of health data is interpreted broadly and includes glucose levels, sample test results and even body mass index (BMI)¹¹⁶

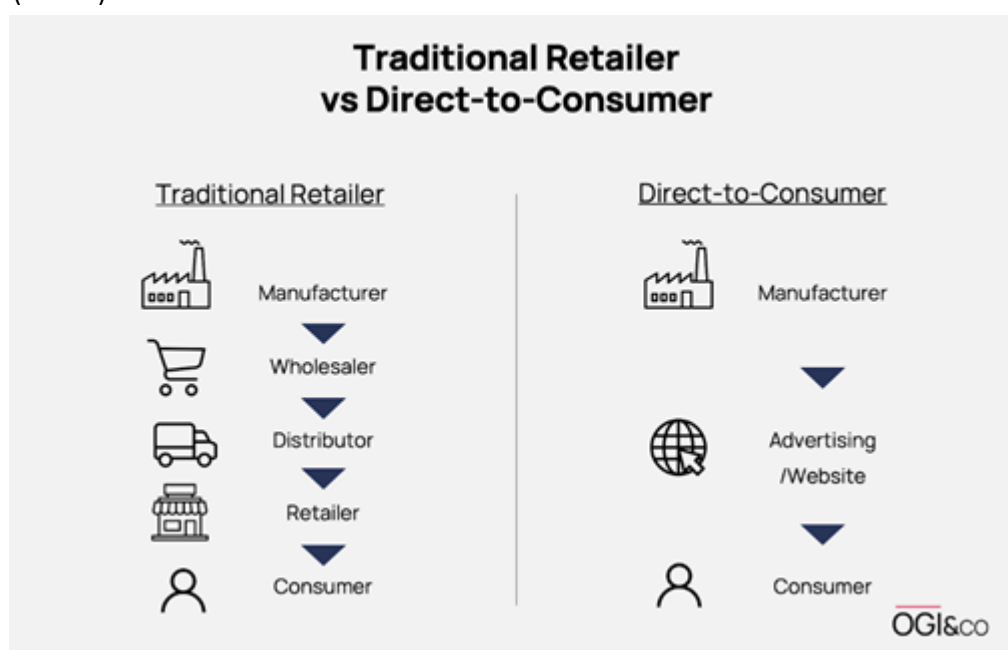


Figure 14 – Traditional Retailer vs Direct-to-Consumer

On the other hand, another of the most outstanding challenges is how the authorities can check the quality and the safety of food sold directly to consumers, making it an interesting issue for further studies. In this case we are talking about the Direct-to-consumer models¹¹⁷ (see previous Figure) that have accelerated in the previous months, driven also by the COVID-19 pandemic and that many times eliminate the presence of intermediaries who in turn carry out quality controls. These new distribution chains must be carefully studied to prove their resilience and traceability properties.

¹¹⁴ Food and Agriculture Organisation. Realising the Potential of Digitalisation to Improve the Agri-food System; FAO: Rome, Italy, 2020

¹¹⁵ Piatti C., Khajehei F. (2019) Food Consumption and Technologies. In: Piatti C., Graeff-Hönniger S., Khajehei F. (eds) Food Tech Transitions. Springer, Cham. https://doi.org/10.1007/978-3-030-21059-5_7

¹¹⁶ What does GDPR mean for personalised nutrition?. Vitafoods Insights, <https://www.vitafoodsinsights.com/personalised-nutrition/what-does-gdpr-mean-personalised-nutrition>

¹¹⁷ Food and drinks companies shifting to D2C models. <https://forwardfooding.com/blog/foodtech-trends-and-insights/direct-to-consumer-food-industry/>

4.5 Waste management solutions

With Food Loss & Waste (FLW) broadly estimated at 30% of total food production, and with little to no progress on its reduction achieved in recent years, it is clear that any initiative targeting significant impact in this sector must address the main lock-in effects embedded in the current organization and operation of the food system. Reducing food loss and waste is seen as a way to lower production costs, improve food security and nutrition, and contribute towards environmental sustainability, notably by easing the pressure on natural resources and decreasing greenhouse gas (GHG) emissions. In the context of the challenge of sustainably feeding a world, the population projected to reach almost 10 billion in 2050, minimizing food loss and waste and making the most of resources underpinning the food system are considered particularly important.

Food loss and waste has become a major global issue and is summarized in Sustainable Development Goal (SDG) 12 (responsible consumption and production), which even sets a specific target related to the reduction of food loss and waste:

SDG Target 12.3 calls for halving per capita global food waste at retail and consumer levels and reducing food loss along production and supply chains, including post-harvest loss, by 2030.

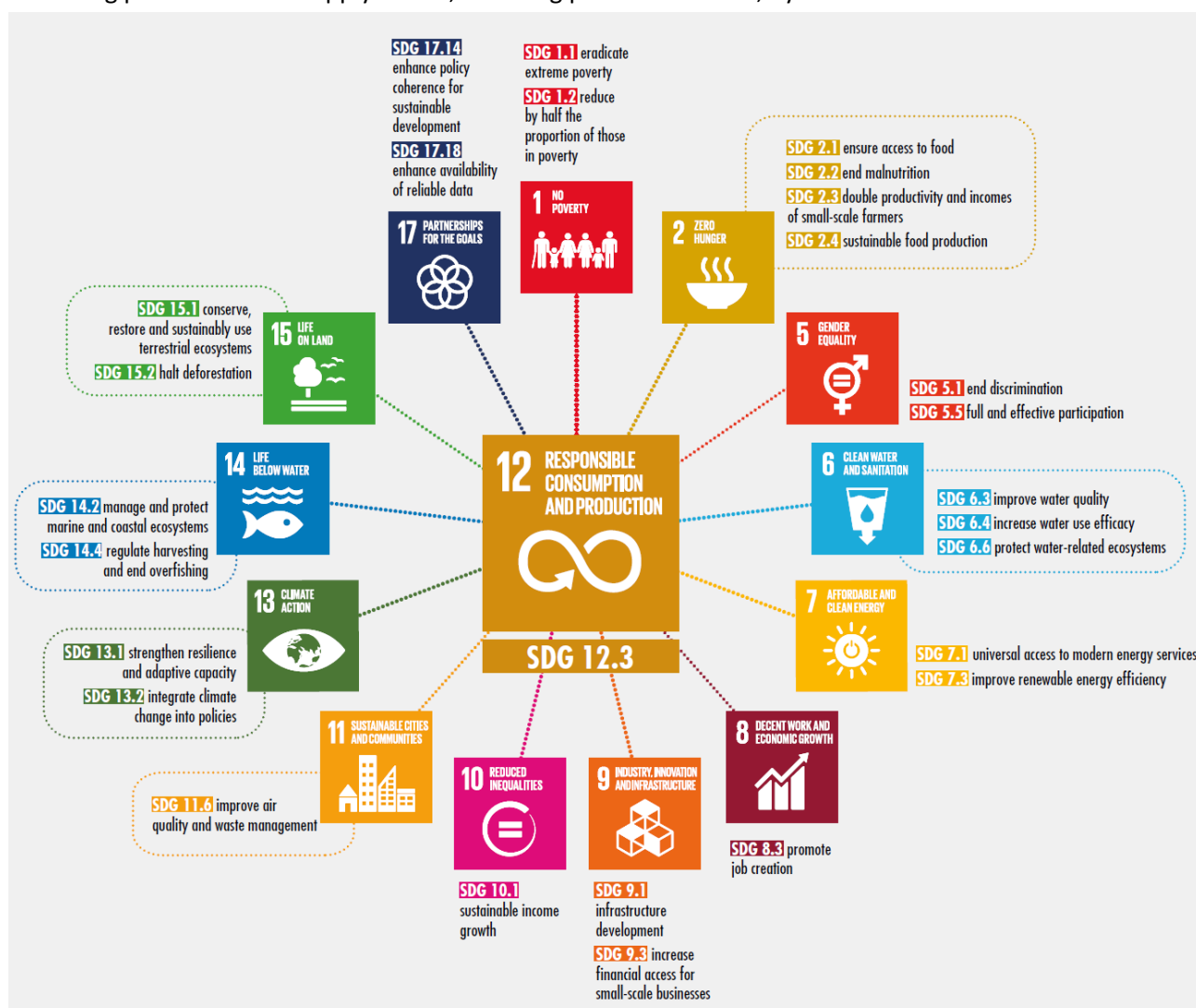


Figure 15 – Potential linkages between reducing food loss and waste and various SDGs (Source: FAO)

Previous research has identified a variety of factors affecting FLW, including: (i) poor forecasting & demand-supply mismatch; (ii) inadequate harvesting, processing & logistics practices; (iii) high food cosmetic requirements in retail; (iv) consumer buying habits. When deciding what action to take to address food loss and waste, several questions arise, including:

- Why is food lost or wasted?
- How much food is lost or wasted?
- Why is it important to reduce food loss and waste?
- How can food loss and waste be reduced?
- Can all food loss and waste be avoided?
- Who benefits (or loses) from food loss and waste reduction?
- How can food loss and waste reduction contribute to achieving food security and nutrition or environmental sustainability?

4.5.1 Food loss vs food waste

We must distinguish between food loss and food waste. No common definition of food loss and waste exists, although there are several definitions in different literature. Most definitions focus on the quantitative loss and waste along the food supply chain, but others also consider loss in quality (nutritional, cosmetic, food safety).

The distinction between food loss and food waste is not only conceptually relevant, but also useful from a policy point of view. Conceptually speaking:

Food loss – the result of suppliers' decisions and actions – affects the supply of food: if food losses are reduced, the supply of food into the food supply chain increases. Therefore, strictly speaking, food loss concerns all stages of the food supply chain up to, but excluding, the point where there is interaction with the final consumer and thus excludes retail, food service providers and consumers.

Food waste is the result of consumers' purchasing decisions or decisions by retailers and food service providers that affect consumer behavior.

Quantitative food loss and waste (also referred to as physical food loss and waste) is the decrease in the mass of food destined for human consumption as it is removed from the food supply chain. As such, quantitative food loss refers to the decrease in the mass of food destined for human consumption from decisions and actions by food suppliers in the chain. Quantitative food waste is the physical decrease in food mass resulting from retailers, food services, and consumers' decisions and actions.

Qualitative food loss and waste refers to the decrease in food attributes that reduces its value in terms of intended use. It can result in reduced nutritional value (e.g. smaller amounts of vitamin C in bruised fruits) and/or the economic value of food because of non-compliance with quality standards. A reduction in quality may result in unsafe food, presenting risks to consumer health. Qualitative food loss refers to the decrease in food attributes that reduce the value of food in terms of its intended use – it results from food suppliers' decisions and actions in the chain. Qualitative food waste is the same but results from actions by retailers, food services and consumers.

The following Figure distinguishes between the intended use of plants and animals produced (both food and non-food economic uses); their fragmentation into food, inedible parts, feed and non-feed parts; and, ultimately, their destination (as food, productive non-food use, or food loss and waste).

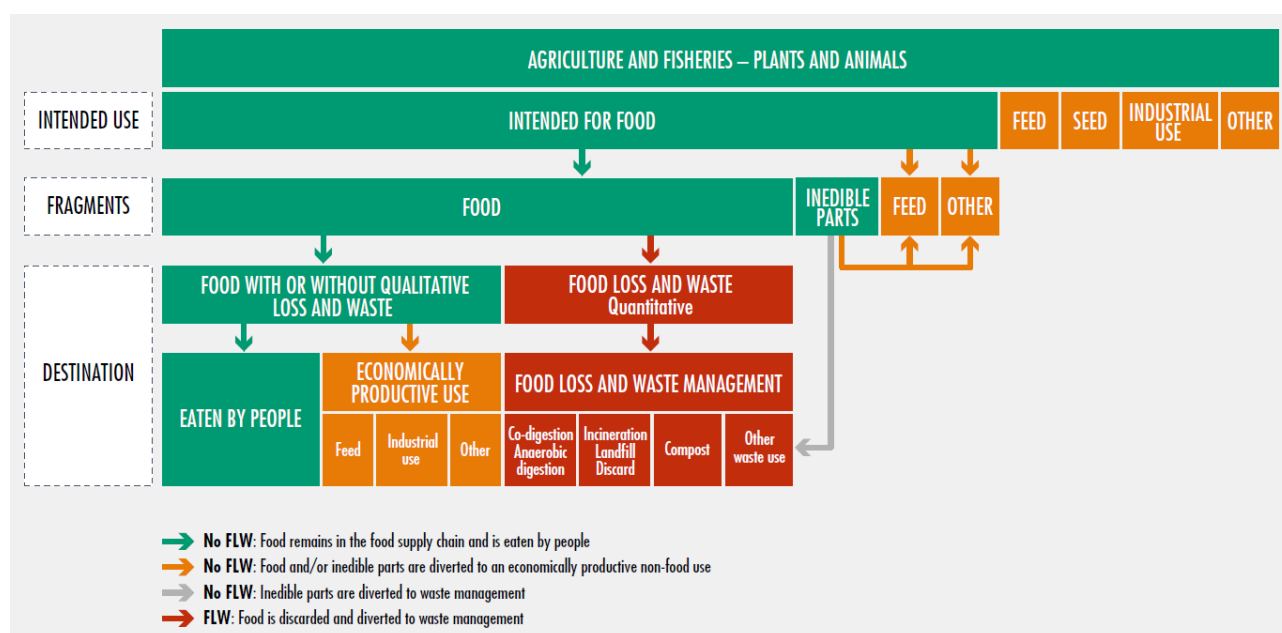


Figure 16 – Intended use of plants and animals produced and subsequent fragmentation

4.5.2 Food loss and waste in the world and the data around it

How much do we actually know about food loss and waste in the world? Surprisingly little, but the SDG monitoring framework is expected to contribute precisely to bridging this gap through enhanced efforts to collect data that enable estimation of total food loss and waste at the highest possible disaggregated levels. The following Figure shows food loss in the world from post-harvest to distribution in 2016. As we are able to see, the world percentage is at around 13.8, while Europe percentage is a little bit higher, with approximately 16 percent of food being lost from harvest to distribution.

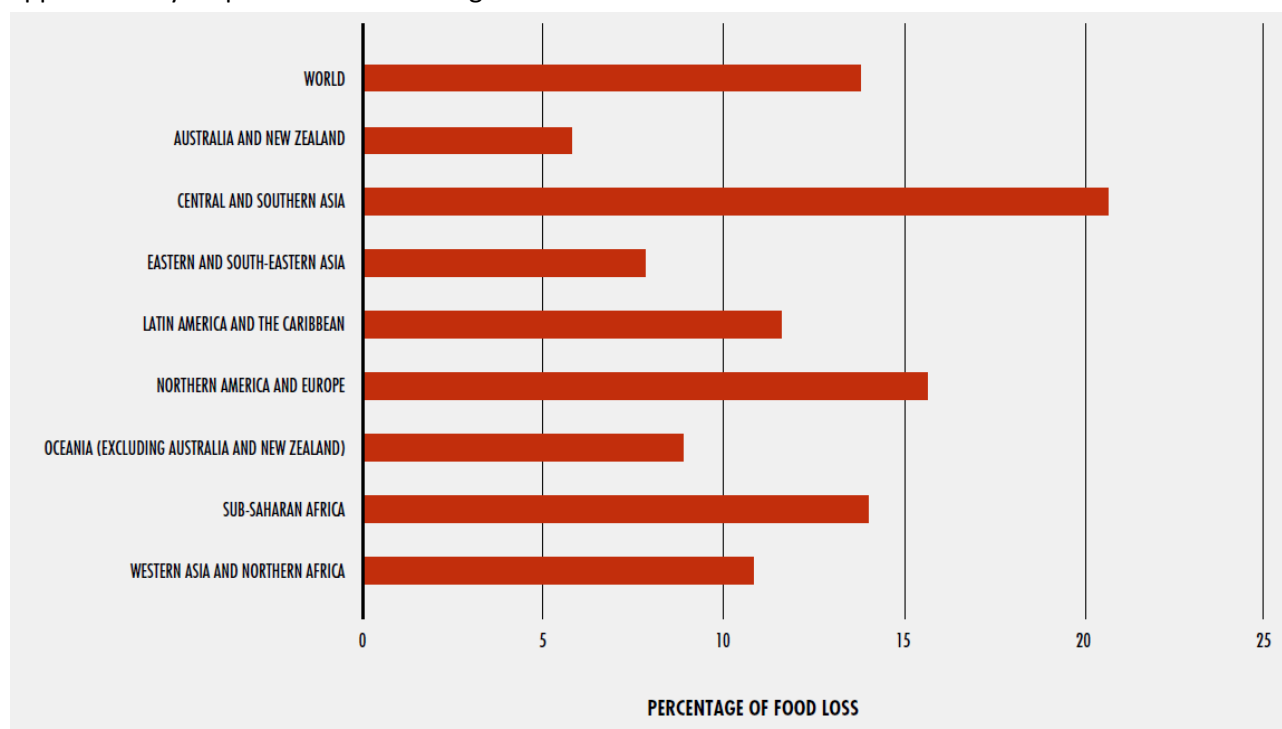


Figure 17 – Food loss from post-harvest to distribution in 2016, globally vs regions (Source: FAO)

Identifying the causes and drivers of food loss and waste, formulating possible reduction solutions, prioritizing objectives and monitoring progress towards these objectives will require more reliable, comparable and transparent data, since the data gap remains high due to several reasons:

1. divergent food loss and waste definitions together with measuring methods and metrics
2. surveys on the extent, location and causes of food loss and waste are complex, time-consuming and costly

The complexity of collecting food loss data explains why only 39 countries have officially reported loss data annually between 1990 and 2017 through FAO's Questionnaire.

4.5.3 Best practice examples on how to tackle food loss and waste

The following table resumes different technologies and approaches from around the world:

Table 5 - Best practice examples on how to tackle food loss and waste

Solution / good practice	Description
Apeel ¹¹⁸	Apeel uses materials that exist in the peels, seeds, and pulp of all fruits and vegetables to create a protective extra peel that seals moisture in and keeps oxygen out. That means their produce stays fresh, nutritious, and delicious twice as long.
Wasteless ¹¹⁹	At Wasteless, they help supermarkets and online grocery stores recapture their perishable products' full value and reduce food waste through AI-powered dynamic pricing.
Flashfood ¹²⁰	Get massive savings on fresh food items like meat and produce that are nearing their best before date at grocery stores across Canada and the U.S.
Too Good To Go ¹²¹	Application is the most direct way for consumer to get involved - just download, log on, and get saving perfectly good, surplus food from your local stores.
Whole Surplus ¹²²	Whole Surplus is an effective waste management platform for businesses. It creates economic and social value from surplus food by managing the unsold products (food) of the businesses in the most effective way. On the other hand, it also provides donation announcements through the platform for food banks and voluntary organizations to get food donations regularly.
The Good Food ¹²³	The Good Food is a shop where customers can save groceries with their purchase. They make sure that rejected but still delicious food ends up on the plate instead of in the bin.

¹¹⁸ <https://www.apeel.com/>

¹¹⁹ <https://www.wasteless.com/>

¹²⁰ <https://www.flashfood.com/>

¹²¹ <https://toogoodtogo.org/en>

¹²² <https://wholesurplus.com/>

¹²³ <https://www.the-good-food.de/>

Phenix ¹²⁴	Determined to build a world without waste, Phenix founded a solution so that unsold goods never become waste: donating to charities, selling to individuals through mobile app, reusing items, animal food, upcycling...
Brøi ¹²⁵	With the slogans of <i>business</i> , <i>activism</i> and <i>circularity</i> , this Copenhagen-based beverage innovators transform surplus, wild ingredients and stories into craft drinks, giving customers a deliciously simple way to bring a positive change.
Olio ¹²⁶	OLIO connects neighbors with each other and with local businesses so surplus food can be shared, not thrown away.

4.6 Enhancing technologies for social inclusion

CRFS implementation entails a notion of the food system being equitable and empowering people to engage. Using technology to support also aspects of social inclusion is important to reflect an equitable food production ecosystem.

To provide a definition, social inclusion is basically about ensuring that all groups of society can participate - in everyday life, education, labor market, democratic processes etc. United Nations provides the following definition¹²⁷:

"The process of improving the terms of participation in society, particularly for people who are disadvantaged, through enhancing opportunities, access to resources, voice and respect for rights."

Social inclusion is on the agenda of every city which naturally aims to prosper and create attractive living spaces for its citizens. Large cities have more complexity and social diversity and stratification giving an extra impetus to consider active action for social inclusion.

Social inclusion is also integral to the concept of city resilience. In Vejle, one the partner cities in Cities2030, social resilience is concretely about social and economic cohesion as well as investing in future generations.

"Social inclusion is a matter not only of an adequate share of resources but also of "participation in the determination of both individual and collective life chances"¹²⁸. It overlaps with the concept of socioeconomic equality but is not equivalent to it. There are many ways that the poor can have fuller participation and inclusion even if they lack an equal share of resources"¹²⁹.

In this way, access to ICT for the promotion of social inclusion must engage a range of resources, all developed and promoted with an eye toward enhancing the social, economic, and political power of the targeted clients and communities. These resources can be categorized as follows:

- **Physical resources** access to computers and telecommunication connections.
- **Digital resources** refer to digital material that is made available online.
- **Human resources** concern issues such as literacy and education (including the particular types of literacy practices that are required for computer use and online communication).

¹²⁴ <https://wearephenix.com/en/>

¹²⁵ <https://broel.nu/>

¹²⁶ <https://olioex.com/>

¹²⁷ <https://www.un.org/esa/socdev/rwss/2016/chapter1.pdf>

¹²⁸ A. Stewart, Social inclusion: An introduction, England, Macmillan (2000).

¹²⁹ Rethinking the Gap: Digital Preparedness and Social Inclusion of Young Generations in Remote Area to Lessen Digital Inequality, N. Aristi, ICENIS 2018.

- **Social resources** refer to the community, institutional, and societal structures that support access to ICT

It is important to distinguish here between using technology to improve social inclusion (participation) and what has often been referred to “digital divide” - meaning an exclusion of people with no capacity to participate in the digitized society. Using technology to enhance social inclusion is providing new opportunity to participate because of technology. However, the potential digital divide should be considered in any digital CRFS solution - considering how complex the solution is and which user requirements are entailed.

CRFS and SOCIAL INCLUSION

Socially vulnerable groups are typically also vulnerable when it comes to food - whether it be access to healthy food or capacity to manage an appropriate diet. CRFS can improve social inclusion in the following ways:

- Sustainable food systems are also about social equity and giving a more equal access to food (i.e. economy, food deserts, food skills, minority groups); Many cities may not be challenged on food deserts (*A food desert is an area that has limited access to affordable and nutritious food, in contrast with an area with higher access to supermarkets or vegetable shops with fresh foods, which is called a food oasis*) but can still work on inclusion of different food cultures and regimes in i.e. public meals offer.
- CRFS create new or better opportunities for food related value creation, i.e. urban start-ups, small-scale farmers rural-urban links. Sustainable food systems with shorter value chains and based on circularity principles incite much more local job potential for food related value creation
- CRFS give an awareness about local ecosystem and importance of food on prosperity and sustainability. About influencing the direction and co-creating the role of food production and consumption in society. Becoming a co-grower! Ultimately this is the city resilience perspective.

DATA-driven DIGITAL SUPPORT of CRFS

Digital solutions can enable, facilitate, and enhance CRFS solutions. Digital can unleash the enhanced participation and support social inclusion of CRFS in many dimensions. By better information (enhancing transparency), by creating variety of choices (products and stakeholder's mapping through marketplaces and innovation hubs), by providing new opportunities (i.e. value from data and connectivity, open data and open API's), and improving decision making (sharing Key Performance Indicators and evaluating relevant data with data analytics).

However, digital solutions should *actively seek the equity* and be aware about the potential for social inclusion and exclusion. When business and governmental processes become digital it is important to consider digital divide, i.e. difference in access, devices and skills:

- Can all see and understand the data? Readiness and audience reflection
- Can all interested use the marketplace/ be matched? What is the infrastructure (device) and skills (training) needed? Can the target group (i.e. small scale producers) enter?
- Are we providing the open data to build new value from? How are we making it accessible and commercially interesting?
- Are we reflecting citizens - all groups - in the decisions regarding the food system? Are we building with the 'usual suspects' or are we reflecting methods and outreach to also vulnerable groups?

Digital solutions hold the potential of empowering the consumers and giving citizens a more participatory role. It also can create new opportunities for value creation, i.e. shorter value chains, urban food production, re-distribution or re-valorization of surplus food. The important things to consider in the development is the potential upside to social inclusion, creating both socially equitable solutions, making healthy and appropriate food accessible to all, and reflecting the food value-creation across the rural-urban segments.

Drivers to consider social inclusion in digital solution's architectural design

As stated above many considerations should be made to consider participation and inclusions as predicaments of sustainable development and the definition of IT/digital frameworks:

- How will the CRFS solution actively seek to leverage the potential of social inclusion?
- How is the solution adapted to the real circumstances of the audience in terms of needs and digital divide?
- What training or surrounding action is needed to support the implementation and uptake of a digital CRFS solution?

4.7 Data-driven ecosystem services

Ecosystem services are increasingly incorporated into explicit policy targets in the frame of CRFS and can be an effective tool for informing decisions about the use and management of the City-Region's resources.

4.7.1 Definition of Environmental and Ecosystem services

Ecosystem services are the benefits people obtain from natural ecosystems^{130 131}, including provisioning, regulating, cultural and supporting services, as described in the following Figure.

¹³⁰ Daily, G.C., et al. (1997) Ecosystem Services: Benefits Supplied to Human Societies by Natural Ecosystems. Issues in Ecology, 2.

¹³¹ Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Synthesis. Isl. Press, Washington, DC.

