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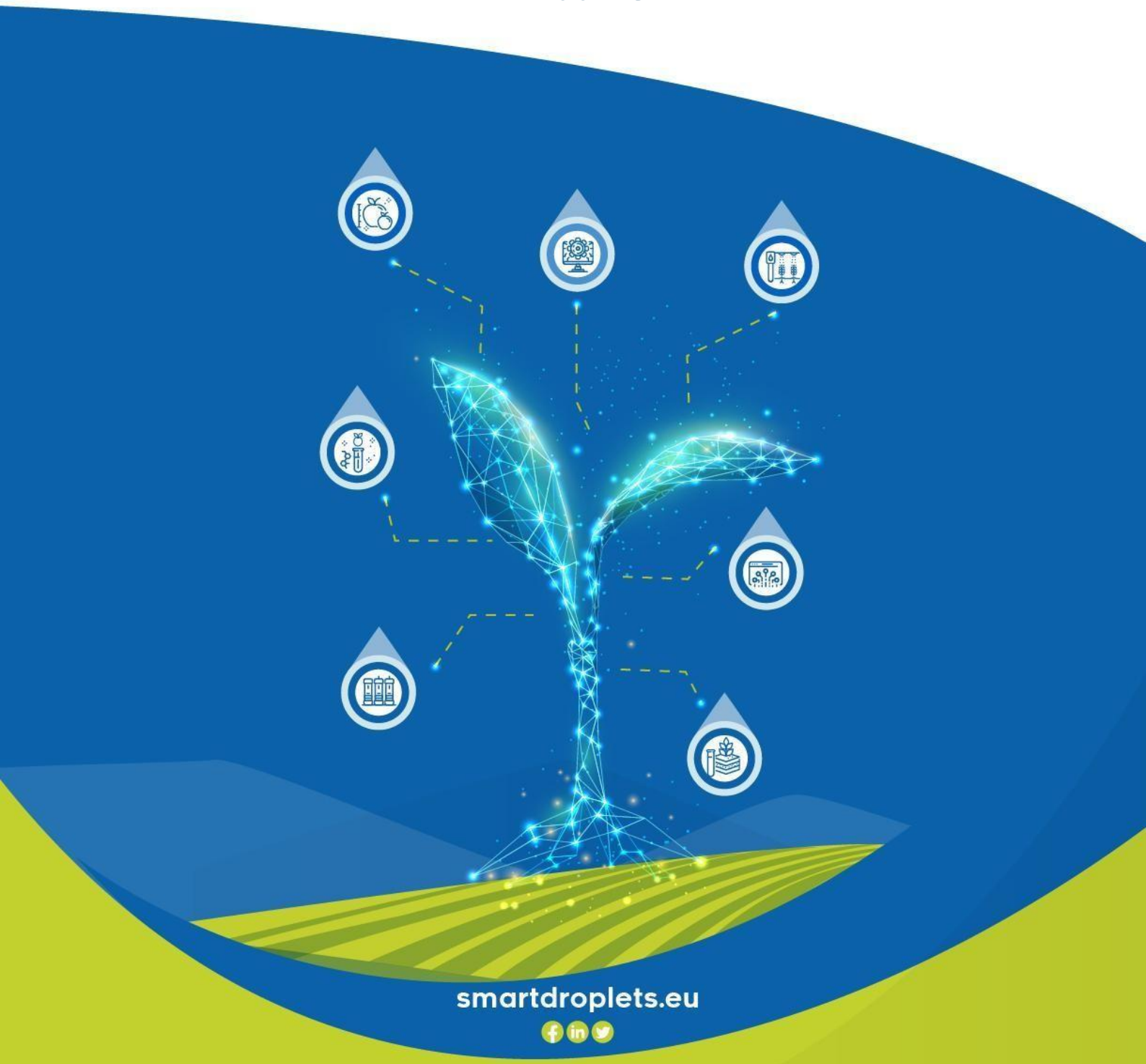
Smart Droplets

D2.2 Reference Architectures and Resources Mapping



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Project acronym: Smart Droplets
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List of Abbreviations and Acronyms	
AI	Artificial Intelligence
IoT	Internet of Things
WUR	Wageningen University & Research
FMIS	Farm Management Information Software
DIS	Direct Injection Spraying
KO	Key Objective
KPI	Key Performance Indicators
EU	European Union
CAP	Common Agricultural Policy
WP	Work Package
DIH	Digital Innovation Hub
BDVA	Big Data Value Association
IDSA	Data Spaces Association

Table 1 List of Abbreviations and Acronyms

1. Introduction

Agriculture is an important sector that provides food and raw materials for human and animal consumption. With the advent of new technologies and increasing demand for sustainable food production, there is a growing interest in the application of AI, data analytics, and robotics in agriculture. To this end, the Smart Droplets project introduces a novel approach for crop care tasks, by connecting key-technological aspects during open field spraying. Based on the scope of the EU Green Deal and the recently reformed Common Agricultural Policy (CAP), Smart Droplets is committed to advance both hardware and software capabilities during chemical application, in order to meet the sustainability goals. This report provides a comprehensive review of reference architectures, common resources, and prospective links with other AI, data, and robotics projects and initiatives in agriculture.

1.1. Purpose, context, and scope of this deliverable

The current document constitutes the outcome of T2 "Building on Existing Reference Architectures & Results" and includes the first results of a process that will be concluded by M18 of the project. The aim of this report is to present the current status of the online desk research process conducted by AFL and contributed by WUR, AUA and EUT, on currently available reference architectures and open common resources that could contribute to the SmartDroplets solution and enhance its interoperability by utilizing common open APIs and common layers for data and services. In addition, D2.2 includes the results of the initial research that was conducted on potential prospective links of the SmarDroplets solution with other existing solutions and initiatives in AI, Data and Robotics, and other programs (DIHs, pilots, data platforms, and other projects). The goal of this deliverable is to provide a set of recommendations and upcoming action points that will be fed into the Autonomous Robotic Spraying System reference architecture under WP5 of the project.

1.2. Deliverable