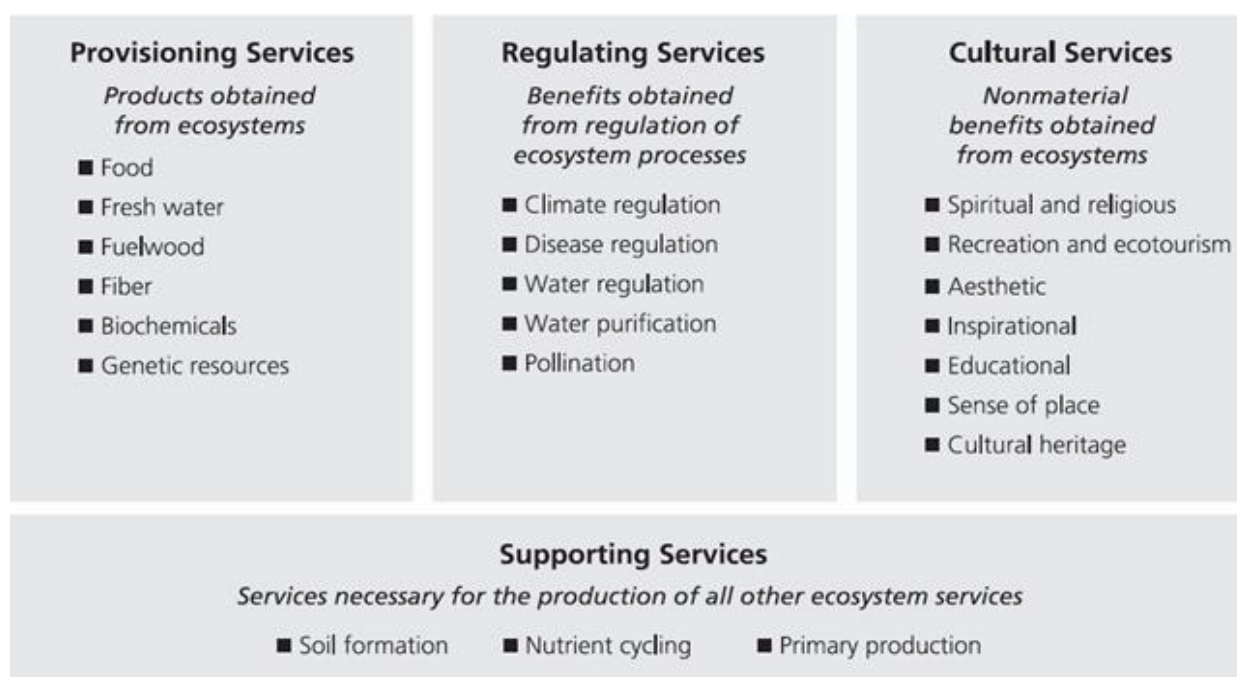


Figure 18 – Ecosystem Services. Source: Alcamo, J. (2003). *Ecosystems and human well-being: a framework for assessment*. p57

Ecosystem services in CRFS refer either to

- 1) agricultural ecosystem beyond the city limits providing food, fiber, and fuel¹³² or
- 2) to urban ecosystems such as street trees; lawns/parks; urban forests; cultivated land; wetlands; lakes/sea; and streams¹³³. These systems generate a range of ecosystem services such as air filtration, micro climate regulation, noise reduction, rainwater drainage, sewage treatment, and recreational and cultural values, which have a substantial impact on the quality-of-life in urban areas.

Adequate production of locally produced services and services which are more accessible when produced locally is challenging in the context of dense urban development. Management approaches are needed to address scale mismatches in the production and consumption of ecosystem services. By coordinating along multiple scales of management and promoting best management practices, urban leaders have an opportunity to ensure that nature and ecosystem processes are protected in cities to support the delivery of fundamental urban ecosystem services¹³⁴.

Though urban agriculture (UA), defined here as growing of crops in cities, is increasing in popularity and importance globally, little is known about the aggregate benefits of such natural capital in built-up areas¹³⁵.

¹³² Zhang, W., Ricketts, T. H., Kremen, C., Carney, K., & Swinton, S. M. (2007). Ecosystem services and dis-services to agriculture. *Ecological economics*, 64(2), 253-260.

¹³³ Bolund, P., & Hunhammar, S. (1999). Ecosystem services in urban areas. *Ecological economics*, 29(2), 293-301.

¹³⁴ McPhearson, T., Hamstead, Z. A., & Kremer, P. (2014). Urban ecosystem services for resilience planning and management in New York City. *Ambio*, 43(4), 502-515.

¹³⁵ Clinton, N., Stuhlmacher, M., Miles, A., Uludere Aragon, N., Wagner, M., Georgescu, M., ... & Gong, P. (2018). A global geospatial ecosystem services estimate of urban agriculture. *Earth's Future*, 6(1), 40-60.

4.7.2 Quantitative evaluation of ecosystem services

Tracking of progress towards targets for ecosystem services is required at local and global level to contribute to key global policies, such as the Convention on Biological Diversity (CBD), the Sustainable Development Goals or the Commission on Climate Change and Development. To reduce the rate of loss of biodiversity, it is critical that targets are grounded in the real interests that people have in benefits provided by biodiversity. To evaluate targets, the ecosystem services framework developed by the Millennium Ecosystem Assessment (MA) balances resource conservation and use according to how societies value consumptive (e.g., food and fuel) and non-consumptive (e.g., health and aesthetics) services provided by ecosystems¹³⁶.

Ecosystem services are an effective tool for informing decisions about the use and management of resources¹³⁷. In order to address sustainability challenges, decision-makers need credible and legitimate measurements of ecosystem services. In order to fully understand ecosystem services, four different components need to be measured and monitored: (1) supply, (2) delivery, (3) contribution to well-being, and (4) value¹³⁸¹³⁹.

A wide variety of data sources is available and relevant to ecosystem services monitoring, including national statistics, field-based assessments, remote sensing and models. Outputs from monitoring a range of ecosystem services and their components at different spatial scales can actively support decision-making.

Ideally the quantitative evaluation of ecosystem services follows a standard like the Common International Classification of Ecosystem Services (CICES) developed by the European Environment Agency for ecosystem accounting with link to economic accounting.

¹³⁶ Perrings, C., Naeem, S., Ahrestani, F., Bunker, D. E., Burkill, P., Canziani, G., ... & Weisser, W. (2010). Ecosystem services for 2020. *Science*, 330(6002), 323-324.

¹³⁷ Balvanera, P., Quijas, S., Karp, D. S., Ash, N., Bennett, E. M., Boumans, R., & Walz, A. (2017). Ecosystem services. In *The GEO handbook on biodiversity observation networks* (pp. 39-78). Springer, Cham.

¹³⁸ Tallis, H., Mooney, H., Andelman, S., Balvanera, P., Cramer, W., Karp, D., et al. (2012). A global system for monitoring ecosystem service change. *BioScience*, 62, 977–986.

¹³⁹ Li, W.; Dong, R.; Fu, H.; Wang, J.; Yu, L.; Gong, P. Integrating Google Earth imagery with Landsat data to improve 30-m resolution land cover mapping. *Remote Sens. Environ.* 2020, 237, 111563

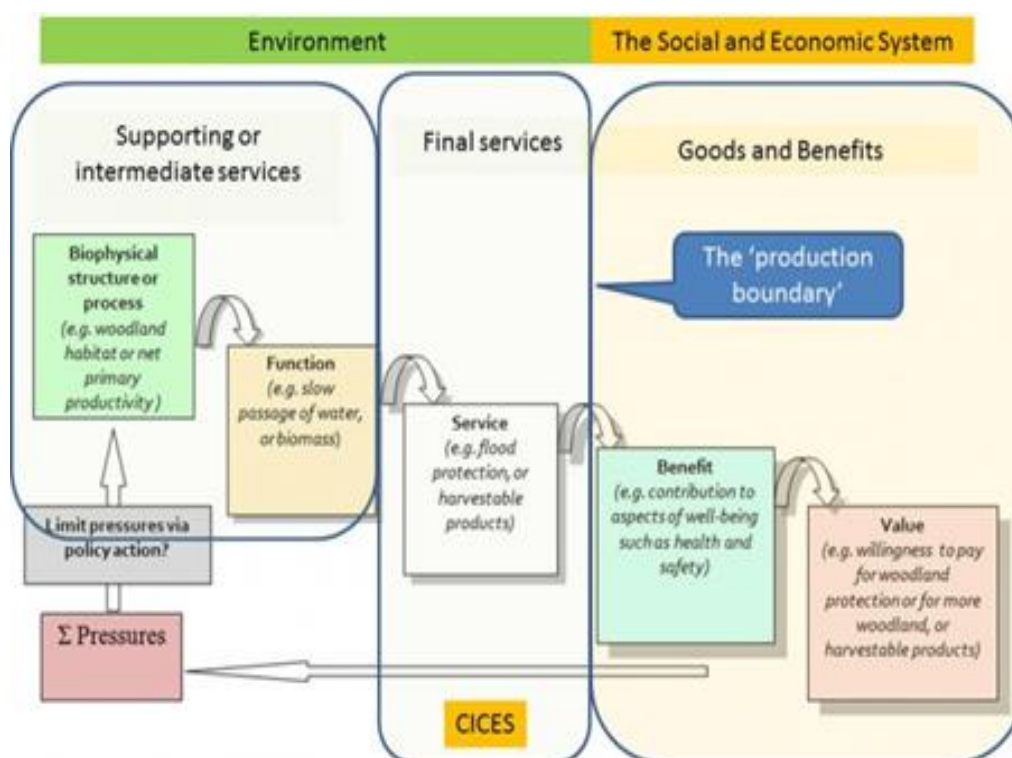


Figure 19 – Conceptual background for Common International Classification of Ecosystem Services¹⁴⁰

4.7.3 The Challenge of monitoring Ecosystem Services

Around the world, leaders are increasingly recognizing ecosystems as natural capital assets that supply life-support services of tremendous value. The challenge is to turn this recognition into incentives and institutions that will guide wise investments in natural capital, on a large scale. Shortcomings in our ability to accurately measure, map, and value Ecosystem Services have surfaced so that advances are required on three key fronts: (i) the science of ecosystem production functions and service mapping and the complex, multi-scale biophysical and socioeconomic dynamics inherent in Ecosystem Services provision, flow, and use, (ii) the design of appropriate finance, policy, and governance systems; and (iii) the art of implementing these in diverse biophysical and social contexts.

Scientific understanding of ecosystem production functions is improving rapidly but remains a limiting factor in incorporating natural capital into decisions, via systems of national accounting and other mechanisms. Novel institutional structures are being established for a broad array of services and places, creating a need and opportunity for systematic assessment of their scope and limitations. Finally, formal sharing of experience, and defining of priorities for future work, could greatly accelerate the rate of innovation and uptake of new approaches¹⁴¹. On the practitioner side, application of methods remains onerous due to data and model parameterization requirements. Further, it is increasingly clear that the dominant “one model fits

¹⁴⁰ Source: Potschin, M. B., & Haines-Young, R. H. (2011). Ecosystem services: Exploring a geographical perspective. *Progress in physical geography*, 35(5), 575-594.

¹⁴¹ Daily, G. C., & Matson, P. A. (2008). Ecosystem services: From theory to implementation. *Proceedings of the national academy of sciences*, 105(28), 9455-9456.

all" paradigm is often ill-suited to address the diversity of real-world management situations that exist across the broad spectrum of coupled human-natural systems. While many observations and datasets are available, their coverage is patchy, incomplete and inconsistent¹⁴². Major data gap linking ecosystem characteristics to final ecosystem services exist¹⁴³.

4.7.3.1 Tools for monitoring Ecosystem Services

National statistics

The United Nations' Food and Agriculture Organization publishes a global database¹⁴⁴ of the amount produced or extracted (delivery), traded, and the monetary value (value) of several ecosystem services, for example, total production of all commercial crops for countries or regions, export or import quantity of trade crops and their economic value per unit.

The World Bank¹⁴⁵ reports water withdrawals and water availability to people. Some of the services are monitored in most countries and updated annually (e.g., crops), while others are only available for a small subset of nation states and updated infrequently (*5 years, e.g., water withdrawal).

Remote sensing

Remote sensing of ecosystem services relies on hybrid methods, that use models to combine in situ information (collected either by humans or machines) with data collected at coarser spatial scales (e.g., climate, landform, social or economic variables).

Remote sensing has the capacity to assist the adaptive evolution of agricultural practices in order to face major challenge of environmental sustainability and climate change by providing repetitive information on crop status throughout the season at different scales and for different actors. Such agricultural applications include crop breeding, agricultural land use monitoring, crop yield forecasting, as well as ecosystem services in relation to soil and water resources or biodiversity loss¹⁴⁶. For example, greenness measures of vegetation indicate plant vigor, which is used to assess crop delivery (through potential productivity of known plant/crop species), carbon stocks and carbon uptake, fisheries (through ocean productivity), water quality (through changes in watercolor), and land use change (a driver).

High-resolution data can inform on small-scale ecological features, such as individual trees. Information on roads, fields and habitat patches can be used to provide information on drivers of many ecosystem services. Products from radar devices provide high-resolution information for topography, vegetation and water cover, and potentially on the aboveground biomass. These can contribute to assessing land use change, crops, or water cover (superficial water bodies) over a targeted region.

Products based on Laser Imaging Detection and Ranging (LIDAR) devices provide high resolution information on above-ground carbon stocks, water (water surface elevation, and in combination with bathymetry, the

¹⁴² Egoh, B., Dunbar, M. B., Maes, J., Willems, L., & Drakou, E. G. (2012). Indicators for mapping ecosystem services: A review. Ispra, Italy: European Commission.

¹⁴³ Wong, C. P., Jiang, B., Kinzig, A. P., Lee, K. N., & Ouyang, Z. (2015). Linking ecosystem characteristics to final ecosystem services for public policy. *Ecology letters*, 18(1), 108-118.

¹⁴⁴ FAO's database: <http://faostat.fao.org/>

¹⁴⁵ The World Bank national statistics: <http://data.worldbank.org>

¹⁴⁶ Weiss, M., Jacob, F., & Duveiller, G. (2020). Remote sensing for agricultural applications: A meta-review. *Remote Sensing of Environment*, 236, 111402.

volume of freshwater bodies), and ecosystem structure, that can be used to model a range of provisioning, regulating and cultural services.

High resolution images are increasingly available from commercial satellites and used to refine information for particular locations. The cost is currently high, but cost-effective if compared with manual mapping on the ground, and is being driven down by the advent of unmanned autonomous vehicles or 'drones' equipped with cameras.

Digitization can also influence these and other ecosystem services (e.g. climate regulation) through the use of modern networked sensors. Low hardware prices and automated processing and analysis of the data can provide a great insight into the actual pollutants emitted and can indicate needs or potentials for action¹⁴⁷.

The analysis of high volumes of digital photographs (quantifying geo-tagged digital photographs uploaded to social media resources) extends the methodological tool-box available and provides a powerful new means to quantify and map Cultural Ecosystem Services at broad spatial scales¹⁴⁸.

Ecosystem service assessments based on virtual globes (remote sensing via *Google Earth*) can be universally applied providing valuable information on riverscape ecosystem service delivery for example¹⁴⁹.

Network of wireless, low cost, and multiparameter monitoring devices, which operate using Internet of Things (IoT) technology, can provide real-time monitoring of regulatory ecosystem services in the form of meaningful indicators for both human health and environmental policies. These parameters are used as input variables to quantify indicators of ecosystem services related to climate, air quality, and water regulation¹⁵⁰.

Field based estimations

Field-based estimations contribute to local or site-based monitoring and assessment, as well as to validation of models and remotely sensed data products. Some services, such as the flow of water in rivers, are routinely monitored by in-field devices, and new technologies such as eddy covariance are extending the range of in situ observations of services such as carbon sequestration.

Conducting field-based data collection can be costly, time consuming and technically specialized, and the methods and information from different data sources need to be standardized. Assessment methods involve bio-physical models, Geographical Information Systems, and valuation¹⁵¹.

Toolkits are emerging to deal with these issues. Such toolkits provide guidance on the steps to be followed, the kind of data to be gathered and the methods suggested to gather or model quantitative data at this scale required to locally relevant assessments of multiple ecosystem services.

- The Toolkit for Ecosystem Service Site-based Assessments (TESSA) was developed to assist site-scale users with limited capacity and resources, to develop simple estimates of ecosystem services¹⁵².

¹⁴⁷ Haag, S., Bauerdick, C., Campitelli, A., Anderl, R., Abele, E., & Schebek, L. (2018). A framework for self-evaluation and increase of resource-efficient production through digitalization. *Procedia CIRP*, 72, 850-855

¹⁴⁸ Retka, J., Jepson, P., Ladle, R. J., Malhado, A. C., Vieira, F. A., Normande, I. C., ... & Correia, R. A. (2019). Assessing cultural ecosystem services of a large marine protected area through social media photographs. *Ocean & Coastal Management*, 176, 40-48.

¹⁴⁹ Large, A. R. G., & Gilvear, D. J. (2015). Using Google Earth, a virtual-globe imaging platform, for ecosystem services-based river assessment. *River Research and Applications*, 31(4), 406-421.

¹⁵⁰ Matasov, V., Belelli Marchesini, L., Yaroslavlsev, A., Sala, G., Fareeva, O., Seregin, I., ... & Valentini, R. (2020). IoT Monitoring of Urban Tree Ecosystem Services: Possibilities and Challenges. *Forests*, 11(7), 775.

¹⁵¹ Haase, D., Larondelle, N., Andersson, E., Artmann, M., Borgström, S., Breuste, J. & Elmqvist, T. (2014). A quantitative review of urban ecosystem service assessments: concepts, models, and implementation. *Ambio*, 43(4), 413-433.

¹⁵² Peh, K. S.-H., Balmford, A. P., Bradbury, R. B., Brown, C., Butchart, S. H. M., Hughes, F. M. R., et al. (2014). Toolkit for ecosystem service site-based assessment (TESSA). Version 1.2, Cambridge, UK. <http://tessa.tools/>

- The Natura toolkit was developed for assessing the socio-economic benefits associated with the ecosystem services of 200 conserved or protected sites in Europe¹⁵³.

Numerical models are practical tools that predict how ecosystem services change through time and space, are increasingly being **used to support decision-making**. These models are often developed when data availability is scarce, when spatially explicit information is needed, and to assess trade-offs among services under alternative future management scenarios.

- The Integrated Valuation of Environmental Services and Tradeoffs (InVEST) suite is a free and open-source software tool to help inform and improve natural resource management and investment decisions¹⁵⁴.
- The Lund-Potsdam-Jena managed Land Dynamic Global Vegetation and Water Balance Model (LPJmL) is a tool that was not specifically designed for ecosystem service assessment, but still allows deducing a number of ecosystem services consistently from the same process-based model¹⁵⁵.
- The ARTificial Intelligence for Ecosystem Services (ARIES) can be used to model supply, demand (delivery), flow (the link between the areas of supply and those of delivery), depletion (the balance between supply and delivery), and values (differential preferences among stakeholders) of ecosystem services¹⁵⁶. To improve fit to diverse application contexts, the methodology is assisted by model integration technologies that allow assembly of customized models from a growing model base. By using computer learning and reasoning, model structure may be specialized for each application context without requiring costly expertise¹⁵⁷.
- The Ecosystem Service Trade-off Analysis (ESTA) was initially developed to inform and evaluate the trade-off between biodiversity and fisheries and has been applied to an increasing number of case studies with a range of ecosystem services, including offshore wind and wave energy, aquaculture, and ecotourism¹⁵⁸.
- The Multi-scale Integrated Models of Ecosystem Services (MIMES) platform is designed to address the magnitude, dynamics, and spatial patterns of ecosystem service values¹⁵⁹.
- Co\$ting Nature is a web-based tool for natural capital accounting and analyzing the ecosystem services provided by natural environments (i.e., nature's benefits), identifying the beneficiaries of these services and assessing the impacts of human interventions¹⁶⁰.

¹⁵³ Kettunen, M., Bassi, S., Gantier, S. & Ten Brink, P. (2009). Assessing socio-economic benefits of Natura 2000: A toolkit for practitioners. Brussels, Belgium: Institute for European Environmental Policy (IEEP). http://ec.europa.eu/environment/nature/natura2000/financing/docs/benefits_toolkit.pdf

¹⁵⁴ Tallis, H. T., Ricketts, T., Guerry, A. D., Wood, S. A., Sharp, R., Nelson, E., et al. (2013). InVEST 3.0.0 user's guide. Stanford, USA: The Natural Capital Project. http://ncp-dev.stanford.edu/*dataportal/invest-releases/documentation/3_0_0/

¹⁵⁵ Bondeau, A., Smith, P. C., Zaehle, S., Schaphoff, S., Lucht, W., Cramer, W., et al. (2007). Modelling the role of agriculture for the 20th century global terrestrial carbon balance. *Global Change Biology*, 13, 679–706.

¹⁵⁶ Bagstad, K. J., Villa, F., Batker, D., Harrison-Cox, J., Voigt, B., & Johnson, G. W. (2014). From theoretical to actual ecosystem services: mapping beneficiaries and spatial flows in ecosystem service assessments. *Ecology and Society*, 19(2).

¹⁵⁷ Villa, F., Bagstad, K. J., Voigt, B., Johnson, G. W., Portela, R., Honzák, M., & Batker, D. (2014). A methodology for adaptable and robust ecosystem services assessment. *PloS one*, 9(3), e91001.

¹⁵⁸ White, C., Halpern, B. S., & Kappel, C. V. (2012). Ecosystem service tradeoff analysis reveals the value of marine spatial planning for multiple ocean uses. *Proceedings of the National Academy of Sciences of the USA*, 109, 4696–4701.

¹⁵⁹ Altman, I., Boumans, R., Roman, J., Gopal, S. & Kaufman, L. (2014). An ecosystem accounting framework for marine ecosystem-based management. In: M. J. Fogarty & J. J. McCarthy (Eds.), *Marine ecosystem-based management. The sea: Ideas and observations on progress in the study of the seas* (Vol. 16, pp. 245–276). Cambridge, MA, USA: Harvard University Press

¹⁶⁰ Mulligan, M. (2015). Trading off agriculture with nature's other benefits. In: C. A. Zolin, R. de A.R. Rodrigues (Eds.), *Impact of climate change on water resources in agriculture* (pp. 184–204). Boca Raton, FL, USA: CRC Press.

- WaterWorld is a web-based tool can be used to understand the hydrological and water resources baseline and water risk factors associated with specific activities under current conditions and under scenarios for land use, land management and climate change¹⁶¹.
- Several existing process-based models linked to economic valuation methods are integrated into a geographic information system (GIS) platform to measure the ecological factors contributing to the provision of certain services^{162,163}.
- The GIS framework (Polyscape) designed to explore spatially explicit synergies and trade-offs amongst ecosystem services to support landscape management includes algorithms to explore the impacts of land cover change on flood risk, habitat connectivity, erosion and associated sediment delivery to receptors, carbon sequestration and agricultural productivity. Changes in land management can be input to the tool and “traffic light” coded impact maps produced, allowing visualization of the impact of different decisions. Polyscape hence offers a means for prioritizing existing feature preservation and identifying opportunities for landscape change¹⁶⁴.
- The Integrated Economic-Environmental Modeling (IEEM) Platform linked to ecosystem services modeling (ESM) is an innovative decision-making framework for exploring complex public policy goals and elucidating synergies and trade-offs between alternative policy portfolios¹⁶⁵.

4.7.3.2 Digital solutions

Creating digital platforms for ecosystem building is an essential strategy of digital transformation as it can produce network effects and externalities in digital space, similar to those deriving from spatial proximity in physical space. As a result, both spatial and digital network effects lead the development of externalities that play a key role in the formation, expansion, and sustainability of ecosystems¹⁶⁶. ***Bringing ecosystem services indicators into spatial planning practice could be done through collaborative development of a web-based visualization platform***¹⁶⁷. The creation of a series of maps created using field-based or remotely sourced data, data-driven models, and socio-economic scenarios coupled with rule-based assumptions can help to shed light on the complex relationships between ecological and social systems¹⁶⁸.

A ***Big Data ecosystem framework***, in contrast to existing frameworks that are technical and bottom-up, is a generic framework with the ultimate objective of meeting the “end-user needs” and considers broad

¹⁶¹ Mulligan, M. (2015). WaterWorld: a self-parameterising, physically based model for application in data-poor but problem-rich environments globally. *Hydrology Research*, 44, 748–769.

¹⁶² Grêt-Regamey, A., Bebi, P., Bishop, I. D., & Schmid, W. A. (2008). Linking GIS-based models to value ecosystem services in an Alpine region. *Journal of environmental management*, 89(3), 197-208.

¹⁶³ Dai, X., Johnson, B. A., Luo, P., Yang, K., Dong, L., Wang, Q. & Yao, Y. (2021). Estimation of Urban Ecosystem Services Value: A Case Study of Chengdu, Southwestern China. *Remote Sensing*, 13(2), 207.

¹⁶⁴ Jackson, B., Pagella, T., Sinclair, F., Orellana, B., Henshaw, A., Reynolds, B., ... & Eycott, A. (2013). Polyscape: A GIS mapping framework providing efficient and spatially explicit landscape-scale valuation of multiple ecosystem services. *Landscape and Urban Planning*, 112, 74-88.

¹⁶⁵ Banerjee, O., Bagstad, K. J., Cicowiez, M., Dudek, S., Horridge, M., Alavalapati, J. R., ... & Rutebuka, E. (2020). Economic, land use, and ecosystem services impacts of Rwanda's Green Growth Strategy: An application of the IEEM+ ESM platform. *Science of the Total Environment*, 729, 138779.

¹⁶⁶ Komninos, N., Kakderi, C., Collado, A., Papadaki, I., & Panori, A. (2020). Digital Transformation of City Ecosystems: Platforms Shaping Engagement and Externalities across Vertical Markets. *Journal of Urban Technology*, 1-22.

¹⁶⁷ Hayek, U. W., Teich, M., Klein, T. M., & Grêt-Regamey, A. (2016). Bringing ecosystem services indicators into spatial planning practice: Lessons from collaborative development of a web-based visualization platform. *Ecological Indicators*, 61, 90-99.

¹⁶⁸ Fisher, B., Turner, R. K., Burgess, N. D., Swetnam, R. D., Green, J., Green, R. E., ... & Balmford, A. (2011). Measuring, modeling and mapping ecosystem services in the Eastern Arc Mountains of Tanzania. *Progress in Physical Geography*, 35(5), 595-611.

socioeconomic issues such as regulating, cultural and supporting services and drivers of change¹⁶⁹. Recent developments in machine learning have expanded data-driven modelling (DDM) capabilities, allowing artificial intelligence to infer the behavior of a system by computing and exploiting correlations between observed variables within it (e.g. Weka or ARIES software). **Machine learning algorithms** may enable the use of increasingly available 'big data' and assist applying ecosystem service models across scales, analyzing and predicting the flows of these services to disaggregated beneficiaries. DDM has a clear role to play when modelling ecosystem services, helping produce interdisciplinary models and holistic solutions to complex socio-ecological issues¹⁷⁰.

Given the accelerating rate of urbanization worldwide, the sustainable provision of urban ecosystem services becomes increasingly important for the growing number of city dwellers. Attempts to increase a single ecosystem service however often lead to reduction or losses of others. For making sound decisions about sustainable urban development, knowledge and awareness of the interactions between ecosystem services are thus necessary. Interactive rulers embedded in a 3D GIS-based procedural modeling environment can assist in making urban ecosystem services trade-offs explicit for sustainable urban planning. The interactive rulers are slider bars that offer stakeholders the possibility to explore trade-offs in ecosystem services reflected in different urban designs¹⁷¹.

4.7.4 Conclusion

There is a huge amount of data and methods currently available to model and analyze ecosystem services. However, it is scattered and requires consolidation and reformatting to be useful. The current methods and models are not well equipped to handle large scale transdisciplinary analyses. There is a need for further development of integrated approaches, which considers all four types of capital (human, built, natural, and social), and their interaction at spatially explicit, multiple scales. This should be facilitated by adapting existing models and make them and their outcomes more accessible to stakeholders. Other shortcomings and caveats of models should be addressed by adding the 'human factor', for instance, in **participatory decision-making and scenario testing**. For integration of the models themselves, a more participatory approach to model development is also recommended, along with the possibility of adding advanced gaming interfaces to the models to allow them to be "played" by a large number of interested parties and their trade-off decisions to be accumulated and compared¹⁷².

A 'SMART' city strategy should aim to build on a uniqueness that can be enabled through tapping and connecting 'SMARTness' to the available assets and resources that enhance and complement the existing ecosystem¹⁷³.

¹⁶⁹ Ghazinoory, S., Nasri, S., Dastranj, R., & Sarkissian, A. (2021). "Bio to bits": the Millennium Ecosystem Assessment (MA) as a metaphor for Big Data ecosystem assessment. *Information Technology & People*.

¹⁷⁰ Willcock, S., Martínez-López, J., Hooftman, D. A., Bagstad, K. J., Balbi, S., Marzo, A., ... & Athanasiadis, I. N. (2018). Machine learning for ecosystem services. *Ecosystem services*, 33, 165-174.

¹⁷¹ Grêt-Regamey, A., Celio, E., Klein, T. M., & Hayek, U. W. (2013). Understanding ecosystem services trade-offs with interactive procedural modeling for sustainable urban planning. *Landscape and urban planning*, 109(1), 107-116.

¹⁷² Turner, K. G., Anderson, S., Gonzales-Chang, M., Costanza, R., Courville, S., Dalgaard, T., ... & Wratten, S. (2016). A review of methods, data, and models to assess changes in the value of ecosystem services from land degradation and restoration. *Ecological Modelling*, 319, 190-207.

¹⁷³ Josefsson, M. Y., & Steinhörsson, R. S. (2021). Reflections on a SMART urban ecosystem in a small island state: the case of SMART Reykjavik. *International Journal of Entrepreneurship and Small Business*, 42(1-2), 93-114.

4.8 Technological solutions for the economic development

Information and Communication Technologies (ICT) has become increasingly part of the economic life in the majority of the economies around the globe. By generating new technologies applicable to a wide range of sectors, including here the food sector, ICT plays a strategic role in the promotion of growth, innovation and competitiveness across economies with effects at macro as well as micro geographical level. Because ICT has the potential to improve productivity in a multitude of industries and sectors and thus boost economic development, it is often considered a general-purpose technology. ICT is able to improve productivity in several ways: by increasing the amount of capital deployed per worker, by speeding up the aggregated productivity of an economy due to technological improvements, and as an enabler of products, processes and organizational innovation¹⁷⁴. Productivity directly influences the economic aspects, but the advantages of ICT within the food chain can go far beyond. However, as network-based technology, its economic impact and benefits generated are strongly dependent by the number of users and to the extent to which the different ICT technologies are integrated in the market and further within regions and or countries. USA, EU, China, Japan and India are the countries with the biggest market share on ICT¹⁷⁵, accounting together for three quarters of the total market.

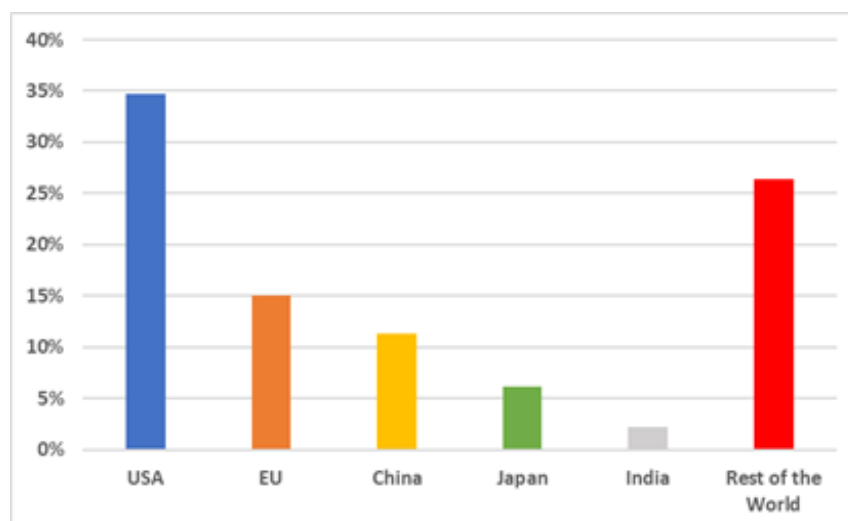


Figure 20 – Countries with biggest CT market share 2021¹⁷⁶

The European position on the ICT market is a strong foundation on which further economic development can be built, but overall access to capital and strategic investments in innovation are further needed. Within last decades a growing scope of ICT application, a rapid technological progress, an increase competitive pressure and a decrease in price in the production of key ICT technology (e.g. computer equipment, semiconductors) have been registered. This has made an attractive frame for investment in ICT which generated a constant and high growth¹⁷⁷.

Actually, investments in Information and Communication Technologies (ICT) are seen as a key driver of productivity and economic growth. The relationship between ICT and economy has been extensively studied, the majority of studies showing the productivity effect of ICT as positive and economically significant. Already

¹⁷⁴ Rhiel Matthias, 2018, ICT, Productivity and Economic Growth Empirical Results on Country Level, Dissertation, Technische Universität Darmstadt

¹⁷⁵ Mlitz Kimberly, 2021, Global ICT market share by country 2013-2021, Statista 2021

¹⁷⁶ Mlitz Kimberly, 2021, Global ICT market share by country 2013-2021, Statista 2021

¹⁷⁷ OECD 2004, The Economic Impact of ICT- Measurement, Evidence and Implications, OECD Publications Service

in 2012, the World Bank have taken an optimistic view stating that “Information and communication technologies (ICTs) have great promise to reduce poverty, increase productivity, boost economic growth” [4]. The figure below shows an overview of ICT investment across different countries.

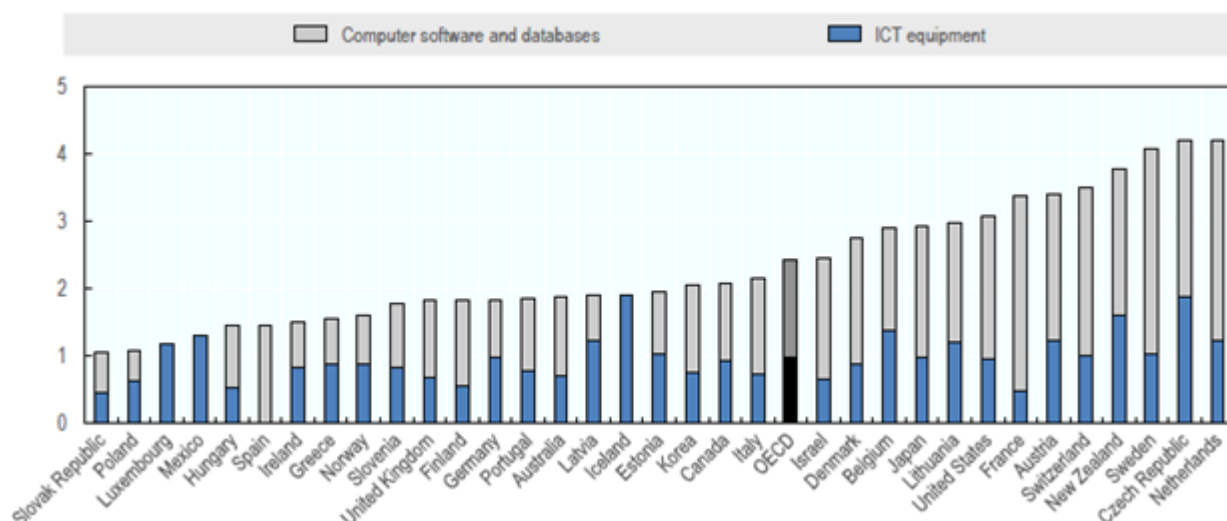


Figure 21 – ICT investment shares in GDP 2017 or latest (source OECD 2019)¹⁷⁸

The ICT investment, relative to GDP (gross domestic product), has a very different economic profile across countries. Usually developed countries possess a higher economic profile of ICT than developing countries. Even so the developing countries are lagging behind with the ICT sector, they are having the opportunity of adopting directly (from developed countries) state of the art technologies and Best Practices for business and regulation strategies. The magnitude of the ICT impact on the economic development is dependent of the capacity to attain certain level of conventional capital and public infrastructure within a region and/or country. Further since economic growth has an exponential behavior, even small rates of annual growth can have large effects through compounding on long term¹⁷⁹.

The ICT applications and diffusion across countries have been strongly accelerated by the occurrence of internet connections and mobile technology¹⁸⁰. Nowadays, companies in their majority are using ICT related devices and have an internet connection as part of their daily business. Actually, presently it is hard to imagine activities such as buying, selling, outsourcing of goods and services without the use of a computer or other sort of network device. ICT technology may offer large potential benefits for a company especially related to information flow and productivity. The increasing use and importance in today's society made from ICT as one of the largest industries in the world with further growth perspective for the future. The ICT market is forecasted to reach a size of over five trillion dollars in the next years¹⁸¹. The ICT, comprise technologies related to computer and telephone networks, but also their related hardware, software and services. Presently the highest revenue generating ICT branch is still the telecommunications, even so this branch had a relatively slow growth within the last years, in comparison to other ICT branches. However, in

¹⁷⁸ OECD 2019, ICT Investments In OECD Countries and Partner Economies: Trends, Policies and Evaluation, OECD Digital Economy Papers April 2019 No. 280

¹⁷⁹ Detschew Stefan, 2007, Impact of ICT in the developing countries on the economic growth, Diplomarbeit, Technische Universität Ilmenau (Institut für Wirtschaftswissenschaften).

¹⁸⁰ Jorgenson D.W., Vu K.M. (2016), The ICT Revolution, World Economic Growth, and Policy

¹⁸¹ IDC ,Global ICT Spending, Forecast 2020-2023; IDC Corporate USA

short future, this seems to be overcome by the spending in the new technologies branch of the ICT, which will reach \$1.3 trillion by 2023¹⁸².

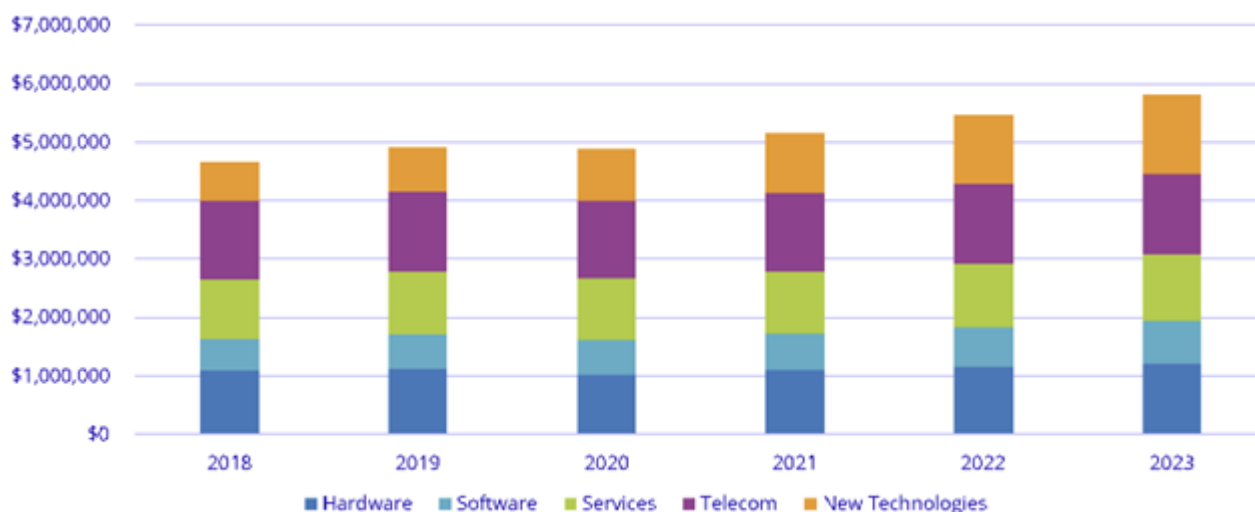


Figure 22 – Worldwide ICT spending (source: IDC Corporate USA)

Cloud, social and big data/analytics as well as mobile, represent the main platforms on which the growth in the traditional ICT technology spending is attributed for the next years. Cloud and automation are important contributors to cost savings and therefore are registering a constant increase, especially diverted toward new technologies such as AI, robotics, AR/ VR and blockchain together with the next-gen security related to them. Furthermore, due to a rapid growth of mobile and IoT users the traffic data increased 100 time in the last 10 years¹⁸³; and this does not seem to stop, but contrary. For example, by 2023 it is predicted that the number of people having a mobile device will increase with almost 40% reaching a total number of 7.33 billion¹⁸⁴. This will generate enormous amount of data and will require high-capacity connections. ICT technology namely 5G services might play here an important role with a 4,7 times higher capacity for data than 4G and 10.7 times larger than 3G. Under this context, mobile consideration as part of digital transformation strategy is a prerequisite for future development and for organizations to maintain their competitiveness, globally but also at CRFS level. In relation to food industry, beside food processing and management, there are also factors such as type of food, quality control, consumer trends and special requirements (e.g health), customer psychology, etc. that can influence the economic development and give rise to the need of ICT inclusion¹⁸⁵.

Consumers do increasingly use their handheld devices for shopping, so the streamline and the generation of positive experience is essential. Nowadays there is also a shift in consumer demands towards preferring fast, affordable, easily accessible but also environmentally friendly food options. This is leading more and more to a transformation of the food and beverage industry, where adoption of ICT such as AI and machine learning are increasingly adopted by companies to remain competitive. Such ICT technologies goes all the way from food production optimization to packaging as well as to safety and environmental sustainability. By turning

¹⁸² IDC ,Global ICT Spending, Forecast 2020-2023; IDC Corporate USA

¹⁸³ Clark Joe, 2017, Cisco: By 2021 more people will have smartphones than running water, TECHMONITOR

¹⁸⁴ www.bankmycell.com , article by Ash Turner

¹⁸⁵ Kakani V, Nguyen V.H, Kumr B.P, Kim H. , and Paupuleti V.R, 2020, A critical review on computer vision and artificial intelligence in food industry, Journal of Agriculture and Food Research, vol 2, Elsevier B.V.

intelligence into clear actions it can generate exceptional economic benefits for the food systems with effects at micro and macro geographical level. It is expected that the spending on AI within food and beverage to have a tremendously tenfold increase (CAGR of over 45%) from a value in 2020 of USD 3.07 billion to almost USD 30 billion by 2026¹⁸⁶.

Furthermore, in line with the implementation of strong network and an increase number of users, e-commerce is steadily increasing and will influence the economic development of organizations. It is aimed that by 2025 almost half of the EU workforce as well as 70% of the industrial sites and 80% of the main logistic routes to be covered by 5G¹⁸⁷. This will strongly be favoring the e-commerce. In parallel to the expanded network the necessity of ICT solutions related to cybersecurity is also growing, more and more enterprises defining clear ICT security policies. In Europe, there is still a strong difference with regard to e-commerce, especially between Western and Eastern regions, but the difference is likely to be reduced in the future by a fast and solid growth from the East side. Some East European countries (e.g. Romania) are registering in the last years a growth of more than 30 % / year on e-commerce. Growth at that rate can only occur in a market that is not yet mature and as a result, there is likely to be many years of solid growth and indeed catching up for Eastern European markets – and therefore for the total of European e-commerce¹⁸⁸. However further investments in technology adoption and the creation of innovative eco-systems enhancing innovation in areas like AI, IoT, 5G are crucial. Having in mind the necessity to boost innovation it is expected that by 2025, 10% of total EU Research & Innovation spending to be targeted at ICT technologies (almost one third more spending than for example in 2016). Another important aspect of digital transformation capable to deliver economic growth within CRFS, but not limited to, is related to the manufacturing sector. Manufacturing sector despite that is having currently in Europe the highest concentration of robots is also comprising 36 million jobs; every new job in manufacturing creates 1,5 -to 2 jobs in other sectors. Automation is necessary for increasing quality and productivity, majority of manufactures (over 80 % globally) planning to adopt some sort of machine learning by 2022. Automation analysis is performed in near-real time, and makes use of machines and computers, instead of relying solely on people. In contrast to what is generally believed, automation is foreseen to create more jobs than it will displace (overall 58 million more jobs than it will displace). While long-range studies vary in their predictions, virtually all of them outline a net positive outlook for jobs; from 1,8 new jobs per job disrupted all the way to 3,74. Thus at CRFS level, as similar to other systems/sectors, automation can be seen as a strong technological solution that can boost job creation and economic development. However, especially in the manufacturing factor massive reskilling of workers will be required in order to adapt with digital transformation. This can be seen as a challenge for the educational system with potential effect on the dynamic of economic growth of CRFS. The manufacturing sector is strongly present within the food system, with a high proportion especially in food processing.

¹⁸⁶ Mordor Intelligence, 2020, Artificial Intelligence (AI) in Food & Beverages Market - Growth, Trends, Covid-19 Impact, And Forecasts (2021 - 2026)

¹⁸⁷ DIGITALEUROPE, A stronger Digital Europe, Our Call to Action towards 2025

¹⁸⁸ White Nick, 2019, How European E-Commerce Is Catching Up To The Rest Of The World, BUSINESS COMPUTING WORLD

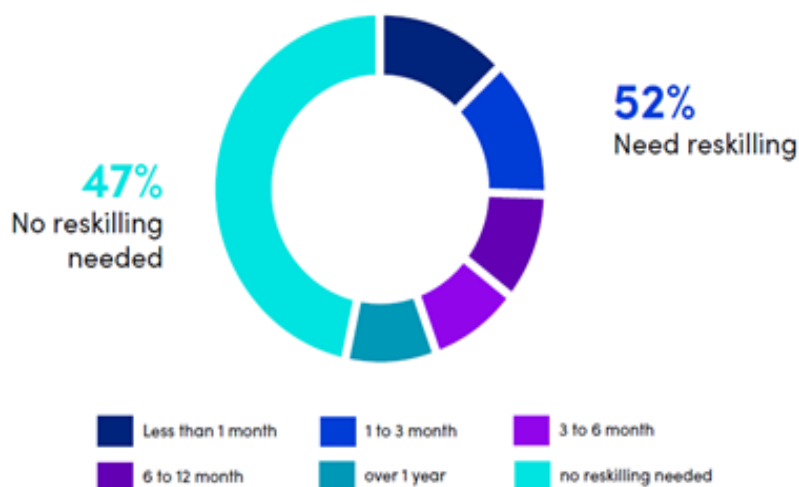


Figure 23 – Workers (%) in need of reskilling (source :DIGITALEUROPE)¹⁸⁹

In contrast to automation and machine learning adoption perspectives, big data analytics, is still underused, despite its strong economic potential. Only aprox 11 % of the European manufactures are using it currently leaving thus place for a strong growth. CRFS can take economical advantage of this technology, and evolve from a relatively rigid knowing based system to a continuous improving and more adaptable one, by uncover the hidden patterns, correlations and also providing insights for proper economic decision making. The big data analytics growth is projected to be relatively fast happening, for example by 2025 already 30 % of the European manufacturing industries being expected to implement big data analytics. Big data analytics is a suitable tool for the companies to boost business, research and identify consumer trends and reduce expenses. The food industry and agriculture have an immense worth and generates enormous amount of data, which, if processed and analyzed, provides an evident and strong economic advantage, which can obviously be transposed and explored at CRFS level.

Even more, big data analytics combined with further specific ICT technologies (e.g. radio-frequency identification-RFID), capable to track inventories all the way from primary production to selling, it can ensure the specific optimal condition during transport and storage, provide product traceability and minimize product loses (especially for perishable product)¹⁹⁰.With the growth of e-commerce across food economies, besides the ICTs previously mentioned, ICT used for tracking and managing of primary production and the subsequent food products (e.g. food products of animal origin) increase also in necessity (especially within CRFS context) and influence on economic figures (reduced costs, increase consumer protection, improve customer satisfaction, product transparency and traceability, sales increase).

Within CRFS context, all in one, ICT can have high potential for economic development and contribution towards the sustainability of agro-food systems, with positive impact on multiple sectors such as agriculture and primary food production, food processing, distribution and consumption. For maximizing the economic benefits of ICTs within CRFS, the necessary investment in infrastructure must be complemented by actions in policy and innovation that can promote the development and integration of relevant, affordable, convenient and locally appropriate ICT solutions.

¹⁸⁹ DIGITALEUROPE, A stronger Digital Europe, Our Call to Action towards 2025

¹⁹⁰ The importance of ICT in food security A Technology Watch Report, 2009, ITU's Telecommunication Standardization Bureau

4.9 Data-driven food security solutions

Global environmental change, loss of biodiversity, hydrology changes, and climate patterns changes resulting from enhanced anthropogenic emission of greenhouse gas emissions, have serious consequences for food security, especially for vulnerable groups. Other problems, such as land erosion, arable land aluminum toxicity, are also huge problems that affect whole system security. Growing population and urbanization also has to be taken into account when discussing supply and demand for food and the flow of the goods as an integral part of food systems.

The scenarios such as COVID-19 virus pandemic, which caused global lockdown is the most recent example which points out the necessity to have more flexible but durable food system management solution for any variable destabilization in food system. These kinds of unplanned situations bring to light a need for holistic approach towards food management systems. To get insight of pieces that make the system, let's take a closer look on some different approaches towards food system's variables.

The food chain approach is now well established to identify the nature of the actors involved, and the roles they play in different food system activities. Food systems can be described as five sets of activities - producing food, processing food, packaging and transporting food, retailing and consuming food. -These activities lead to a number of outcomes, many of which contribute to food security, and others which relate to environmental and other social welfare concerns.

The food systems approach can be helpful to identify the importance of considering multiple scales and levels in food security analysis. Although studies focus on local area to research food systems and conclusion can be dependent on locality of resources (e.g. water resource distance) some alterations can be done and same model can be used in model replication in different localities. This is because food system vulnerabilities are linked across scales and levels; vulnerabilities in different aspects of the same food system may be synergistic; and adaptation actions relating to one level on one scale may be enhanced or frustrated by factors at another scale or level. Globalization and global environmental change have changed the nature of many of these linkages, further increasing the prospects of unexpected outcomes and feedbacks. One example of putting together different stakeholders after facing global crisis is an international conference on "Food Security and Environmental Change" held at the University of Oxford in April 2008 which linked Science, Policy and Development for Adaptation¹⁹¹. The mission of the conference was to bridge disciplinary and well as policy science boundaries and issues. The 2008 conference covered a range of topics pertaining to environmental change and food systems and brought together over 230 scientists from more than 50 countries around the world. The conference addressed integration across the natural and social sciences, the importance of the regional level, and linking scientific research to development policy.

The major conclusion from the conference was that technical fixes alone will not solve the food security challenge, and the major environmental changes bringing additional threats to food security need a food system approach, not just a focus on agricultural practices.

Dozens of academic researchers have been conducted on food security and stability after the food price crises and its consequences in 2009, many of them suggesting development of holistic model for food management. Since 2008, computing power has increased scientifically and wide variety of IoT solutions has been developed which can now be deployed and be part of integral solutions for all problems identified in comprehensive problem analysis such as in "Food Security and Environmental Change" or smaller studies carried out on micro level. All said, main determination of food security to keep in mind are availability, safety, appropriateness, utilization, and transparency.

¹⁹¹ Proceedings of Food Security and Environmental Change: Linking Science, Development and Policy for Adaptation (GECAFS): <https://www.sciencedirect.com/journal/environmental-science-and-policy/vol/12/issue/4>

Another aspect of food safety is its safety in general. In order to be safe for consumption food usually has to be processed to increase the shelf life, enhance the bioavailability of critical nutrients in food, and destroy the toxic ingredient of food material. Food security is a wide spectrum of possible risks which can affect normal food production, food distribution and normal food diet in all groups of people.

4.9.1 Data collection for food security

Most common approach to food security measurement has been to use **aggregate data**. This type of data often suffers even greater measurement error, because gaps are filled by estimates, extrapolations and even with analysts' assumptions. Some scientific efforts have been invested in attempting to assess the quality of the food environment using aggregate data, but this data alone cannot be used as a representational numeric value of food security. Data collected in this manner should be used only as a part of the equation for food security management and early warning systems. To simplify the approach of aggregate data let's take a look into examples of basic aggregate values which can be used on EU and international level.

Agricultural prices and price indices¹⁹² are data sets issued by Eurostat. Apri_pi contains quarterly and annual data on agricultural price indices and annual data on absolute prices and agricultural land prices and rents. The agricultural price statistics provide information on the development of producer prices of agricultural products as well as of the purchase prices of the goods and services consumed by agriculture in the production process.

On the international level, most used indexes are FAO Food Price Index¹⁹³, used as an indicator for "global" food prices. It usually consists of 5 commodity group price indices (cereals, meat, dairy, sugar and oils). Consumer price indexes (CPI) are based on data collected from household expenditure surveys. Such indexes are obtained as a weighted average of the domestic prices of a set of items included in representative consumption baskets for various aggregates (total consumption, food and beverages, housing, etc.). PPI - purchasing power index is another similar price index for food security measurement which is not used as frequently as above-mentioned indexes due to unfrequented data collection rounds and public publications.

Eurostat also provides key statistics around agriculture¹⁹⁴: *Agricultural products* include **food supply annual data** shown in physical units (number, weight, quantity) for land use, livestock, crop production, meat, milk and milk products production and activity of hatcheries. This data can be **useful for decision making and food security improvement** when analyzing developments in agricultural markets and how they respond to policy actions, for ensuring quality in food and animal feed and animal welfare and health and for actions in case of serious animal diseases or human health risk due to agricultural products. *Structure of agricultural holdings* - summarizes the main data in the Eurofarm database and contains the results of Community surveys on the structure of agricultural holdings, i.e., labor force, size of holdings, land use, livestock, subsistence farming. *Structure of orchards* contains data on the plantations of seven species of fruit trees: dessert apples, dessert pears, peaches, apricots, oranges, lemons, and small-fruited citrus fruits; certain information is also available on cooking apples and cooking pears. *Economic Accounts for Agriculture* shows detailed results of the income generated by agricultural activities over a given accounting period. Values for output, input, gross value added, subsidies and taxes are available in current and constant prices. *Structure of vineyards* contains the results of surveys of areas under vines (basic, every 10 years, and intermediate, annually).

¹⁹² Price indices of agricultural products (apri_pi): https://ec.europa.eu/eurostat/cache/metadata/en/apri_pi_esms.htm

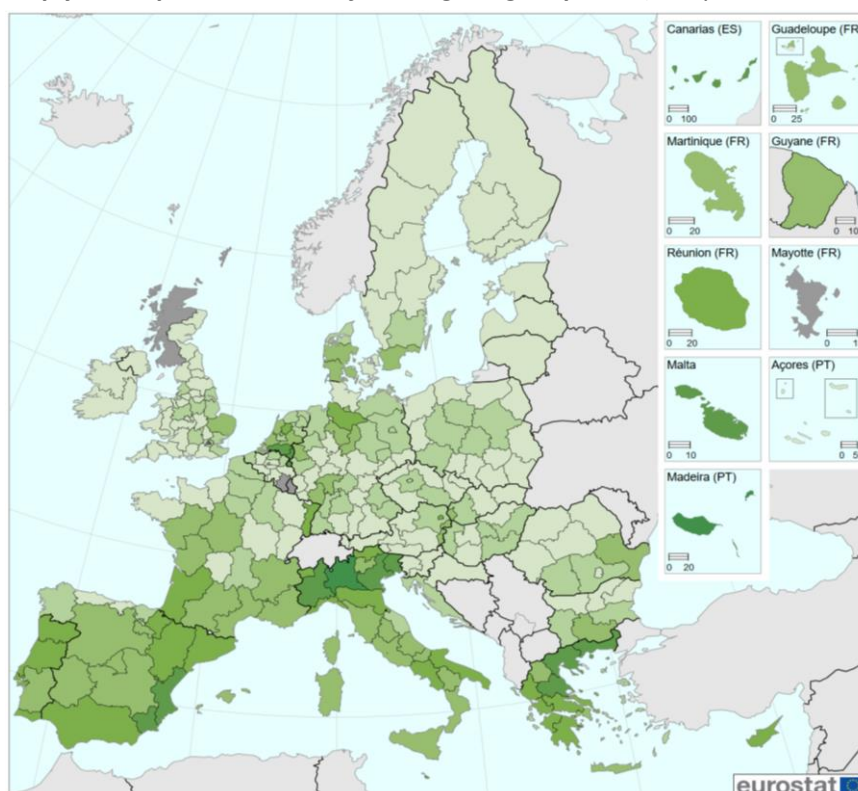
¹⁹³ FAO Food Price index: <http://www.fao.org/worldfoodsituation/foodpricesindex/en/>

¹⁹⁴ Eurostat agriculture - <https://ec.europa.eu/eurostat/web/agriculture/data>

On international level there are the two main sources of food availability that are global in scope are FAO's **Food Balance Sheets (FBS)**¹⁹⁵, and the **Production, Supply and Demand Online system**¹⁹⁶. These databases provide estimates of yearly production, trade and utilization of agricultural commodities, at the level of single countries and by territories. By compiling complete accounts of supply and utilization of food commodities, both systems provide yearly assessment of food available for human consumption in the country as a whole, in a specific year.

This kind of (aggregated) data can be useful for policy and decision makers as tool for channelizing subsidies for different foods producer's groups who are recognized as underdeveloped as well for food producers which can use this data for benchmark competition and other food sectors in order to switch to different culture, analysis of production feasibility (e.g., purchasing power of potential buyers and levels of demand for specific goods, buying habits etc.).

From production point of view there are biotic, abiotic and organizational production risks which threaten the security of agricultural production can significantly decrease the food production and can lead to food supply shortage for general population, but also, due to increase of food prices, can lead to food shortages especially to vulnerable groups like the one with low incomes. Frosts, hails, heat waves are more and more common climate events which affect food production. Pest pressure which are more and more frequent due to monoculture, low biodiversity and pesticides with narrow spectrum of action. **Data on availability of phytopharmaceutical products, availability of water for irrigation** (irrigated areas and groundwater), **soil type and quality, electric grid, gas supply, road network etc. can be mapped and be used as input tools for productivity and crop yield expansion as well for mitigating crop loss** (as a prediction tool).



¹⁹⁵ FAO's Food Balance Sheets: <http://www.fao.org/faostat/en/#data/FBS/metadata>

¹⁹⁶ United States Department of Agriculture: <https://apps.fas.usda.gov/psdonline/app/index.html>

Figure 24 – Cap indicator “Share of irrigated area in total UAA” in 2016, of EU 27 countries¹⁹⁷

On the other side, government (from country to regional and city level) has to have active role in food security and has to keep in mind all variables (political, social, cultural, knowledge, infrastructure, (macro)economic, climate, disease outbreak, policies, programs, conflicts, technology, food environments, legal systems, ethical values) that affect food security by analyzing them and adapting to new situation in case of change. There is a lot of issues regarding production food security which must be considered when trying to achieve stable food supply to general population. Policy and decision makers should be interested in:

- a) data concerning the differences within states regarding certain security production standards (e.g. percentage of orchards protected with anti-frost and anti-hail nets, percentage of agricultural production covered with irrigation). So, the database of such information is valuable, especially on a city level due to very limited amount of subsidies for agriculture producers which has to be allocated in the most efficient way to help.
- b) Policy makers should be interested to see whether all farmers within the EU have the same tools for production regarding availability of pesticides. It is common that certain states have their own regulations regarding pesticide registrations which leads to the situation that farmers within the EU don't have the same tools to protect their crops.
- c) Regarding b), common databases describing which pesticides are forbidden in which states would enable policy makers to rethink if certain pesticides should be still allowed.
- d) Producers would be interested to share the solutions to certain production challenges they are facing. Such data sharing would decrease the danger of food loss within agricultural production.

Presence of pesticides on food is primary due to respecting the waiting period from spraying to harvest. MRL analysis shows if the presence of pesticides is within allowed reference values. Number of different active substances of the pesticides should be also monitored. Usually, market chains have their own standards regarding MRL's and the number of allowed active substances.

- a) database of food analyzed on pesticides. Periodic food analysis to pesticides not only from market chains, but from city markets, from institutional supply (kindergartens, hospitals, schools etc.)
- b) monitoring if imported food is treated with certain pesticides which are forbidden in domestic agriculture. It is important to be fair both to consumers and to domestic farmers.
- c) Overview of pesticide standards for different market chains like Lidl, Aldi, Hofer, Kaufland.

Food security issues regarding nutrition are also as follows: obesity, hunger, low share of fruit and vegetables in nutrition, so government should have an overview of institutional food supply: percentage of fruit in diet (kindergartens, schools, hospitals), percentage of vegetables in diet etc., using updated algorithms from practice such as The Food Variety Score (FVS) or Household Dietary Diversity, Index (HDDI), a count of the number of different food items consumed in the past week; The Dietary Diversity Score (DDS), a count of food groups consumed. The Food Frequency Score (FFS), a sum of food groups that integrates the frequency of consumption of each food group. The Food Consumption Score (FCS), which adds to the FFS by weighting food groups based on their nutritional quality. There are other indicators such as HFSSM, ELCSCA, HFIAS, HSS, CSI, HDDS, IY CDDS, WDDS, IDDS or FCS which can also be taken into account.

There are other aspects of food safety management system risks that can affect food security and could be taken into account are risks in shipping and transportation, rising demands placing pressure on continuity of supply (especially in time of crisis), changes in (trans)national and regional statutory regulations, mismatch in technological capabilities and market requirements, risks associated with product information misrepresentation and cyber-attacks.

¹⁹⁷ Eurostat: Irrigation: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Agri-environmental_indicator_-_irrigation

5 Stakeholders and beneficiaries

This fifth section opens the capture of information on requirements and expectations of end users (both internal and external to the Cities2030 project). As explained in the methodology section, this second phase begins with a preliminary stage of identifying potential stakeholders in the use of the S2CP platform. This section shows the results of such identification work by the Focus Group.

The new challenges of the contemporary society highlight the need for change or even transformation of the urban food systems. The impact upon environment, life quality, demographic challenges, healthy alimentation, social inequity are chapters of issues which need to be addressed and approached as smart/intelligent as possible by the urban environment. The intelligence of the intervention strategies and actions for changing/ transforming these systems is provided through integrating data collected from the immediate reality with scientific research, political vision and will, civic involvement, ethics of the economic environment, and last but not least, data driven digital transformation. To reach such an involvement degree of all these transformation poles in as integrated a manner as possible, it is necessary to actively engage the agents of transformation that play the role of stakeholders (agent meaning here that social role which brings a decisive contribution to the transformation of a system) and the social actors that play the role of beneficiaries (actor meaning here that role which contributes to the resilience of the system for maintaining the good practices).

In urban food systems, the ***stakeholders are the most important nodes and interfaces for a deep understanding of the system*** since they have a vast experience related to food systems and a latent knowledge (tacit knowledge) of these systems. Simultaneously, stakeholders are the most important vectors for food systems change and transformation. As owners of a tacit knowledge on food systems, they act as actors and contribute to the system resilience. Further, they enforce the system. As vectors of change, the stakeholders also play the so-called role of agents. When they are agents, the stakeholders take part in the process of innovation and renewal of the system.

In the process of data gathering and deep understanding of food systems, we view the stakeholders as actors, namely owners of a latent knowledge of the system. To get information on food systems, in the course of living and policy labs, ***essential data can be collected from the stakeholders through different methods of drawing them into the processes of co-creation and innovation***. In the following figure we can notice the most important ways of interacting with stakeholders for data collecting.

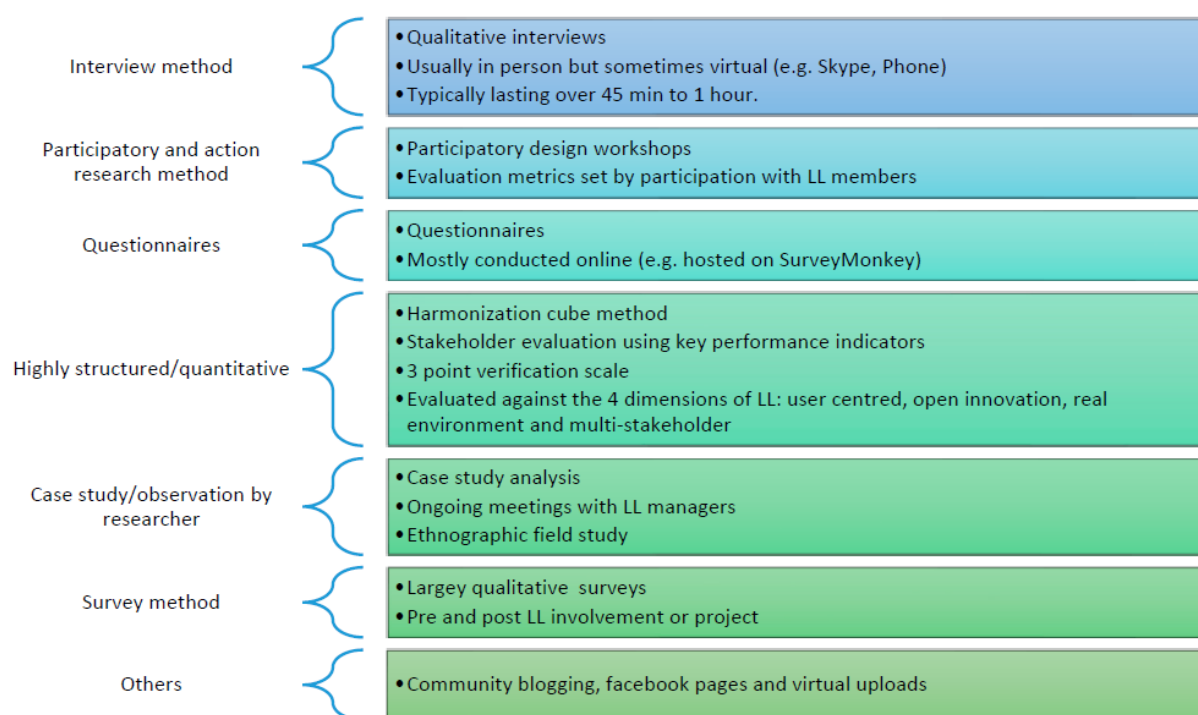


Figure 25 – Different approaches in collecting data from stakeholders¹⁹⁸

As it has been already mentioned earlier, when **stakeholders** act as vectors of change of food systems, they **play the role of system agents**. By embracing this role, they can take part in the process of innovation and change of food systems. Therefore, during the activities run in the living and policy labs, the stakeholders can be drawn in the process of understanding of the system and in the innovation process as well, for the betterment of the system.

CITIES2030 proposes a novel food system management framework that enables dynamic management of complex interconnected subsystems considering a cradle-to-cradle approach and connects all agents and stakeholders across the food supply chain enabling proactive co-creation and management (*Grant Agreement, PartB-p.12*). Simultaneously, CITIES2030 has a holistic approach which is also visible on the project platform incorporating data, software components, human actors, network topology, and device infrastructure (*Grant Agreement, PartB-p.14*). Further, the process monitoring will be integrated in a multimodal interface in the form of a dashboard with the aim that stakeholders can use this environment to compare the results of applying different processes or techniques to their data, and to monitor the performance of their solutions (*Grant Agreement, PartB-p.26*).

Regarding the expected results, CITIES2030 builds a service-based open collaboration space that facilitates interoperability between various stakeholders and services across systems. (*Grant Agreement, PartB-p.27*). For this purpose, CITIES2030 starts with building the CRFS Alliance community stakeholders across the food system arena, the inception of synergies with other networks and initiatives to plan a hosting program for the upcoming project's labs, and the set up and activation of the project digital collaborative platform (*Grant Agreement, PartB-p.35*). At the same time, in this context, CITIES2030 designs multi-device interfaces that facilitate access to ICT technologies to non-technological participants, for broader scope in the

¹⁹⁸ Bronson, K.; Devkota, R.; Nguyen, V. Moving toward Generalizability? A Scoping Review on Measuring the Impact of Living Labs. Sustainability. 2021. <https://doi.org/10.3390/su13020502>.

implementation of this type of technology in food systems across Europe. This technical work package facilitates the generation of impact on the project, according to the expected impact in the CE-FNR-07 call, **in which food systems policies and actions must be shared and compared among various stakeholders in order to increase the transferability of the food system model all over Europe** (*Grant Agreement, PartB-p.36*). A set of technological solutions will be provided in CITIES2030 to facilitate interoperability between various stakeholders and services across systems. These digital solutions will convert an individual or relevant need to a challenge to be solved in a collaborative way. Decision making processes and KPI comparisons will be collectively available among living labs, policy labs and other action groups (*Grant Agreement, PartB-p.42*). The CITIES2030 messages for the stakeholders will aim at increasing the visibility of the policy labs and living labs and their importance in the development of the sustainable CRFSs (*Grant Agreement, PartB-p.53-54*). Last but not least, CITIES2030 project has an inclusive approach. Project activities will forever support the women's assertion and their role played in the urban food supply chains. Within WP2 will be organized workshops with women entrepreneurs involved in urban food supply chains. Based on the cooperation of all partners involved in the project, a guide of good practices will be made for reducing and, hopefully, eradication of gender discrimination (*Grant Agreement, PartB-p.33*). In the following table we can see the categories of stakeholder considered by CITIES2030 project.

Table 6 - Categories of stakeholder considered by CITIES2030 project

Category	Subcategory	CITIES 2030 expected level of intervention
Entrepreneurs	Producers	Medium to high
	Processors	
	Distributors	
	HoReCa sector	
	Vendors	
Consumers	Individual consumer	Medium
	Family	
	Cultural communities of food consumption	
Governance	Local authorities	High
	Regional authorities	High
	National authorities	Medium
	EU norms and regulations	Medium to high
	Global treaties, recommendations and strategies	Low
Civil society	NGOs	High
	Local communities	Medium to high
	LAG's	High
	Churches	Medium to high
Academia	Universities	Low to medium
	Research institutions	
Knowledge brokers	Social media influencers	Medium to high
	Chef	

	Nutritionists	
	Physicians	
	Consultancy	

5.1 Direct and indirect beneficiaries

The beneficiaries of a project are those persons, communities, institutions, companies, or organizations which are directly or indirectly affected, in a positive way, by the activities, results, and deliverables of this project.

In CITIES2030 project, the direct beneficiaries are the following: CITIES 2030 partners, Stakeholders, Cities and regions. The indirect beneficiaries are as follows: Business environment, Citizens, Consumers, Farmers, Processors, Distributors, Retailers, Academia, Public authorities. CITIES2030 project aims at contributing (through its deliverable actions and results) to the beneficiaries' wellbeing and life quality in as sustainable and durable way as possible. Concurrently, the focus is also on raising awareness among beneficiaries so they can become stakeholders in their own food systems and thus contribute to the system development.

As one of the activities of task T3.7, and as part of the community building processes carried out in the frame of CITIES2030, a list of stakeholders has been contacted that includes project partners and other partners from their network involved in CRFS topics. To comply with GDPR aspects, in this public deliverable we will only mention the type of organization and the interest in the CITIES2030 project and in particular the technological tools that the S2CP platform could provide.

The following table describes this information. It is important to emphasize that these partners have been the primary source from whom the necessary feedback has been obtained for the preparation of the guidelines and the KPI indicators of the following sections.

Table 7 - Direct and indirect beneficiaries and their interest in CRFS management platform

Institution / Alias	Interest in CRFS management platform
Univ Politecnica de Madrid (P20)	Research interest. Looking for state of the art technologies to be applied to Urban Food Systems
Winery in Spain	Origin certification and fraud prevention of Food Supply Chains
Experts of green growth in Macedonia	Visualization and statistical analysis of data
UNIC - UNRF (P07)	Member of the consortium looking forward to using the platform
Union of Communities in Cyprus	Member of the project will use the platform
Social Innolabs (P19)	Multi-actor approach, representativity of stakeholders, assessment tools
Romanian Academy, Iasi Branch (P29)	Models of good practices in living and policy labs. Online databases on production, distribution, and food consumption. Digital tools for text analysis. Online surveys. Predefined questionnaires for consumer behavior. Mapping facilities.
Ca'Foscari UNIVE (P01)	Data Visualization
Primelayer (P37)	Spatial decision support based on city cartography

VE-GO-RA. Razvojna agencija, Croatia.	The possibilities and potential solution to develop an efficient and adaptable food management system
Quantitas SRL (P11)	CITIES 2030 Partner WP3 Co-leader
Latvian Rural Forum	Visualization and statistical analysis of data, representation of real-time data, origin certification and fraud prevention of Food Supply Chains.
Iasi Municipality	Visualization and statistical analysis of data, spatial decision support based on city cartography, representation of real-time data
Ayuntamiento de Quart de Poblet (P18)	CRFS Pilot city – Visualization and statistical analysis of data
Ruddersstove (LTP to P3)	Mealcare platform - personalizing meals for elderly people at home or in a residential care setting
Bruges (P03)	Visualization and statistical analysis of data, spatial decision support based on city cartography, representation of real-time data
ITC - Innovation Technology Cluster (P30)	Project partner - origin certification and fraud prevention of Food Supply Chains.
Kmetija Wernig, Slovenia	Origin certification of Food Supply Chains.
Zelena Točka (Green Point)	Visualization and statistical analysis of data, origin certification and fraud prevention of Food Supply Chains.
BIOZOOM GmbH (P17)	Interest in urban/ regional food systems and ecosystems
Gemeente Haarlem (P41)	Partner in Cities2030. Interested in the possibilities of data driven decision making in municipal policy
Institute for Environmental Studies, VU University Amsterdam (P33)	Test the platform as part of the consortium
AgFutura Technologies (AGFT) (P27)	Visualization and statistical analysis of data
City of Bremerhaven (P15)	Visualization and statistical analysis of data, spatial decision support based on city cartography, representation of real-time data.
Into Seinäjoki Ltd (P12)	Digital tool for companies and the city to enhance their dialogue - a supportive tool for the city to the innovative public procurement
Member of ministry of agriculture in an EU country.	High interest
Inventivna rješenja d.o.o.	Interest on S2CP platform
Association of Agriculture from Macedonia	Visualization and statistical analysis of data
University specialized in agriculture in Macedonia	Most of the functionalities mentioned above.
Matis ohf (P22)	Food science in general and sustainability specifically

KEG on Behalf of Small Farmers & Small Business owners	Visualization and statistical analysis of data, and origin certification and fraud prevention of Food Supply Chains.
KEG on behalf of Medium sized companies in the food sector	Visualization and statistical analysis of data, representation of real-time data, origin certification and fraud prevention of Food Supply Chains.
Municipality of Vicenza (P32)	Interest on IT technologies applied to food systems
Vejle Municipality (P10)	Support the development of actions towards sustainable CRFS - by supporting additional/ new types of data collection, analysis and representation in dashboards. Using the platform to support i.e. dialogue, awareness and ultimately decision making at the municipal level
TTZ (P16)	Interest in support platform for the development and implementation of CRFS.
EPC (P02)	EPC is involved in Cities2030 activities providing direct support to the coordinator in project management. Furthermore, it is also involved in WP3, WP4 and WP5 activities supporting the local partners in the implementation of policy and living labs.
Local Enterprise Office Laois	To see the potential of such a platform for food companies in Co. Laois.
Kilkenny County Council	Research interest
Future Food Institute (P23)	Evolve positive change, promote food innovation as a strategic element to achieve sustainable and impactful growth: leaner, quicker, rewarding. We aim to do this through our Living Labs, as they are spaces of community creations where we can shape more responsible food consumers, food and beverage entrepreneurs and employees, as well as policymakers.
RTU (P39)	Design and implement a new technological platform for City-region Food System

6 First contact with final users: initial questionnaire

The capture of information about the needs and expectations of those interested in the S2CP platform is a process, as explained in the methodology section, of certain complexity. For this reason, in order to avoid that the quantitative survey phase was not very decisive, and the answers were not very specific, the definition of a previous survey was proposed. This first initial questionnaire was sent to a select group with a high level of engagement in the Cities2030 project.

To carry out this selection, the end users integrated within the Focus Group (CRFS-focused partners) chose those stakeholders who showed a more active participation (whether they are agents internal or external to the project itself). A group of 10 interested parties was selected and the questionnaire was sent to them in Word format. The contact was established personally and through email.

The initial questionnaire consisted of 10 qualitative questions intended to be heuristically analyzed. The questionnaire was divided into two blocks of 5 questions, the first one dedicated to general questions about CRFS and the technologies currently used in the different settings; and the second one dedicated to those technologies already identified in the review of the State of the Art carried out in the first phase and which in the context of the Focus Group were identified as potential enabling technologies for the S2CP platform.

Deliverable D3.8 Guidelines for a data-driven CRFS management platform

Prepared by P20 | Edited by P5, P9, P10, P16, P17, P20, P21, P27, P29, P30, P37 | Checked and reviewed by EX COMM | Approved by P1

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The annex I contains the questionnaire that was used with the interested parties.

Through this initial questionnaire we were able to identify a crucial aspect within the concerns of the interested parties: cybersecurity, and the use, management, and governance of data. Therefore, it was essential that the quantitative survey not only addressed general aspects of their needs and expectations, or of the technologies already previously identified, but also other regulatory, cross-cutting security or data management and governance aspects.

Likewise, the initial questionnaire showed enormous interest on the part of all those interested in blockchain technology and artificial intelligence solutions. At this point it becomes clear that the future S2CP platform should include both enabling technologies as key points to achieve greater impact. In addition, the questions related to enabling technologies collected in the quantitative survey placed special emphasis on both technologies.

Other technologies, such as spatial-based services, were also of interest and were selected to be part of the survey.

On the other hand, many of the participants reported that generic office tools or specific software are still used for some operations (such as accounting), which can make it difficult to integrate all the data in the same decision-making panel. The quantitative survey should also address this aspect to investigate further.

Similarly, the initial questionnaire showed great heterogeneity in terms of data management in the different companies, and it is even possible that in some agents this data is not even digitized. There is also a great difference between agents in terms of the volume of data handled and in terms of their personal nature or not. The quantitative survey should also address these aspects in order to obtain more information in this regard. On the other hand, the platform, in order to reach all the agents of the different CRFS, should also incorporate (this seems clear at this point) mechanisms that allow the digitization of data or the transformation of data between different formats. As well as mechanisms to integrate different data sources in the same repository.

7 Stakeholders' information capture: quantitative survey

In view of the initial information collected on the end users through the initial questionnaire, at the end of the second phase of the work methodology, an exhaustive quantitative survey was designed, which sought to extract specific and relevant information on the end users, also with respect to the technologies already identified and in accordance with the goals and objectives set out in Cities2030.

In this section we explain both the design and analysis methodology of said quantitative survey, as well as the statistical analysis carried out and the conclusions that we have drawn from it.

7.1 Methodology: data capture and analysis

In order to generate the quantitative survey, and in view of the discussions and conclusions drawn by the Focus Group about the initial questionnaire, an open call was made to all the members of the Focus Group to propose those questions that they considered relevant. After the open proposal period, a first evaluation of the questions posed was carried out, trying to eliminate those that were repeated or were too similar to observe a relevant difference between them, and they proceeded to group them into different categories.

After this first curation of the content, the document with all the questions was distributed among all the members of the Focus Group for their discussion. The final discussion took place in an extraordinary meeting of the Focus Group with the sole objective of approving the final composition of the surveys.

In order to facilitate the subsequent statistical treatment of the results, and also to minimize the response time required to complete the survey, and therefore and thus maximize the number of participants, all questions were formulated in the affirmative form, to be responded using a Likert scale (scale from 1 to 5 where 1 means strongly disagree and 5 strongly agree). A space was also included to leave comments that would be analyzed separately and differently.

The annex II contains the survey that was used with the stakeholders.

The set of questions as they were distributed among all interested parties are included in 7.2 Results section. After the final approval of the set of surveys by the Focus Group, and given that in this case the target audience is much broader than in the case of the initial questionnaire, the questionnaire was implemented using an online tool, which allowed a simple distribution of the survey by electronic means and a subsequent collection of the answers automatically.

The survey was distributed to all stakeholders internal to the Cities2030 project, and distribution among external agents was delegated to end-user partners that were part of the Focus Group. The process began in a round lasting 15 days, after which a general reminder was sent to try to increase the number of responses, leaving a second phase of shorter duration and one week. After these 3 weeks of capture time, the target number of responses was achieved, so the data was analyzed.

To perform the data analysis, the responses were exported in spreadsheet format. This document was injected into two different analysis systems:

- On the one hand, the question dedicated to free comments was processed through word-cloud-based analysis system, which would allow locating those terms that were repeated more frequently and that therefore were of greater interest and relevance. The analysis was developed in two methodologies. In the first one the analysis was made on individual words, while in the second methodology the analysis was carried out on groups of words considering groups that could be equivalent.
- The rest of the questions were analyzed using a statistical procedure and the mathematical calculation tool Matlab. For this, the spreadsheets were imported into the corresponding workspace, and an analysis was carried out using the statistical libraries consisting of the calculation of the means and variances, as well as the representation of the responses in box-plot format. From the observation of these tables and the box-plots, the corresponding conclusions were drawn about the initial expectations of the users, and how these should be considered in the design of the platform.

7.2 Results

According to the designed survey, questions were structured into groups as follows: General questions, General Context and CRFS, Use of IoT technology, Off the Shelf Software vs Customized Software vs Bestpoke systems, Data and Data requirements, Data governance, Functionality Values, ICT technologies, Questions related to data protections, Digital Security, and Administrative Security. The following subsections will provide the set of questions, their statistical analysis and the discussion of results.

7.2.1 General questions

The questions related to the characteristics of the respondents have been analyzed individually, in terms of type of company to which they belong, size of the organization and the specific profile of the person in charge of answering the survey.

The type of company that has responded to this survey is **mostly a private company**. However, there are also 3 main types of organizations whose representation among the total of participants is similar and close to

7%: educational entities, non-governmental organizations, and public capital companies. The representation of other types of consortiums or freelancers is minority (does not exceed 3% aggregate).

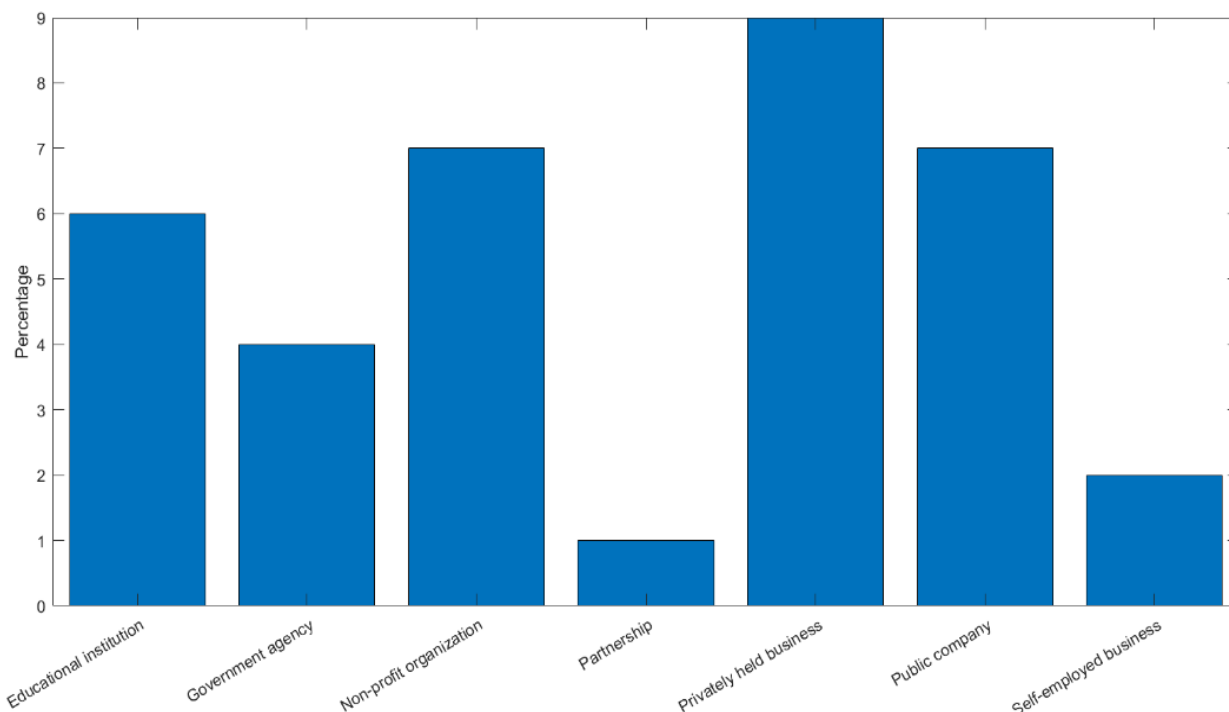


Figure 26 – Type of institution

Regarding the size of the organizations, however, small-sized companies predominate in a massive way (with a representation close to 14%). It can be seen that companies with less than 10 employees are the majority. The imbalance that occurs in the following group by size among those surveyed is very interesting, since both medium-sized companies (with between 11 and 50 employees) and large companies (with workforce between 1000 and 5000). By combining what is observed in the previous graph and in the current one, we can conclude that **the profile of the surveyed company with the highest representation in our sample is a small private company which is consistent with employability of companies in the EU** (Small and medium-sized enterprises employed two thirds of the active population in the EU-27's non-financial business economy in 2017)¹⁹⁹.

¹⁹⁹ https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Structural_business_statistics_overview

detected an overall interest regarding the provision of **tools for data analysis, data storage and visualizations**.

analysis city companies consortium consumer crfs data
decision develop dialogue digital element food functionalities
innovation interest involved labs living looking
making management mealcare member municipal online
partner platform policy possibilities potential
project research setting support sustainable
systems tool urban wp

Figure 29 – Word analysis provided by TagCrowd²⁰¹

Looking now at the specific profile of the person in charge of responding to the survey within the different participating organizations, there is a clear bias towards two profiles: the **management profile and the research profile, which is expected as most of the questionnaires end up with managers and researchers. On top of that in a small or medium business the owner / manager is the one making almost all decisions and other functions may not be available**. Between them they account for almost 25% of the total. The rest of the options are minority, including profiles that could be of great interest to the project, such as those in charge of urban development or members of the local government.

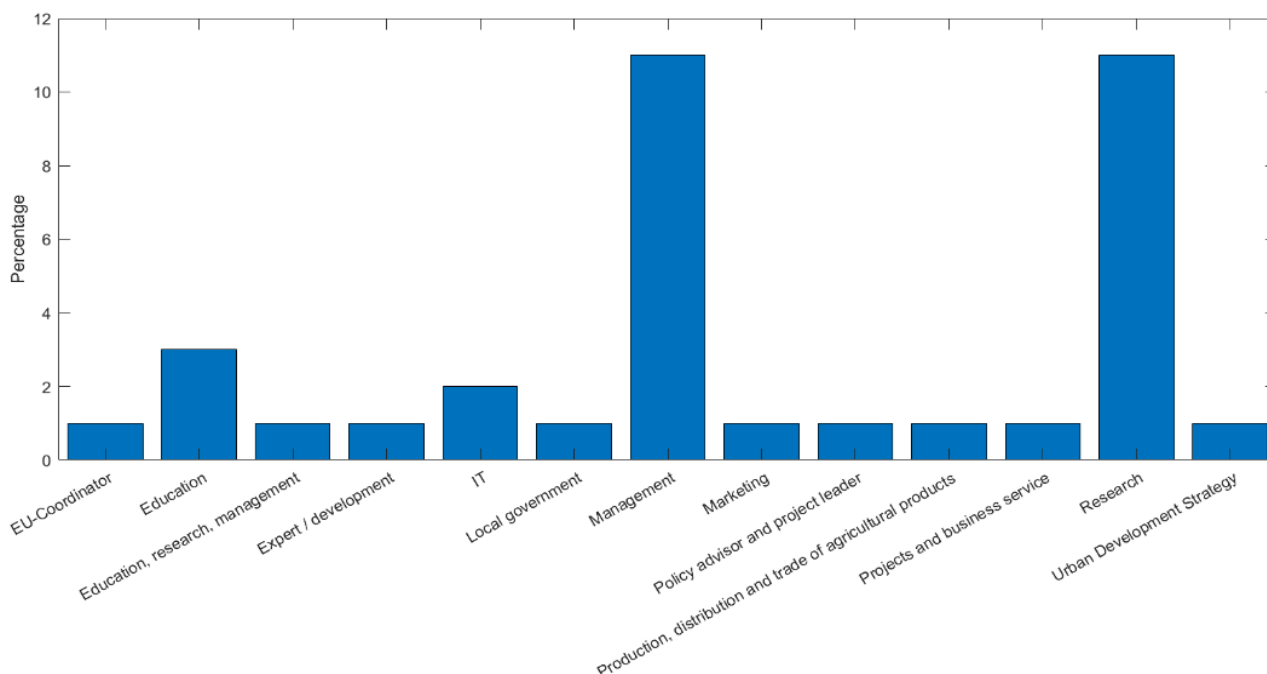


Figure 30 – Profile of respondents

²⁰¹ <https://tagcrowd.com/>

7.2.2 General Context and CRFS

ID	Question	Mean	Standard deviation
Q1	Our documentation should be organized in a single repository	4	0,78
Q2	Decision making is carried out based on non-technological technical reports	3,25	0,9
Q3	Our Information Technology systems are well structured and integrated	3,2	0,98
Q4	We often use qualitative criteria when describing business models	3,7	0,88
Q5	We would need guidance in data sharing	3,7	1
Q6	We believe that value (economic, social, research, etc.) is added when data is shared	4,4	0,6
Q7	The policies in my country enforce gathering of relevant data for food standards across the value chain.	3,5	0,92
Q8	As value chain actors we have access to high-quality data to guarantee food safety	3	1
Q9	CRFS consumers have access to data that assures food safety	3	1
Q10	A marketplace with local products would provide benefits to the regional environment and establishment of the regional short food supply chain	4,3	0,7

As can be seen in this first block of questions, there is general agreement regarding the importance of digitization and the use of data in the New Economy. Most of the people who responded to the survey express the value they recognize in sharing data and making decisions based not on qualitative measures but on quantitative observations. Respondents also value the possibility of accessing higher quality data, which also allows the generation of new local markets to which they recognize the potential to improve the general economic structure of the region where they are located.

Consequently, the platform must be focused on the **management and processing and visualization of data**, with the aim of allowing objective **decision-making**, and the definition and creation of **new local markets** capable of competing with large international markets and platforms.

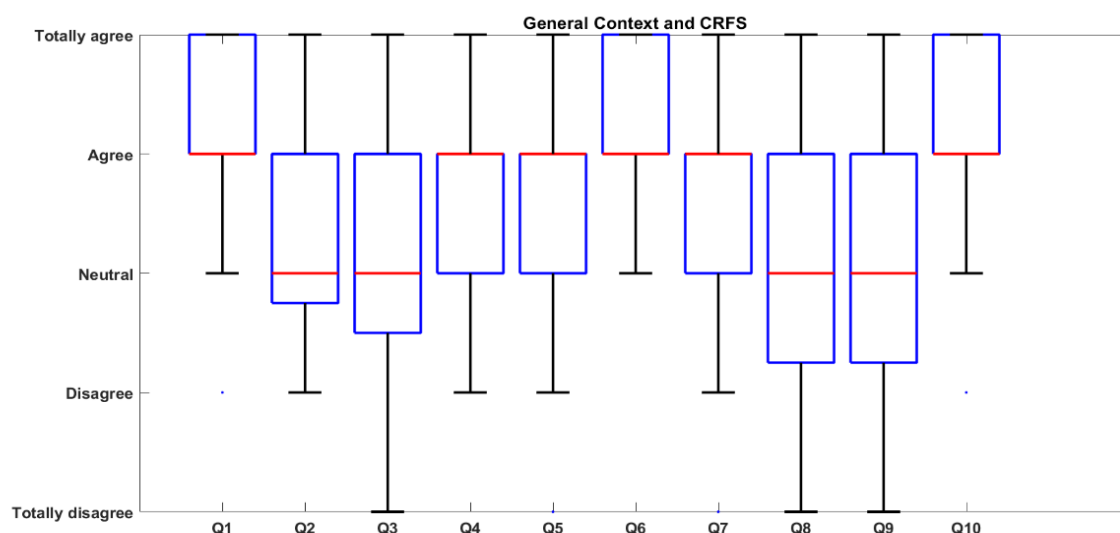


Figure 31 – General context and CRFS box-plot

7.2.3 Internet of Things (IoT) technology

In our CRFS, the use of Internet of Things (IoT) technology can bring benefits to:

ID	Question	Mean	Standard deviation
Q1	In our CRFS, the use of Internet of Things (IoT) technology can bring benefits to farmers	4,4	0,56
Q2	In our CRFS, the use of Internet of Things (IoT) technology can bring benefits to business	4,3	0,64
Q3	In our CRFS, the use of Internet of Things (IoT) technology can bring benefits to consumers	4,3	0,66

From the analysis of the second block of questions, it can be deduced the great value and importance that the surveyed agents recognize to current systems such as the Internet of Things, in the context of increasing the benefits for all possible agents within a CRFS: both consumers as industry as producers. This is to be expected given the proliferation of internet applications especially for mobile units such as smartphones and tablets.

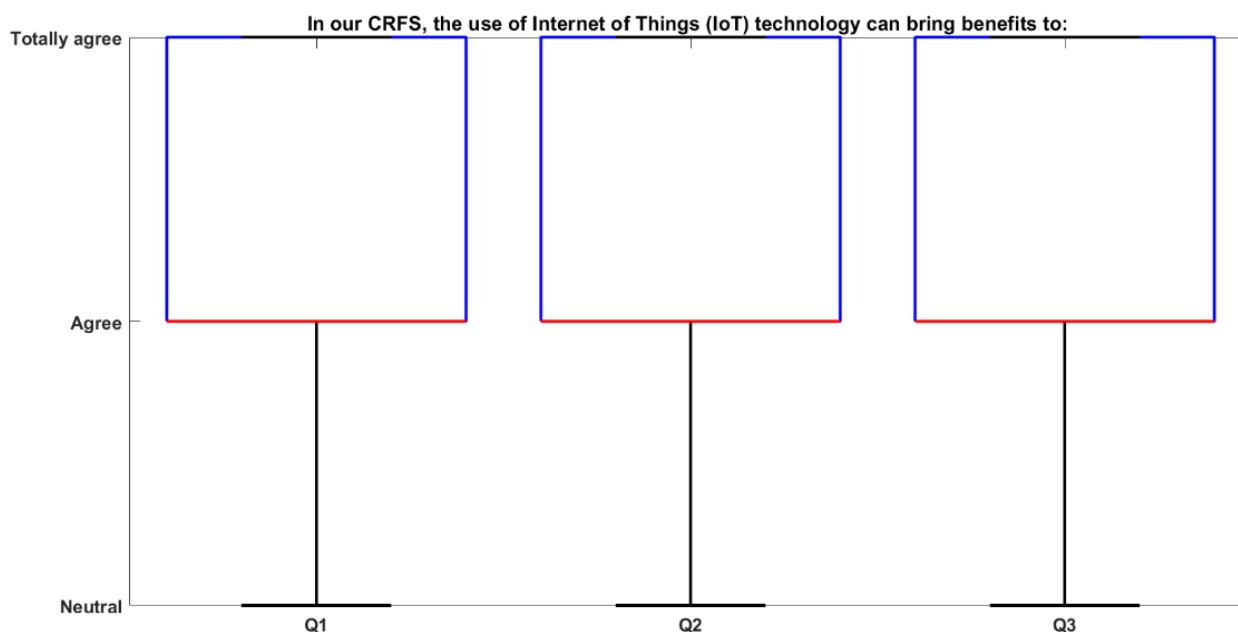


Figure 32 – Use of IoT technology box-plot

7.2.4 Off the shelf vs customized software vs bespoke systems

We prefer off the shelf software to run

ID	Question	Mean	Standard deviation
Q1	Accounting and Finance	3,2	1,1
Q2	Marketing and Sales	3	0,89
Q3	Production	2,9	1,1
Q4	Personnel	3,2	0,92

In the third block of questions, we analyze the value and preferences of users regarding the use of commercial software for their operations in different areas. As we can see, **there is no clear preference for this type of pre-packaged software**, except perhaps for accounting operations in which it is interesting to have an update on the latest tax regulations. In other areas closer to the business level, there is a neutral opinion about the interest and value that these types of solutions provided.

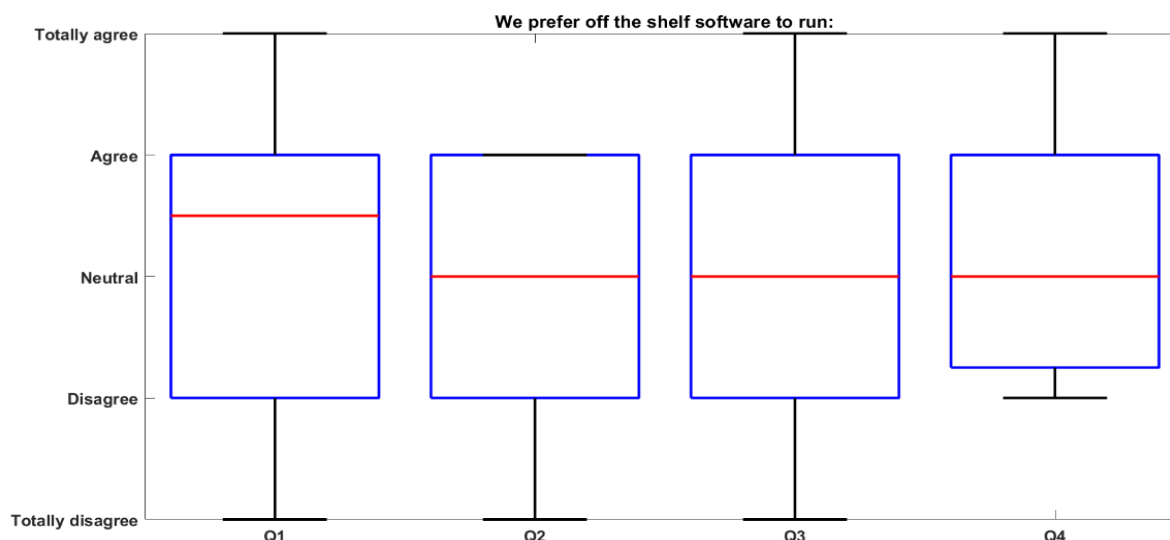


Figure 33 – Off the self software box-plot

We prefer customized software to run:

ID	Question	Mean	Standard deviation
Q1	Accounting and Finance	3,6	0,95
Q2	Marketing and Sales	3,6	0,9
Q3	Production	3,6	0,9
Q4	Personnel	3,4	0,77

On the contrary, in the fourth block of questions in which we investigate the value and preferences of users regarding the use of customized software, that is, commercial software adapted to the needs of users, we can see how there is a clear agreement on the value and necessity of this type of software for business operations. Customized software offers several advantages such as lower distribution cost, fewer bugs and the flexibility to adapt to their own needs

It would therefore be of interest if the proposed platform were based **on fully known commercial software and standards**, which should be adapted to each of the users and specific use cases in order to maximize their value and interest. This will probably make a lot of sense because adopting commercial software and standards will be easier and less risky.

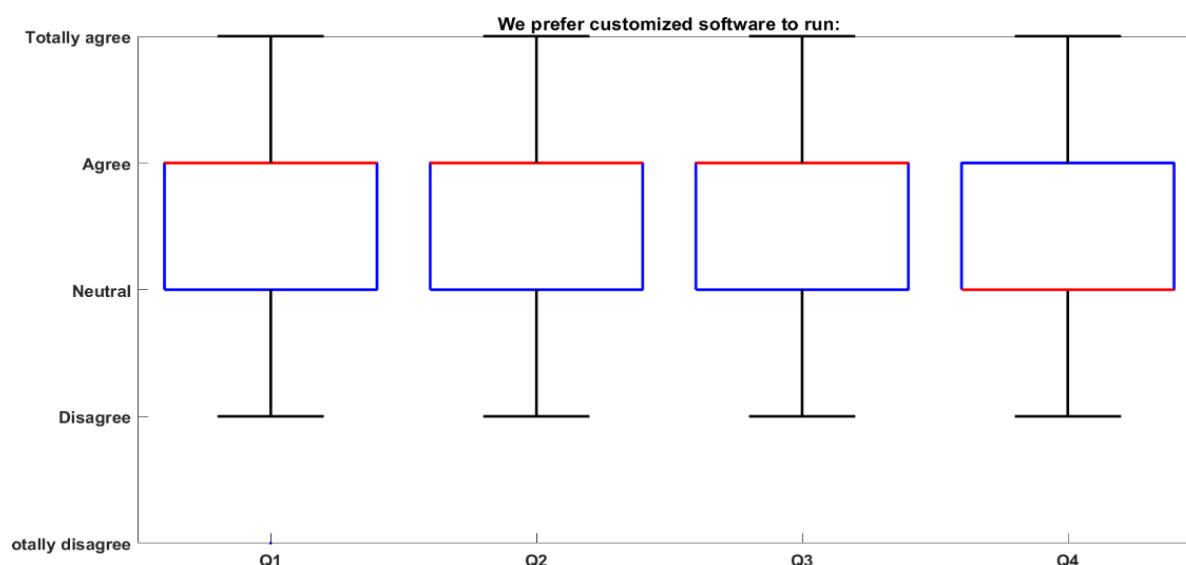


Figure 34 – Customized software box-plot

We prefer bespoke systems to run:

ID	Question	Mean	Standard deviation
Q1	Accounting and Finance	3,4	0,93
Q2	Marketing and Sales	3,5	0,93
Q3	Production	3,7	1
Q4	Personnel	3,2	0,83

In the last of the sections, in the fifth block of questions, we observe how the different agents value the use of software specifically designed for their use cases and needs. As we can see, most of the people who responded to our survey do not see the need to use software specifically designed for them in any of the areas of operation considered. **Only in the case of production activities, it seems that a certain predisposition to the use of specific software is observed.**

The same, however, can be achieved through greater personalization and customization of commercial software following the line described in the previous section where users have more clearly highlighted the **value of customized systems.**

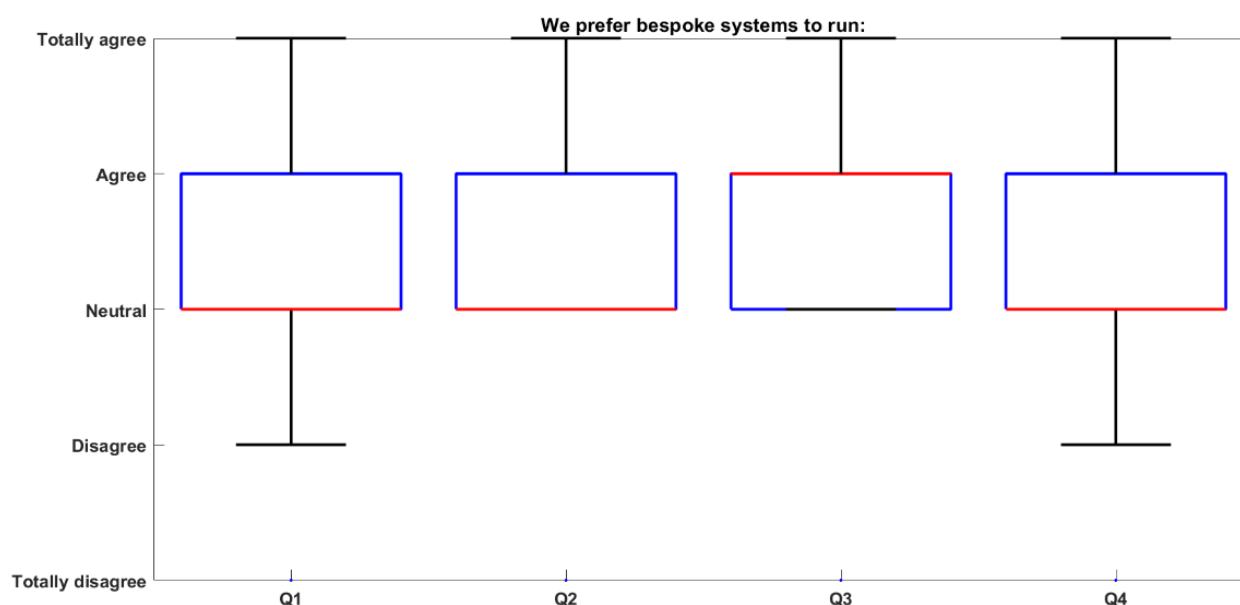


Figure 35 – Bespoke systems box-plot

7.2.5 Data and data requirements

ID	Question	Mean	Standard deviation
Q1	We deal with data from different data sources (weather station data, pest management data, ...)	3,7	1,1
Q2	Often have to access data sources that are difficult to store or process	3,7	1,1
Q3	We manage datasets in multiple formats	3,8	0,8
Q4	Farmers keep good quality data regarding the agricultural processes	3,8	1
Q5	We provide data to other entities	3	0,9
Q6	In my organization and CRFS, the information we need for decisions is located and easily accessible	3,6	1
Q7	The data flow we manage is low (less than five transactions/messages per hour)	2,7	1,1
Q8	Our applications and data are stored on our servers	3,1	0,9
Q9	Our applications and data are stored on the cloud.	3,9	1
Q10	We can record enough relevant data (number of pesticides, fertilizers used) in food production	3,3	0,9

Regarding the block of questions focused on data and its requirements, we can observe how, in a majority, the agents who have responded to the survey report that they handle **large volumes of highly heterogeneous data located in repositories distributed in multiple locations**. Furthermore, it is reported

that the different agents are capable of collecting highly relevant data for the rest of the agents in the value and supply chain. We can also see how there is a double path of equal importance and value by which the applications that the different agents run are in the cloud while the data remains stored in their own facilities. The fact that all agents report the need for decision-making systems to be agile and easily accessible stands out. The possibility offered by most of the respondents regarding their ability to **share the data they store with other agents in the CRFS** is also very interesting.

Consequently, the proposed digital platform must be capable of handling very heterogeneous data sources located in different locations. To respect the management of the data that organizations maintain right now, the platform must be able to **consume data remotely stored in the own facilities of the different end users**. A **highly accessible and intuitive visualization environment** should also be proposed to facilitate decision-making and data analysis.

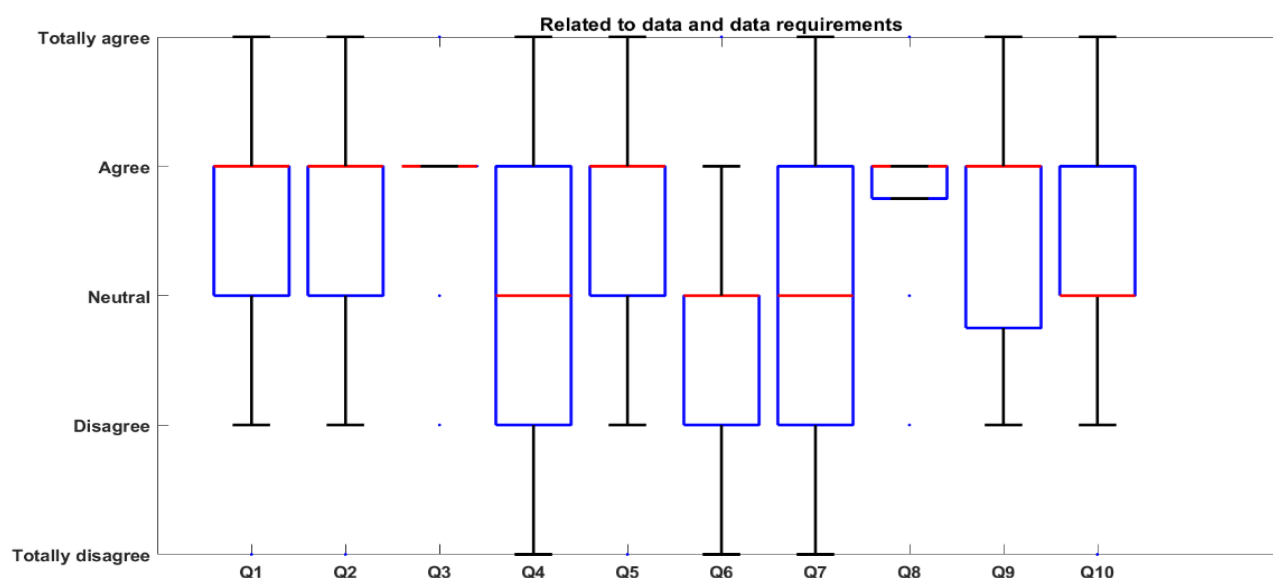


Figure 36 – Data and data requirements box-plot

7.2.6 Data governance

ID	Question	Mean	Standard deviation
Q1	We have implemented a data governance policy	3,5	0,92
Q2	Data access control is clear to all parties	3,3	0,87
Q3	The data access history is registered and available to authorized users	3,3	0,98
Q4	CRFS actors receive value from data sharing	3,5	0,8
Q5	CRFS actors are aware of their data sharing obligations via contractual agreements	3,1	0,89
Q6	We are aware of trust related aspects connected to data sharing	4	0,67

Q7	CRFS actors in the value chain have access to the relevant data	3,2	0,85
Q8	Stakeholders have access to data pertaining to their function.	3,2	0,9

In the seventh block of questions, we focus on the analysis of data governance and its implementation in different organizations. We observe how data governance is a capital issue in most organizations nowadays, with policies and governance mechanisms implemented in most of them. In addition, it highlights the concern about issues related to trust in the handling and treatment of data, and the relationship that this has with data governance and data possession.

It is evident that most of the organizations participating in the study are aware of the importance of maintaining appropriate data governance schemes and in accordance with European directives. Consequently, the digital platform will need to consider **data governance policies**, especially to **comply with European standards and with concerns about trust issues expressed by end users**. Considering also what was studied in relation to data driven food systems in Section 4, together with what was also seen in the same section with respect to other political aspects such as social development, we can begin to observe a platform in which the governance of the data was developed using innovative technologies such as blockchain.

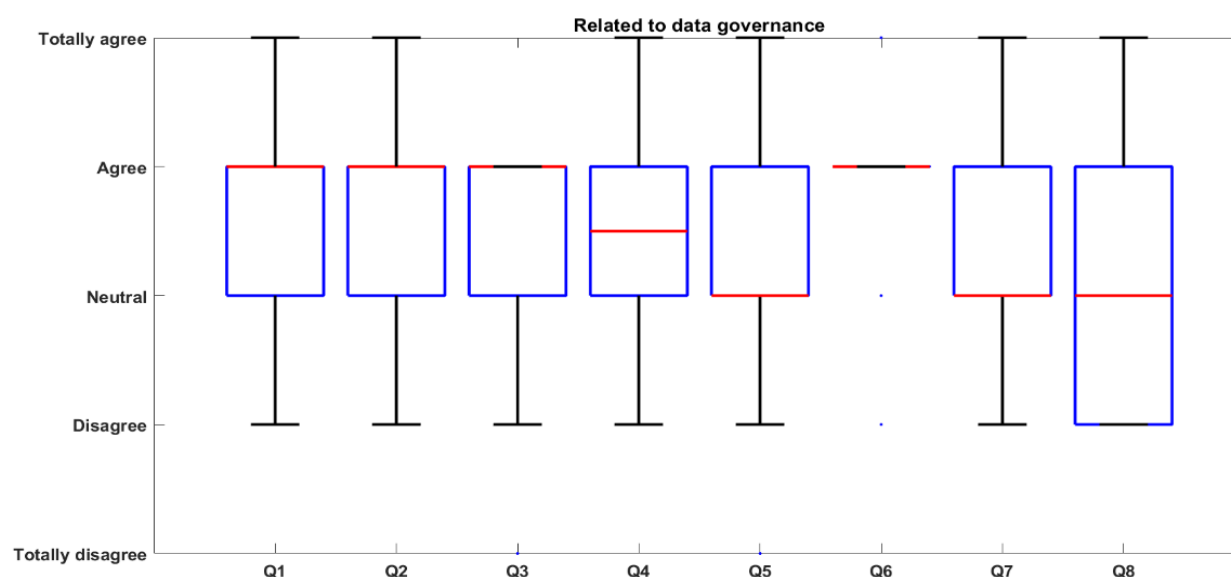


Figure 37 – Data governance box-plot

7.2.7 Functionality values

We can see a value in...

ID	Question	Mean	Standard deviation
Q1	We can see a value in a CRFS management platform for data collection, analysis and representation	4,5	0,56
Q2	We can see a value in visualizing and analyzing statistical data from our (and other) CRFS	4,5	0,56

Q3	We can see a value in a decision support tool based on city-region cartography	4,2	0,71
Q4	We can see a value in a marketplace for optimization of multi-stakeholder dialogue processes	4,2	0,63
Q5	We can see a value in representing real-time data for CRFS monitoring	4,1	0,8
Q6	We can see a value in certifications of origin and fraud prevention of food supply chains	4,4	0,54
Q7	We can see a value in translating interfaces into my local language	4,3	0,68
Q8	We can see a value in a reliable and easy system to track our products through the supply chain	4,4	0,61
Q9	We can see a value in a system to track food waste in the supply chain	4,4	0,66
Q10	Real time visualization applications (using data from sensors and other real-time sources) are important	4,3	0,56

In the eighth block of questions, in which the value that the different functionalities expressed in the technological guides could have for the different participating users is analyzed, the answers are very positive. As can be seen, all users value very positively and agree on the great value that any of the planned functionalities would bring to their systems and companies. We highlight the relevance given to the functionalities related to the acquisition and processing of data, to the visualization of data, and to the traceability functionalities, especially throughout the entire value chain. The preference of the users on their needs is very clear and focused with very high means and small standard deviations.

For this reason, the digital platform should focus its efforts precisely on **data capture and analysis functionalities, as well as information visualization tasks**. It should also include a component dedicated to the **monitoring and traceability of products throughout the value chain** due to the great interest that this arouses. The rest of the planned components are validated, and their interest demonstrated thanks to the great reception they suffer from the participants in the survey.

The proposal is also consistent with the most cutting-edge technologies analyzed in Section 3, and which are endorsed by their broad application in the different scenarios related to the CRFS defined by FAO. Technologies such as geographic systems, blockchain or artificial intelligence for data processing and discovery of hidden patterns, have a high added value, a high innovation factor and a high impact on users and European societies.

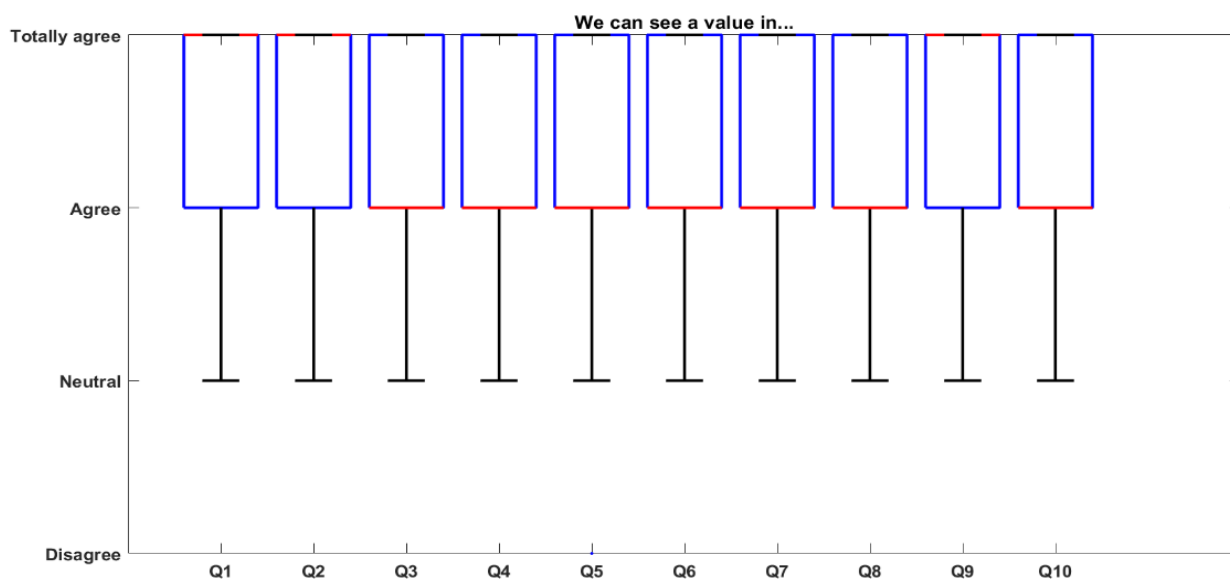


Figure 38 – Functionality values box-plot

7.2.8 ICT technologies

ID	Question	Mean	Standard deviation
Q1	We use a Geographic Information System (GIS) to make decisions	3,2	0,95
Q2	We know the advantages of Artificial Intelligence and machine learning for better information capture.	3,6	0,86
Q3	We prefer mobile applications over desktop/web applications	3,2	0,94
Q4	We prefer a tailored-based GIS frontend platform than a standard service.	3,3	0,74
Q5	We would use Earth Observation imagery and services (satellite data, drones) if available.	3,7	0,85
Q6	We often use GDrive and similar cloud solutions for exchanging data and documents.	3,5	1,22

Regarding the ninth block of questions, it focuses on analyzing the use that different companies currently make of information and communication technologies. As can be seen, all the aforementioned technologies receive great interest from the respondents. Both the systems based on geographic information and the most current information processing systems based on artificial intelligence are widely valued by the respondents.

Therefore, the digital platform proposed must include components that **process geographic information and offer a visualization** for said data, such as components focused on **information processing based on artificial intelligence techniques**, as well as its corresponding visualization.

According to what was studied in Section 4, the use of these technologies is transversal to all application scenarios in the context of CRFS.

Users' preferences for **multiplatform applications based on web solutions** are also observed, so it would be reasonable for the future digital platform to be based on this type of technology.

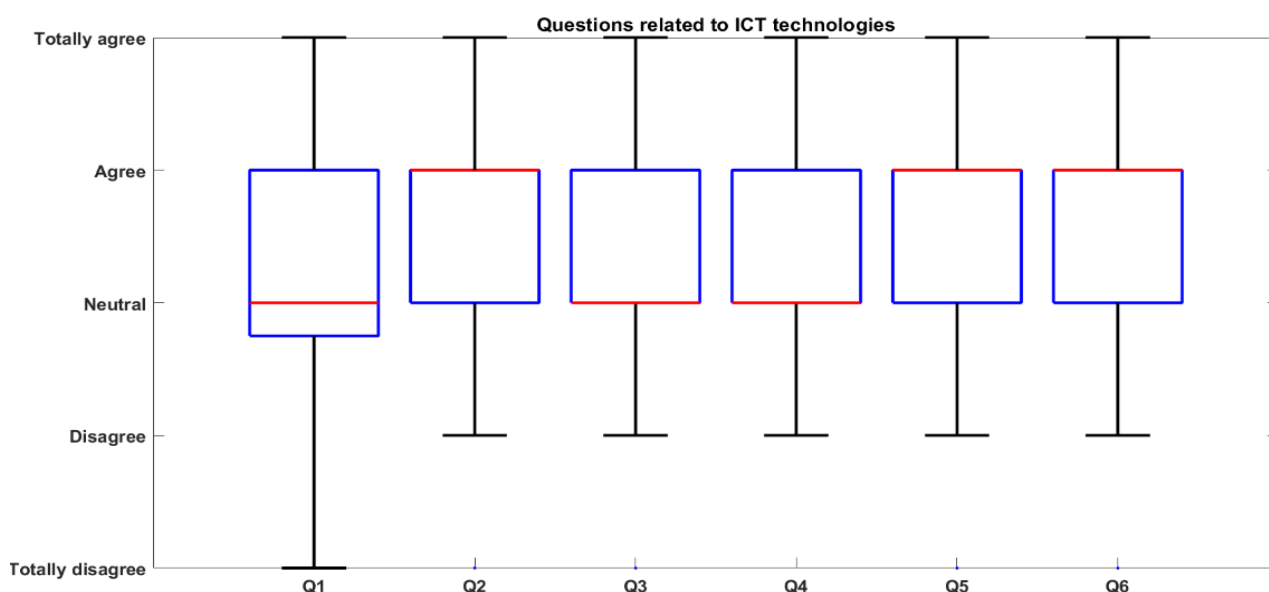


Figure 39 – ICT technologies box-plot

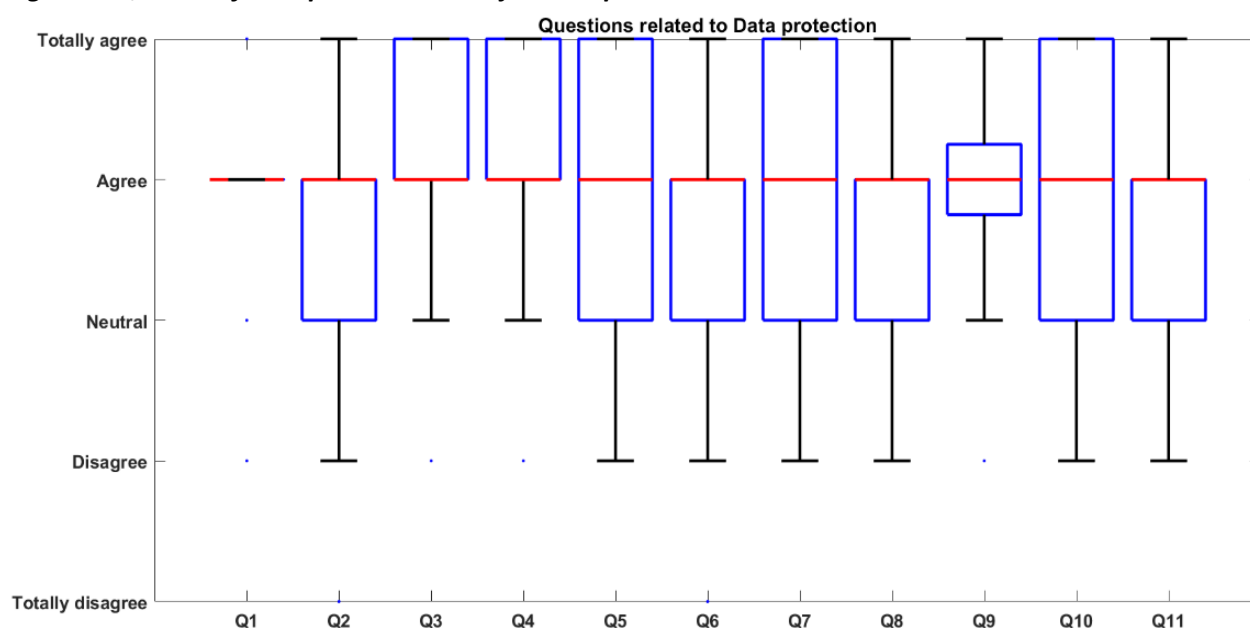
7.2.9 Questions related to Data protection

ID	Question	Mean	Standard deviation
Q1	We have defined roles and not all people are allowed to access all systems and data	3,9	0,79
Q2	We generate sensitive data (personal information, health-related data, trade-union membership, racial or ethnic origin, political opinions, etc)	3,5	1,1
Q3	We are well informed about GDPR regulations	4	0,87
Q4	We manage personal information protected by GDPR or sensitive data	4	0,74

Q5	All sensitive data is secured (in storage and when transmitted) and backed up on a routine basis	3,9	0,97
Q6	We anonymize on a standard basis all sensitive data we are working with	3,5	1
Q7	All employees are expected to know and follow company rules about GDPR	3,9	1
Q8	All data is saved on a general repository (server)	3,7	0,92
Q9	We consider our server for data storage safe	3,9	0,83
Q10	There is a high awareness about the importance of data security	3,9	0,93
Q11	Open data (freely available to everyone to use and republish as they wish, without restrictions from copyright, patents) is important for us	3,9	0,83

The block related to Data Protection in the different organizations shows once again a huge awareness regarding the problems related to personal data. Most of the respondents consider that they have a high level of concern and awareness regarding the importance of data security and consider that their organizations implement adequate mechanisms to comply with European legislation. In addition, they have centralized repositories for data management and in most cases, they also support Open Data initiatives.

Consequently, the digital platform must adjust to these concerns, have **adequate compliance with European legislation, and as far as possible also adjust to Open data initiatives**.



7.2.10 Digital security

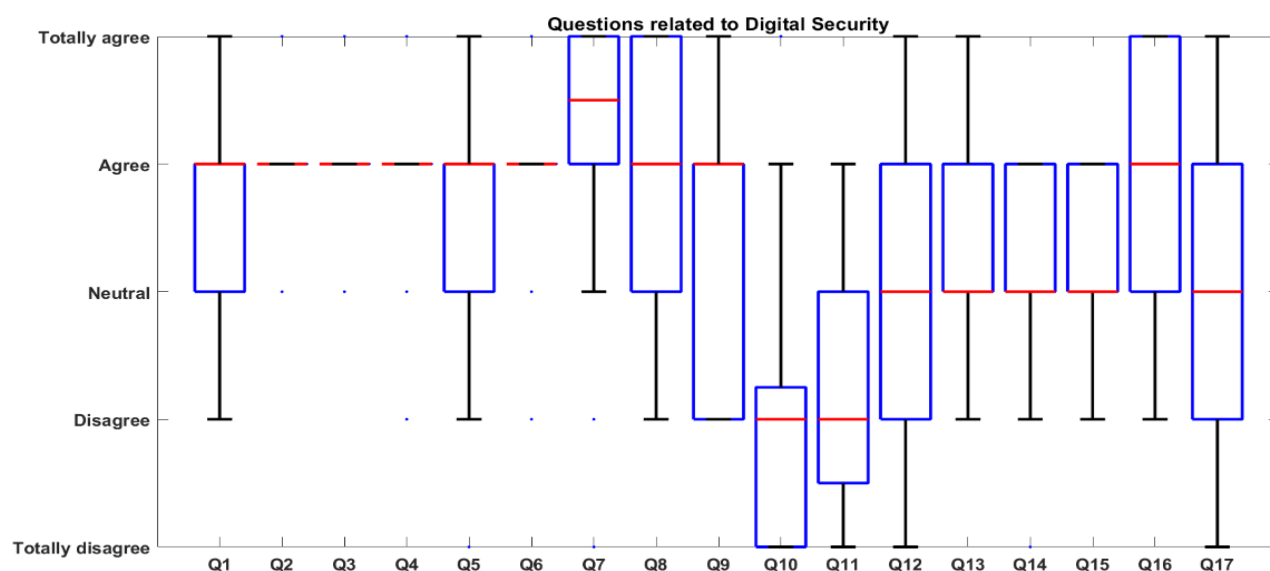
ID	Question	Mean	Standard deviation
Q1	We highly value the use of only one credential to access all data and services	3,5	0,83
Q2	It is very important to be able to access data and services from any place	4	0,58
Q3	Blockchain technology is a reliable method to ensure data integrity	4	0,62
Q4	We are concerned about possible security breaches that could hurt the business	3,9	0,72
Q5	We have separate network accesses for guests only	3,8	1,1
Q6	Portable devices usually connected to the internal network are also used to connect to other external networks (e.g. laptop when business traveling/ or home office)	3,5	1,1
Q7	We use institutional extensions for our email accounts	3,9	0,76
Q8	We use strong passwords (at least 8 characters, letters lower and upper case, numbers and special characters)	4,2	1,1
Q9	Passwords are changed frequently	4,1	0,85
Q10	We use biometric data (fingerprint, facial, voice, iris recognition, etc) for authentication for local and remote access points.	3,3	1,1
Q11	We share passwords for convenience.	2	1
Q12	We prefer onsite servers to cloud services for file storage, mail servers, application deployments, etc.	2,1	0,86
Q13	Our firewall incorporates the latest in threat detection and prevention technologies	3	0,88
Q14	We use third party applications that are hosted on our network	3,5	0,78
Q15	Information coming from sensors or other smart devices have high standards of security in connection to our servers.	3,3	0,81
Q16	If any server crashes, we have updated backups.	3,9	0,67
Q17	We have permissions to install any application on our work computer.	2,9	1,39

The penultimate block of questions is dedicated to digital security. As can be seen, the majority of the respondents implement up-to-date and modern security policies. The systems they manage are also close to the most current trends such as the use of portable devices by workers. In addition, in most cases they have a guest network different from the corporate network, which allows the implementation of more restrictive firewall policies. Policies are also implemented regarding the use of strong and up-to-date passwords that are updated and refreshed periodically.

It is interesting to observe how there is a change in trend regarding the use of biometric mechanisms, shared passwords and the use of local servers. Although we previously saw that local infrastructure is widely used, there is a clear preference for the use of tools in the cloud.

Users also report awareness regarding the use of security standards in their communications and in the communications that sensors and other types of infrastructure establish with their information systems.

The future digital platform must respect all these concerns and address them. **Security mechanisms mainly focused on password-based authentication will be predominantly used**, because most organizations do not implement additional mechanisms such as biometrics. There must also be a **management regarding the permits that are granted (authorization)**. In the same way, it is interesting to consider that most of the respondents do not have permits to carry out installations on their own computers, which is why they insist once again on the ideal of using web technologies that do not require this type of facilities and permissions. The importance of addressing these security challenges has been more than demonstrated in the reviews in Section 4 of the different application scenarios for CRFS technologies.



7.2.11 Administrative security

ID	Question	Mean	Standard deviation
Q1	Employees are allowed to bring their own devices to work and have full access to the network and applications.	2,8	1,2
Q2	We have a Business Continuity Plan	3,2	1
Q3	We outsource cyber-security to external experts	2,8	1,3
Q4	We have an in-house team capable to handle cyber security issues	3,4	1,16

Q5	We have a policy manual on IT and cyber security that is reviewed and updated regularly	3	1,2
Q6	We use external consultants to carry out reviews of the manual on IT and cyber security	2,6	1,1
Q7	We use external consultants to carry out penetration testing	2,6	1,1
Q8	We have a person responsible for cybersecurity	3	1,1
Q9	We have clearly defined protocols for cybersecurity	2,8	0,87
Q10	Employees are familiar with the established protocols for cybersecurity	2,8	0,87
Q11	There is a budget allocated to cybersecurity	2,8	0,92
Q12	There is regular training for cybersecurity	--	--

Finally, the last section is dedicated to the administrative aspects of security. It is noteworthy among all the questions, as most of the respondents emphasize that they do not outsource the security work of their own companies and that they do not employ any external agency to audit their security mechanisms and policies. In most companies there is a budget and a group of people specifically dedicated to cybersecurity; this includes a responsible person.

Because there are different roles within the companies themselves, the digital platform must be able to respect this organization and **offer different options to different users according to the role they occupy within the organization**. At the same time given the more relaxed environment of most of the users a more concerted effort should be given to protect the platform and the other users from security threats and cyber security attacks

It is worthy of highlighting that there was no valid answer to the last of the training questions. It could be of interest to **carry out a series of training actions** to make users aware of the use of the platform and highlight possible security issues, threats and defense strategies and tactics

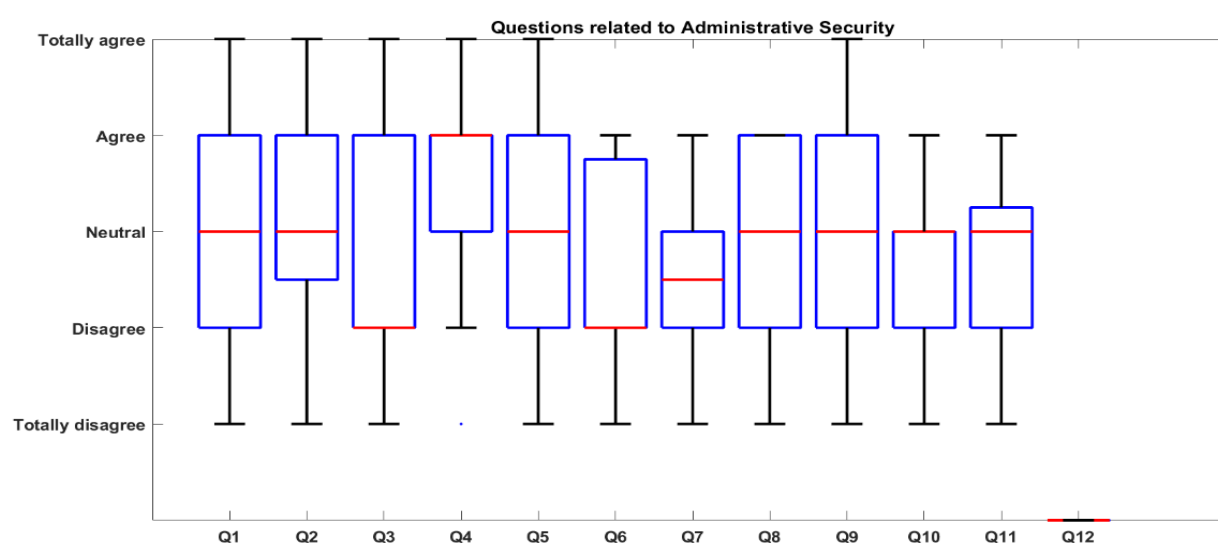


Figure 42 – Administrative security box-plot

8 Guidelines and big picture for a data-driven CRFS management platform

This section contains the result of the discussions within the Focus Group about the design recommendations and the lines that the S2CP platform should work on to achieve the greatest possible impact. For this, it is used as input, as mentioned in the methodology, the review of the state of the art of technology and the needs and expectations of users according to the results of the initial questionnaire and especially in the quantitative surveys.

The section is divided into two subsections to collect the different discussions carried out within the Focus Group. The first subsection is more discursive, and collects the different deliberations carried out regarding the high-level functionalities that the platform should include to adjust to the needs of end users, while integrating innovative technologies with high added value and impact. The second subsection focuses on concrete functional recommendations, creating a more specific course of action for technology partners developing the platform in the context of WP6.

8.1 Global overview: Description of the Single Click CRFS Platform (S2CP)

The Single Click CRFS Platform is the main asset that WP6 will generate. Its key function is to assist cities governing bodies secure the management of sustainable CRFS. S2CP is a data-driven CRFS management platform for data collection, analysis and representation in web and mobile interfaces. This platform provides a key technological asset in data capture and storage and information analysis and allows stakeholders to use a more optimal collaboration and monitoring of data following the maximum of privacy and integrity. This is achieved thanks to a security layer that prevents unauthorized users from accessing confidential information, both in the possible capture of information by sensors, using secure communications and in the establishment of detailed data access policies.

Food-related indicators will be displayed in a dashboard adaptable to different devices and media, to secure transparency and inform stakeholders on the status of their city's food system.

There is a set of core functionalities that have been planned for the S2CP. These functionalities are described below, with a schematic image of what the interaction of S2CP and its users would be like, and finally, some examples of how stakeholders could make use of this functionality are provided.

8.1.1 Visualization and statistical analysis of data coming from city food system

The S2CP platform will have a well-documented mechanism to enter information related to a city, accepting multiple formats (geospatial information, databases, etc.). This information will be provided by different stakeholders (producers, retail, consumers, other businesses) and will allow its statistical visualization for later comparison with other food systems in other cities or in the same city at different times.

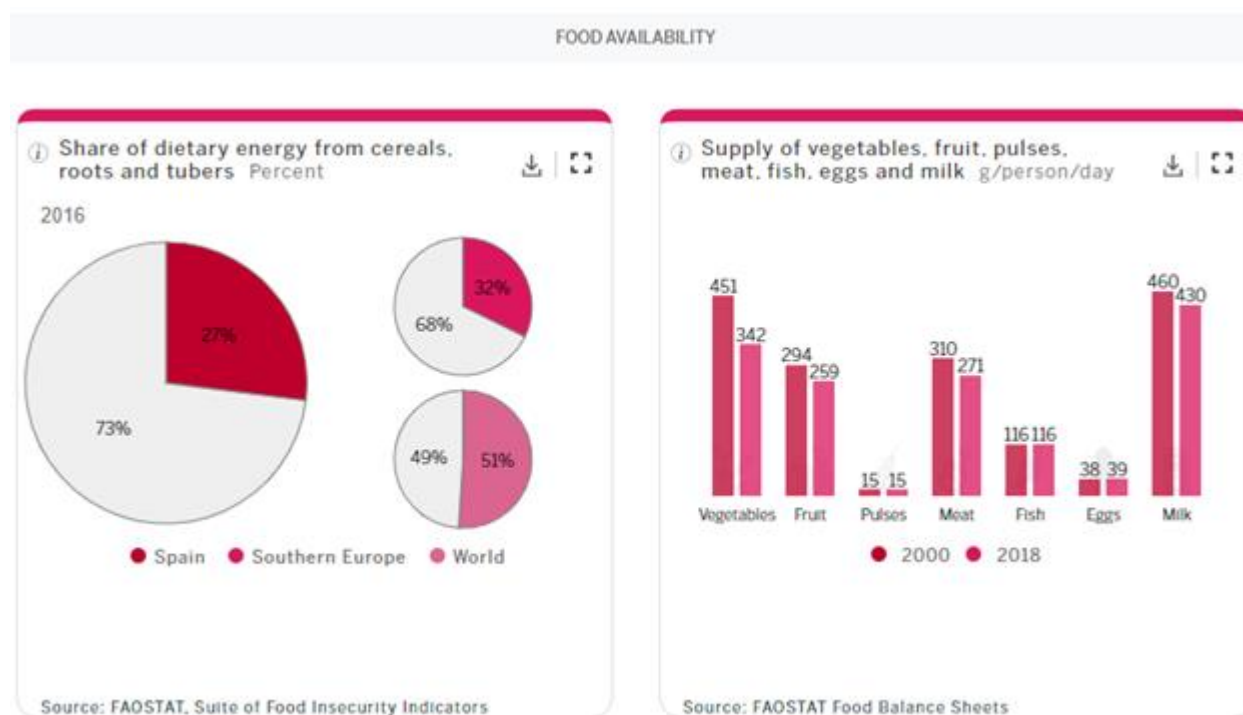


Figure 43 – Possible schematic view of statistical display functionality²⁰²

Use case example:

A council of city (A) wants to improve its policies to promote the consumption of vegetables among its population and wants to find out which are the cities among those available in the database that offer better indicators on this type of consumption, for later review their municipal policies. To do this, the manager of city (A) accesses the platform and searches among the cities available in its database which offer the best data on the consumption of grams of vegetables per person and day, finding the city (B) as a candidate whose policies could be reviewed for adoption. The manager also consults the evolution of this consumption in cities (A) and (B) to evaluate the effectiveness of the policies in place.

8.1.2 Spatial decision support based on city cartography

The most relevant locations in a city in relation to the main actors of the CRFS (Distribution, retail, processing, production, consumption, waste) can be entered on the platform. The platform will allow the generation of maps with different visualizations (heat maps, clusters, filtering by categories) to obtain a spatial vision of the distribution and relevance of locations or points of interest.

S2CP will integrate all necessary tools and services for rendering the datasets, performing spatial operations or complex analysis.

²⁰² Schematic view extracted from <https://foodsystemsdashboard.org/>

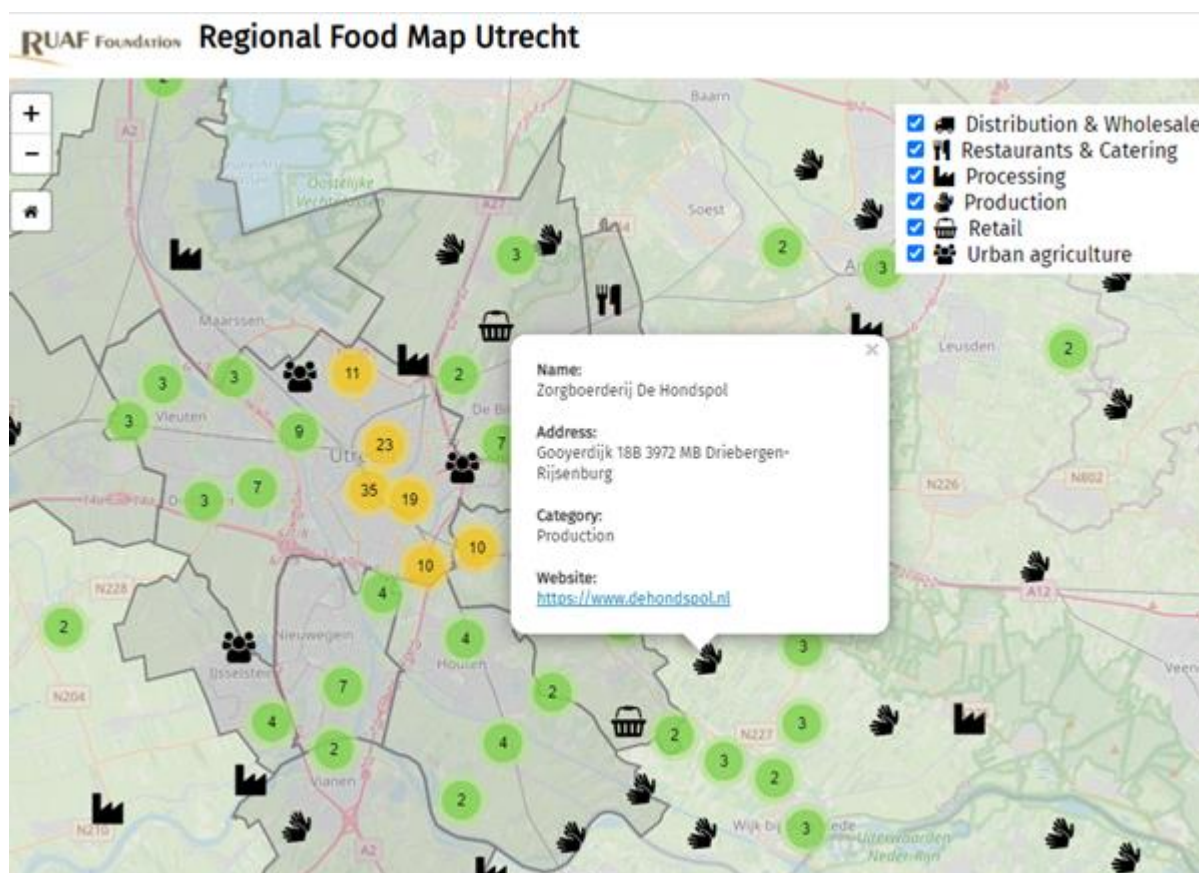


Figure 44 – Possible schematic view of Spatial visualization functionality²⁰³

Use case example:

An entrepreneur is considering whether to invest in a food establishment specializing in local food. To do this, she accesses S2CP, selects her city and view the distribution of retail establishments and their proximity to local production points, such as “Urban agriculture”. This information makes it easier for her to contact other stakeholders to find business opportunities.

8.1.3 Enabling data-driven business opportunities powered by blockchain

S2CP will provide a data-based enabler hub for optimization of multi-stakeholder dialogue processes, in which blockchain will be employed to provide some proof of concepts of contract agreements, in a reliable and transparent way. Specifically, in this communication space, CRFS stakeholders will be able to offer to third parties the data they have for some profit or for free. Once the data is acquired, it can be represented on the dashboard.

²⁰³ Schematic extracted from: <https://www.ruaf.org/regionalfoodmaputrecht/>

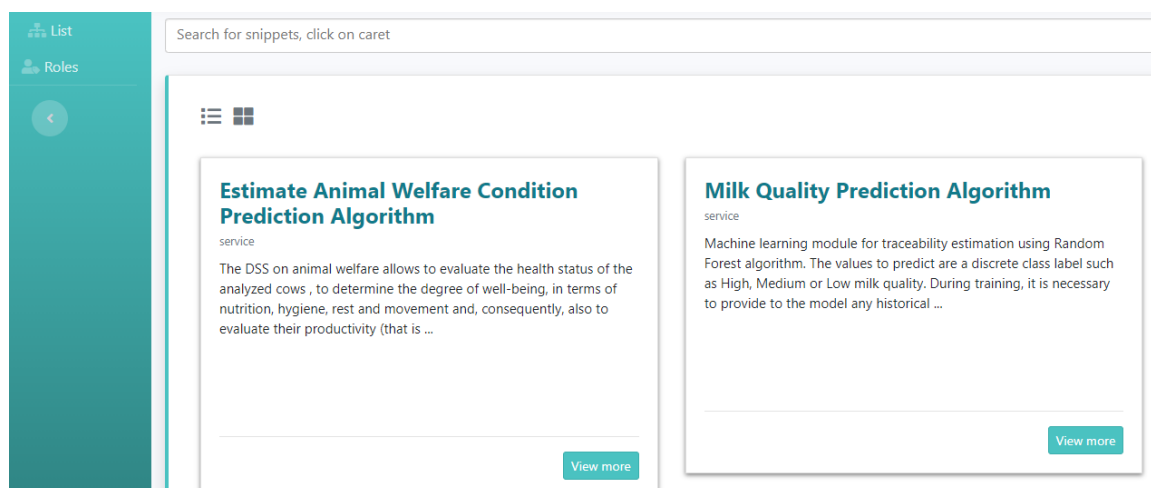


Figure 45 – Possible schematic view of data-based enabler hub²⁰⁴

Use case example:

An innovation center in the field of food has carried out a survey on the consumption habits of the inhabitants of a city, divided by districts. This information can be very useful for local authorities, which is why the innovation center uses the S2CP platform to put this information in the data-based enabler hub.

The city council discovers this repository on the S2CP platform and acquires it to be able to view the information on the dashboard or in other GIS software.

8.1.4 Representation of real-time data for CRFS monitoring

S2CP will incorporate a system for receiving events that can be produced by sensors. Thus, it can collect information produced by sensors that may be deployed in a city or on a farm and generate information repositories for real-time visualization or monetization.

²⁰⁴ Schematic extracted from: <https://h2020-demeter.eu/>

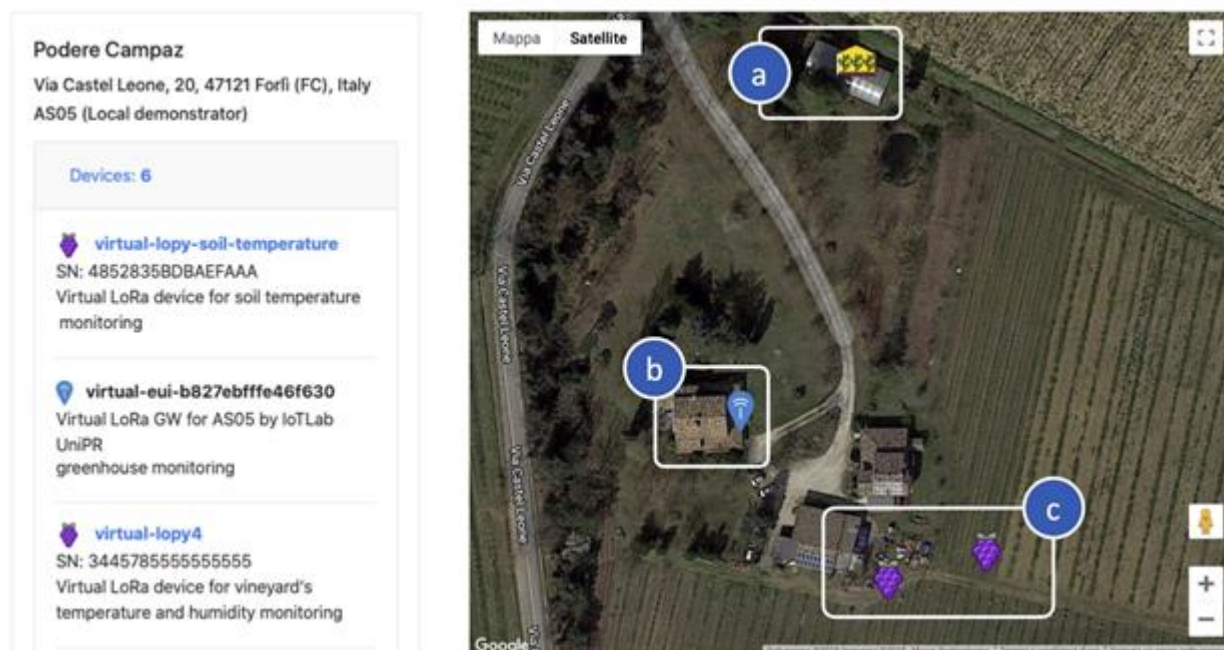


Figure 46 – Possible schematic view of real-time data representation ²⁰⁵

Use case example:

A garbage collection company wants to optimize the actions for the collection of organic waste containers. To do this, it installs a set of sensors that provide information on the level of occupation of the containers over time.

The company can generate notifications from these sensors through the S2CP platform for presentation in a control panel. In turn, another entity interested in these data, such as the person in charge of the Cleaning and Waste Collection Service, can subscribe to this information to, once analyzed, improve decision-making regarding the distribution of containers in the city.

8.1.5 Origin Certification and Fraud Prevention of Short Food Supply Chains

S2CP will provide a solution for optimization of multi-stakeholder dialogue processes, in which blockchain will be employed to provide some proof of concepts of monetization processes, in a reliable and transparent way. In order to ensure transparency, traceability and trust of the local food production, blockchain technology (BC) presents the natural technology fit in the so-called SFSC.

Use case example:

Each SFSC stakeholder (e.g. farmer, logistics, processor, distributor, retailer, except the consumer) is going to be equipped with a BC-related digital identity, whereby every SFSC step will handle a BC transaction, digitally signed by a registered and verified SFSC stakeholder (e.g. producer, delivery service etc.). Each BC transaction can contain BC-related information (i.e., timestamp, digital identity, signature), as well as specific food (i.e., type, harvest region, harvest datetime, etc.) and logistic related information (i.e., LOT number,

²⁰⁵ Schematic extracted from: Codeluppi, G.; Cilfone, A.; Davoli, L.; Ferrari, G. LoRaFarM: A LoRaWAN-Based Smart Farming Modular IoT Architecture. *Sensors* 2020, 20, 2028. <https://doi.org/10.3390/s20072028>

type, etc.). The proposed end-system will also enable the storage of digital proofs (i.e., harvest or delivery photos etc.), which can be stored on a distributed file system.

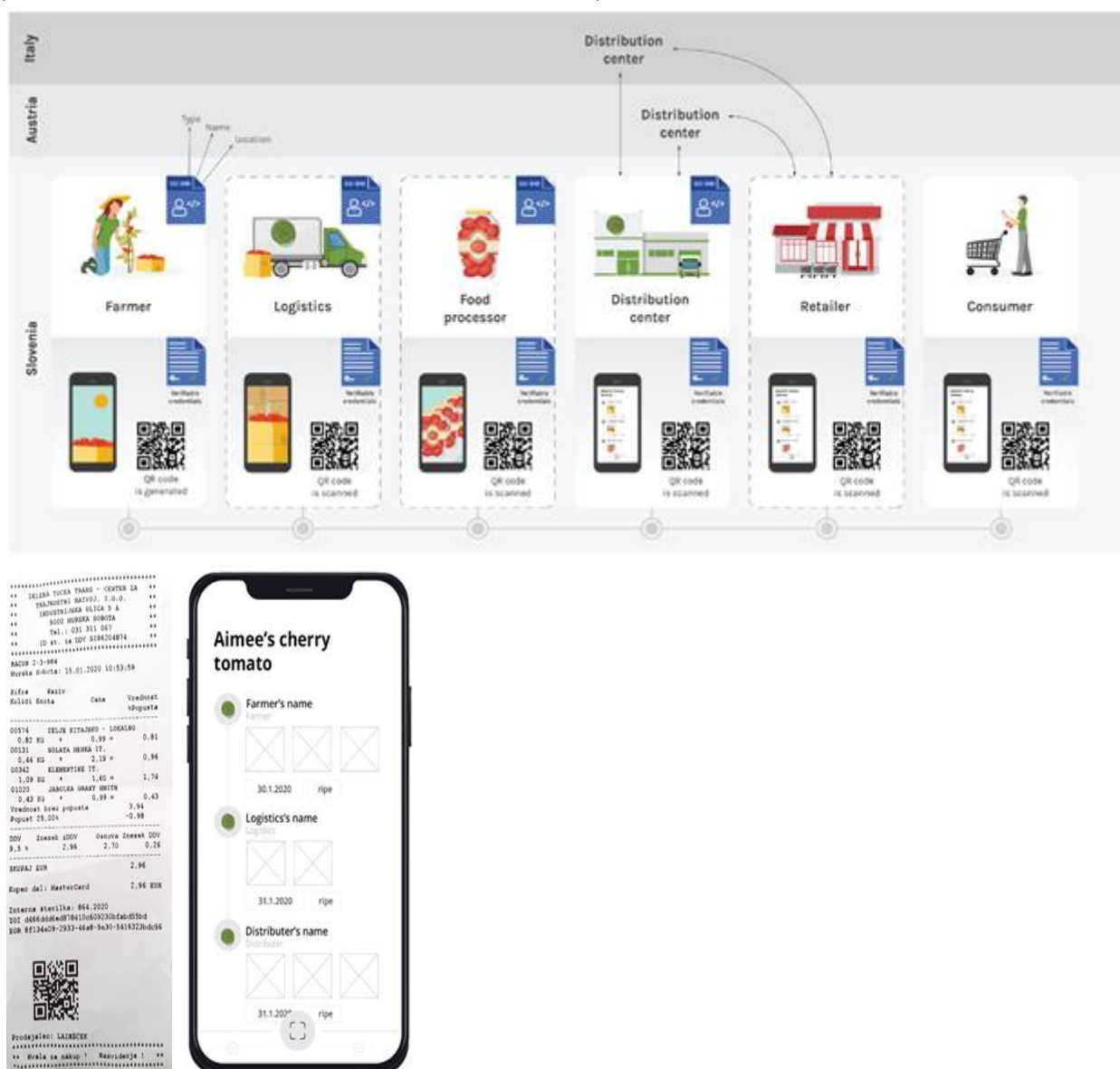


Figure 47 – Possible schematic view of Origin Certification and Fraud Prevention of Short Food Supply Chains

8.2 Functional recommendations

This subsection is intended to be a guide to help T3.7 and WP6 partners in the study of the necessary functionalities for the future design of the functional architecture of the S2CP. To do this, a list of functionalities extracted from the basic definition of the platform is developed. These functionalities represent a starting point to specify in subsequent steps which components would be necessary as integral elements of the S2CP architecture.

With the initial basic functionalities (see previous section, Global overview: Description of the Single Click CRFS Platform (S2CP), end-user requirements answered by the initial surveys, and the description of WP6 work package, we consider the following functional recommendations. The architecture subsystems in terms of information management (data repositories and information in real time), ecosystem of services, security

Deliverable D3.8 Guidelines for a data-driven CRFS management platform

Prepared by P20 | Edited by P5, P9, P10, P16, P17, P20, P21, P27, P29, P30, P37 | Checked and reviewed by EX COMM | Approved by P1

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(and blockchain) and visualization should take these functional needs into account and transform them to possible developments.

Functionality #1: Visualization and statistical analysis of data coming from city food system. This functionality can be broken down into the following functional recommendations:

FR#	Description
1	Access and integration of information repositories in multiple formats, such as open data portals, databases, organized thanks to a data governance framework.
2	Provision of innovative technologies for the capture of information and creation of repositories (data mining, distributed learning, casual, conformance learning techniques), in the form of components.
3	Possibility of registration (identification in user accounts). Policies for access to repositories (authorization).
4	Modular dashboard (possibly based on widgets) that allows customization and operations by users. Information analysis tools and statistics generation, averages, regressions, etc.

Functionality #2: Spatial decision support based on city cartography. This functionality can be broken down into the following functional recommendations:

FR#	Description
1	Access and integration of information repositories in multiple formats, such as open data portals, databases, organized thanks to a data governance framework.
3	Possibility of registration (identification in user accounts). Policies for access to repositories (authorization).
5	Geospatial data download, visualization and processing services.
6	Generation of cartography adapted to different types of data. Cartography display controls of various types (heat maps, clusters, etc).

Functionality #3: Enabling data-driven business opportunities powered by blockchain. This functionality can be broken down into the following functional recommendations:

FR#	Description
1	Access and integration of information repositories in multiple formats, such as open data portals, databases, organized thanks to a data governance framework.
3	Possibility of registration (identification in user accounts). Policies for access to repositories (authorization).
7	Marketplace for data exchange, with blockchain support in the establishment of "contracts"
8	Policy-based management system, considering authentication, authorization (security) tools in data access. Modification of authorization policies in accessing or downloading data.

Functionality #4: Representation of real-time data for CRFS monitoring. This functionality can be broken down into the following functional recommendations:

FR#	Description
4	Modular dashboard (possibly based on widgets) that allows customization and operations by users. Information analysis tools and statistics generation, averages, regressions, etc.
9	Communications broker for the management of information in real time that may come from sensors.
10	Publication of real-time information in some type of control widget.

Functionality #5: Origin Certification and Fraud Prevention of Short Food Supply Chains. This functionality can be broken down into the following functional recommendations:

FR#	Description
10	Publication of real-time information in some type of control widget.
11	Traceability system for the management of the supply chain (from farm to retail), with functionalities for the review of digital proof for certification and authenticity
12	Blockchain support for storage of digital identities, food properties and logistic related information.

9 Key performance indicators (KPI) framework

Finally, to allow the design and implementation process of the S2CP platform not to blur the proposed design lines, and to prevent the global impact of the platform is below what was initially foreseen in this Focus Group, a framework is defined of indicators, which should allow WP6 participants and the other members of the Cities2030 project to monitor the potential impact of the platform in all its development phases.

The objective with this proposal is to check at all times that the designed platform follows the defined design lines, thus guaranteeing the impact.

This framework of KPIs will be dynamic (and can be updated as the project progresses, and new use cases or needs are detected) and will be available to all project members through the Correlate management platform.

In order to adequately capture the duality of impact that has been detected since the beginning of the Focus Group's work, the indicators also belong to two different categories. On the one hand, **technological indicators** that measure the impact of the platform in strictly communication and information engineering terms. On the other hand, **domain or end-user indicators**, which must map in a measurable way the achievement of a platform capable of adapting and meeting the needs and expectations of users.

Next, we are going to study in detail the sets of indicators of each type finally approved and proposed by the Focus group.

According to T3.7, "A specific framework of KPI will be created with an online interactive form generated in the platform "Correlate CITIES2030"

The methodology used considers the need to describe the indicator and the method that will be used to measure it.

For all indicators, once integrated into the dynamic framework, a success threshold will be defined in the future. This threshold will be defined according to the global needs of the Cities2030 project and, above all, of the end users participating in it. According to the schedule foreseen in the project, this work will be carried out during the second year. PMO or WP6 will convene a workshop, or a set of sessions dedicated to this purpose.

9.1 Technological KPI

The following table lists the technological indicators. As mentioned in the section on the initial questionnaire, and especially in the analysis of the quantitative surveys, of the 4 technologies identified in the review of the State of the art of communications and information technology solutions, two are those that arouse the most interest among end users: blockchain and artificial intelligence (in its aspect dedicated to data analysis).

It is therefore essential that, just as the design guides included sections specifically dedicated to these technologies, the technological indicators also have a special follow-up with the use of these key technologies.

On the other hand, and as was also mentioned when studying the initial questionnaire, one of the aspects that arouses the greatest concern among users is cybersecurity and data governance. It is, therefore, essential that an indicator be dedicated to the monitoring that the platform carries out of these aspects.

Finally, the Focus Group considered it essential to also include generic technological indicators that guarantee the quality of the service provided, such as the ability to work concurrently or service availability.

Table 8 – Definition of technological KPIs

Name	Description / Method of collection and measurement	Metric
Open-source standards supported by S2CP components	What is the percentage of open standards implemented against the total number of protocols/technologies/models implemented?	Percentage
Authentication	Percentage of components whose access is protected by credentials (email, password, tokens). In component-to-component interactions we consider the number of secure API end-points.	Percentage
Interoperability	Number of components that communicate with other internal (same system) or external components (different regional system).	Number
Role-based authorization	Number of roles and categories (category of producers) with different authorization policies (producers, consumers, administrators, etc.).	Number
Availability	Percentage of data that is stored in redundant / high-availability services or data repositories, with data integrity and verification mechanisms.	Percentage
Number of data sources connected to the Data Analytics Dashboard	Number of data and database formats to be supported by S2CP services / dashboard.	Number

Blockchain	Presence of benefits associated to blockchain usage in term of revenues, immutability, or consensus	List
Number of concurrent users requesting information in the S2CP platform	Testing and simulation: it should be considered the target number of users plus 60% in order to verify the server's ability to cope with such a large number of requests without compromising the usage of the platform.	Number

9.2 Domain-based KPI

In this subsection we focus on those indicators that seek to monitor and guarantee the impact in terms of end users and domain applications. It is very difficult to express through quantitative metrics the capacity of a technological tool to satisfy the needs and expectations of users. For this reason, in general, it has been chosen to carry out an indirect measure of this coverage of needs. Within the Focus Group it has been understood that a majority and relevant use of the platform is an unequivocal indicator of the impact and interest of the platform.

For this reason, a set of indicators have been dedicated to measure the number of use cases or entities that have incorporated the platform into their activities. Similarly, the number of events in which the platform has played a relevant role in the activities of end users is also an indicator of the way in which the platform meets the needs and the impact achieved. Along the same lines, in those components and technologies (how can blockchain or artificial intelligence do), in which the implementation or delivery of an asset by a user is required to make use of the platform, it is very easy to measure the use of S2CP components. For this reason, we will also measure the number of smart contracts (in the case of blockchain) or data sets (in the case of artificial intelligence) that users have deposited on the platform.

Finally, in order to try to somehow measure user satisfaction with the proposed platform and how it adapts to their needs, the Focus Group found it necessary to include metrics related to ease of use and implementation (with the objective of minimizing possible barriers and therefore maximizing the impact), and the commitment of the different agents with the use of this platform (which can be measured through the active participation of the different agents in the events related to this technological instrument).

Table 9 – Definition of domain-based KPIs

Name	Description / Method of collection and measurement	Metric
# of events	Number of community-participated events in which S2CP components are used.	Number
# of cities	Number Cities (Municipalities) incorporating S2CP enablers in pilots and living lab activities within the time period of the project.	Number
# of use cases	Number of use cases defined as framework for S2CP architectural design	Number
# of datasets	Number of datasets collected / represented by the platform, corresponding to participating cities.	Number
Installation / Instantiation complexity	Complexity in terms of IT knowledge required and local adjustments. Method of collection: Questionnaire. 1 Easiest, 10 very difficult.	Number

Stakeholder's engagement	Level of engagement of stakeholders in platform co-creation. This KPI tries to measure how partners are rewarded or motivated for their involvement and the benefit they perceive. Method of collection: Questionnaire, and meeting minutes.	Frequency of partners interactions and meeting
Consensus and contracts	Number and quality level of consensus and contracts created by different stakeholders by using multi-stakeholder interaction/collection components: SSI-MAA tool, marketplace, supply chain, etc.	Number

10 Conclusions

In order to guide the development of the S2CP technological platform foreseen in the WP6 of the CITIES2030 project, in this task a work Focus Group is constituted whose objective is to guarantee the impact of said platform. To guarantee the impact, this task generates two different results. On the one hand, a set of recommendations regarding the functionalities and design that the platform should follow, and on the other hand, a set of indicators that should monitor the programming and implementation process of the different components, detecting whether they meet the expected impact or if improvement and correction actions are necessary.

In order to provide WP6 with a consistent set of design and implementation recommendations, it is essential to evaluate the two dimensions of the impact of a technological instrument: on the one hand, the enabling technologies that the product uses, and, on the other hand, the needs and expectations of the end users that the product is able to satisfy. For this reason, the Focus Group is constituted with partners of two different profiles. Some members of the Focus Group mainly participate in WP6 and therefore are partners with a technological profile, while approximately the other half of the members mainly participate in WP5 and are therefore CRFS-focused partners (whether they are government agents, industrialists, etc.), acting as end users.

This duality is also transferred to the data sources that need to be considered in order to generate relevant design guides. On the one hand, it is essential to analyze the state of the art of technology to be able to select as foundations of the platform those enabling technologies of greatest relevance and impact today. On the other hand, to meet the needs of users, it is essential to carry out an information capture process that leads to identifying what these needs and expectations are.

The first phase of the Focus Group's work was focused precisely on the study of the state of the art of communication and information technologies, seeking to identify those enabling solutions with the greatest impact today. This study was carried out using two different criteria. On the one hand, looking for those technological solutions with the greatest impact in the scientific world in the last 5 years, and, on the other hand, analyzing the technological solutions of greatest interest in the most relevant application scenarios for the Cities2030 project, such as the pillars identified by FAO for CRFS.

As a possible conclusion of this study, blockchain and artificial intelligence technologies are those that show the greatest interest and relevance today.

The second phase of the work was dedicated to studying the needs of users, for which a somewhat more complex information capture process was designed due to the intrinsic difficulties of relationships with end users. Therefore, in a first preliminary phase, an identification of possible external and internal stakeholders

was carried out, which has led us to have a list of more than 40 agents interested only in the platform (other tasks will identify those agents identified in the project itself). After this, a first initial questionnaire showed how end users also have a great interest in incorporating blockchain and artificial intelligence technologies into their processes. We also saw a relevant concern for cybersecurity and data governance, especially for those of a personal nature.

Carrying out an exhaustive quantitative survey of both internal and external interested agents reported highly relevant information: (i) in general aspects on the use of information technologies by the different agents integrated in the CRFS, (ii) on specific issues of previously identified technologies (blockchain and artificial intelligence), (iii) on concerns detected in the initial questionnaire such as cybersecurity or data governance. Through this survey we were already able to detect the first confirmed design recommendations for the platform that would later be elaborated to give rise to the official lines proposed by the Focus Group. Specifically, as a result of the work, the Focus Group proposed a set of up to 4 high-level functionalities, which, in order to create a concrete and specific route that could be easily followed by technological agents, were broken down into 12 functional low-level recommendations.

Along the same lines, to guarantee that the expected impact for the platform (if it follows the recommendations made) is achieved in an effective way, a framework of KPIs with 14 elements is proposed.



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ANNEX I. Initial questionnaire

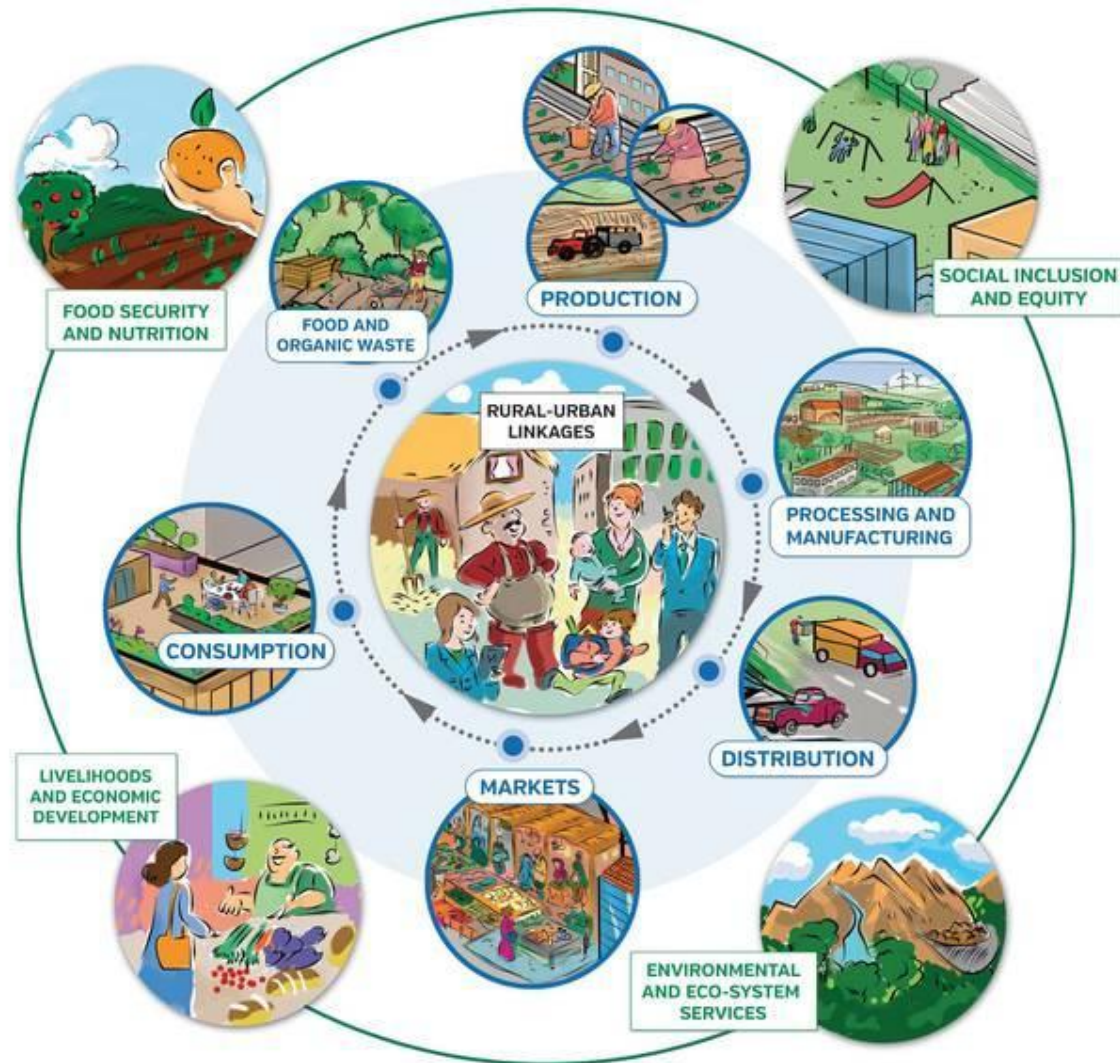


D3.8 INITIAL QUESTIONARY Final users' requirements: CRFS platform



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101000640

A City Regional Food System (CRFS) (please see definition if FAO's website²⁰⁶) is all the actors, processes and relationships that are involved in food production, processing, distribution, and consumption in a given city region. A city region is defined as: "a larger urban center or conglomeration of smaller urban centers and the surrounding and interspersed peri-urban and rural hinterland".



²⁰⁶ CRFS approach: <http://www.fao.org/in-action/food-for-cities-programme/overview/crfs/en/>

Please, answer all these questions according to your knowledge. All answers, perspectives and information are welcomed.

- 1- As an CRFS actor (or entity in contact to CRFS actors), what is your role in the CRFS value chain? What is your knowledge about the CRFS of your city/region/country? Please, describe it in a short paragraph.
- 2- Regarding the City Regional Food Systems where you are integrated, what are the main pending challenges or problems to be addressed?
- 3- Currently, what is your main necessity regarding the management of City Regional Food Systems where you are integrated?
- 4- What kind of computer tools (Excel, SAP, mobile applications, etc.) would allow you to manage in a better way the CRFS?
- 5- Nowadays, do you know what technologies are being employed to improve CRFS management (Artificial Intelligence, Blockchain, Big Data...)? If possible, describe them in a short paragraph

Regarding the management platform to be developed in Cities2030 please answer the following questions:

- 6- Will you be satisfied with functionalities based on IoT, Blockchain, Big Data and/or Artificial Intelligence? Can you provide a use case example that you think it would be beneficial for its implementation in CITIES2030?
- 7- Would you like to propose any additional functionality that you see relevant for the CRFS actors participating in CITIES2030?
- 8- Do you think you could employ the platform to make the process easier? If possible, explain how in a short paragraph.
- 9- What kind of data would you like to visualize in that platform (waste management, commercialization, transport, distribution, etc.)? Are these data open or do they belong to private repositories?
- 10- What kind of statistics or analysis would you like to visualize in that platform (spatial analysis, mean value, monthly or yearly evolution, predictions, comparisons, etc.)?

ANNEX II. Quantitative survey

cities2030

QUANTITATIVE SURVEY Final users' requirements: CRFS platform



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101000640

The city region is a given geographical region that includes one or more urban centres and their surrounding peri-urban and rural hinterland across which flows of people, food, goods, resources and ecosystem services are happening. A CRFS (City Region Food System) encompasses all food system actors and activities taking place in the city region and over which the local/regional government have planning and intervention powers. Any city region will always be fed by multiple food sources, be it local, regional, national and international, so that city regional food system does not exist in isolation from a global food system.

In the context of the project "[CITIES2030: Co-creating resilient and sustainable food systems towards FOOD2030](#)" we are aiming to identify the user needs for Information Technology Systems from the partners and stakeholders. We have created this survey aimed at different audiences to gather the necessary data that will help us develop the appropriate deliverables.

The information collected through this survey will be employed to define some relevant guidelines for technological partners in the project. The objective is to **design and implement a new technological platform for City-Region Food Systems**. Its key function will be to assist governing bodies and other CRFS agents to secure the management of sustainable CRFS supporting data collection, analysis and representation in dashboards, following the maximum of privacy and integrity. To achieve this, functionalities such as **visualization and statistical analysis of data**, **spatial decision support based on city cartography**, **representation of real-time data**, and **origin certification and fraud prevention of Food Supply Chains** are proposed.

Data collected from this survey will be stored and analyzed by "Universidad Politécnica De Madrid" only for the project needs; they will be rendered anonymous, if compatible with project requirements and deleted after the mandatory storage period defined by the funding authority.

Please answer all the questions and provide as much information as you feel comfortable with. If there are questions that you prefer not to answer please leave blank.

1. Organization name:
2. Organization's interest in CITIES2030 project and specifically in its data-driven CRFS management platform (see functionalities in bold above):
3. Your role within the organization: (Select from: marketing, management, IT, finance, research, education, other).
4. Type of business & sector of the economy: (We need to include a list of answers).
Food production, agriculture

Food distribution / logistics
Public/social services
Retail/Commerce
Research / Education
Financial studies or financial services
Food manufacturing/processing
Other

5. Type of organization:

Public company
Educational institution
Self-employed business
Government agency
Non-profit organization
Self-owned business
Privately held business
Partnership

6. Number of employees:

Self-employed
1-10 employees
11-50 employees
51-200 employees
201-500 employees
501-1000 employees
1001-5000 employees
5001-10,000 employees
10,001+ employees

Instructions:

Please tick/cross the appropriate response for all the questions below according to the following Likert Scale: 1 (totally disagree) – 5 (totally agree).

General Context and CRFS

The questions should be answered in terms of the Organization or CRFS (when identified as such)

No		Totally Disagree	Disagree	Neither Agree/ Neither Disagree	Agree	Totally Agree
10	Our documentation should be organized in a single repository	1	2	3	4	5
11	Decision making is carried out based on non-technological technical reports	1	2	3	4	5
12	Our Information Technology systems are well structured and integrated	1	2	3	4	5
13	We often use qualitative criteria when describing business models	1	2	3	4	5
14	We would need guidance in data sharing	1	2	3	4	5
15	We believe that value (economic, social, research, etc) is added when data is shared	1	2	3	4	5
16	The policies in my country enforce gathering of relevant data for food standards across the value chain.	1	2	3	4	5
17	As value chain actors we have access to high-quality data to guarantee food safety	1	2	3	4	5
18	CRFS consumers have access to data that assures food safety	1	2	3	4	5
19	A marketplace with local products would provide benefits to the regional environment and establishment of the regional short food supply chain	1	2	3	4	5
20	In our CRFS, the use of Internet of Things (IoT) technology can bring benefits to farmers	1	2	3	4	5
21	In our CRFS, the use of Internet of Things (IoT) technology can bring benefits to business	1	2	3	4	5

22	In our CRFS, the use of Internet of Things (IoT) technology can bring benefits to consumers	1	2	3	4	5
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Current State of Industry (Only For Industrial Partners)

The questions should be answered in terms of the Organization or CRFS (when identified as such)

No			Totally Disagree	Disagree	Neither Agree/ Neither Disagree	Agree	Totally Agree
24	Accounting and Finance	We prefer off the shelf software to run accounting and finance	1	2	3	4	5
25		We prefer customized software to run accounting and finance	1	2	3	4	5
26		We prefer bespoke systems (tailored software) to run accounting and finance	1	2	3	4	5
27	Marketing and Sales	We prefer off the shelf software to run marketing and sales	1	2	3	4	5
28		We prefer customized software to run marketing and sales	1	2	3	4	5
29		We prefer bespoke systems to run marketing and sales	1	2	3	4	5
30	Production	We prefer off the shelf software to run production	1	2	3	4	5
31		We prefer customized software to run production	1	2	3	4	5
32		We prefer bespoke systems to run production	1	2	3	4	5
33	Personnel	We prefer off the shelf software to run personnel.	1	2	3	4	5
34		We prefer customized software to run personnel.	1	2	3	4	5
35		We prefer bespoke systems to run personnel.	1	2	3	4	5

Data and Data Requirements

The questions should be answered in terms of the Organization or CRFS (when identified as such)

No		Totally Disagree	Disagree	Neither Agree/ Neither Disagree	Agree	Totally Agree
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36	We deal with data from different data sources (weather station data, pest management data, ...)	1	2	3	4	5
37	Often have to access data sources that are difficult to store or process	1	2	3	4	5
38	We manage datasets in multiple formats	1	2	3	4	5
39	Farmers keep good quality data regarding the agricultural processes	1	2	3	4	5
41	We provide data to other entities	1	2	3	4	5
42	In my organisation and CRFS, the information we need for decisions is located and easily accessible	1	2	3	4	5
43	The data flow we manage is low (less than five transactions/messages per hour)	1	2	3	4	5
44	Our applications and data are stored on our servers	1	2	3	4	5
45	Our applications and data are stored on the cloud.	1	2	3	4	5
46	We can record enough relevant data (amount of pesticides, fertilisers used) in food production	1	2	3	4	5

Data Governance

The questions should be answered in terms of the Organization or CRFS (when identified as such)

No		Totally Disagree	Disagree	Neither Agree/ Neither Disagree	Agree	Totally Agree
48	We have implemented a data governance policy	1	2	3	4	5
49	Data access control is clear to all parties	1	2	3	4	5
50	The data access history is registered and available to authorized users	1	2	3	4	5
51	CRFS actors receive value from data sharing	1	2	3	4	5
52	CRFS actors are aware of their data sharing obligations via contractual agreements	1	2	3	4	5
55	We are aware of trust related aspects connected to data sharing	1	2	3	4	5
56	CRFS actors in the value chain have access to the relevant data	1	2	3	4	5
57	Stakeholders have access to data pertaining to their function.	1	2	3	4	5

Platform Functionalities

The questions should be answered in terms of the Organization or CRFS (when identified as such)

No		Totally Disagree	Disagree	Neither Agree/ Neither Disagree	Agree	Totally Agree
58	We can see a value in a CRFS management platform for data collection, analysis and representation	1	2	3	4	5
59	We can see a value in visualizing and analysing statistical data from our (and other) CRFS	1	2	3	4	5
60	We can see a value in a decision support tool based on city-region cartography	1	2	3	4	5
61	We can see a value in a marketplace for optimization of multi-stakeholder dialogue processes	1	2	3	4	5
62	We can see a value in representing real-time data for CRFS monitoring	1	2	3	4	5
63	We can see a value in certifications of origin and fraud prevention of food supply chains	1	2	3	4	5
64	We can see a value in translating interfaces into my local language	1	2	3	4	5
65	We can see a value in a reliable and easy system to track our products through the supply chain	1	2	3	4	5
66	We can see a value in a system to track food waste in the supply chain	1	2	3	4	5
68	Real time visualization applications (using data from sensors and other real-time sources) are important	1	2	3	4	5

ICT Technologies

The questions should be answered in terms of the Organization or CRFS (when identified as such)

No		Totally Disagree	Disagree	Neither Agree/ Neither Disagree	Agree	Totally Agree
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				Neither Disagree		
69	We use a Geographic Information System (GIS) to make decisions	1	2	3	4	5
70	We know the advantages of Artificial Intelligence and machine learning for better information capture.	1	2	3	4	5
71	We prefer mobile applications over desktop/web applications	1	2	3	4	5
72	We prefer a tailored-based GIS frontend platform than a standard service.	1	2	3	4	5
73	We would use Earth Observation imagery and services (satellite data, drones) if available.	1	2	3	4	5
74	We often use GDrive and similar cloud solutions for exchanging data and documents.	1	2	3	4	5

Data Protection

The questions should be answered in terms of the Organization or CRFS (when identified as such)

No		Totally Disagree	Disagree	Neither Agree / Neither Disagree	Agree	Totally Agree
10	We have defined roles and not all people are allowed to access all systems and data	1	2	3	4	5
11	We generate sensitive data (personal information, health-related data, trade-union membership, racial or ethnic origin, political opinions, etc)	1	2	3	4	5
12	We are well informed about GDPR regulations	1	2	3	4	5
13	We manage personal information protected by GDPR or sensitive data	1	2	3	4	5
14	All sensitive data is secured (in storage and when transmitted) and backed up on a routine basis	1	2	3	4	5
17	We anonymize on a standard basis all sensitive data we are working with	1	2	3	4	5
20	All employees are expected to know and follow company rules about GDPR	1	2	3	4	5
21	All data is saved on a general repository (server)	1	2	3	4	5

22	We consider our server for data storage safe	1	2	3	4	5
23	There is a high awareness about the importance of data security	1	2	3	4	5
24	Open data (freely available to everyone to use and republish as they wish, without restrictions from copyright, patents) is important for us	1	2	3	4	5

Digital Security

The questions should be answered in terms of the Organization or CRFS (when identified as such)

No		Totally Disagree	Disagree	Neither Agree/ Neither Disagree	Agree	Totally Agree
26	We highly value the use of only one credential to access all data and services	1	2	3	4	5
27	It is very important to be able to access data and services from any place	1	2	3	4	5
28	Blockchain technology is a reliable method to ensure data integrity	1	2	3	4	5
29	We are concerned about possible security breaches that could hurt the business	1	2	3	4	5
30	We have separate network accesses for guests only	1	2	3	4	5
31	Portable devices usually connected to the internal network are also used to connect to other external networks (e.g. laptop when business traveling/ or home office)	1	2	3	4	5
32	We use institutional extensions for our email accounts	1	2	3	4	5
33	We use strong passwords (at least 8 characters, letters lower and upper case, numbers and special characters)	1	2	3	4	5
34	Passwords are changed frequently	1	2	3	4	5
35	We use biometric data (fingerprint, facial, voice, iris recognition,etc) for authentication for local and remote access points.	1	2	3	4	5
36	We share passwords for convenience.	1	2	3	4	5
38	We prefer onsite servers to cloud services for file storage, mail servers, application deployments, etc.	1	2	3	4	5
39	Our firewall incorporates the latest in threat detection and prevention technologies	1	2	3	4	5
40	We use third party applications that are hosted on our network	1	2	3	4	5
41	Information coming from sensors or other smart devices have high standards of security in connection to our servers.	1	2	3	4	5
42	If any server crashes, we have updated backups.	1	2	3	4	5

43	We have permissions to install any application on our work computer.	1	2	3	4	5
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Administrative Security

The questions should be answered in terms of the Organization or CRFS (when identified as such)

No		Totally Disagree	Disagree	Neither Agree/ Neither Disagree	Agree	Totally Agree
44	Employees are allowed to bring their own devices to work and have full access to the network and applications.	1	2	3	4	5
45	We have a Business Continuity Plan	1	2	3	4	5
46	We outsource cyber-security to external experts	1	2	3	4	5
47	We have an in-house team capable to handle cyber security issues	1	2	3	4	5
48	We have a policy manual on IT and cyber security that is reviewed and updated regularly	1	2	3	4	5
49	We use external consultants to carry out reviews of the manual on IT and cyber security	1	2	3	4	5
50	We use external consultants to carry out penetration testing	1	2	3	4	5
51	We have a person responsible for cybersecurity	1	2	3	4	5
53	We have clearly defined protocols for cybersecurity	1	2	3	4	5
54	Employees are familiar with the established protocols for cybersecurity	1	2	3	4	5
55	There is a budget allocated to cybersecurity	1	2	3	4	5
56	There is regular training for cybersecurity	1	2	3	4	5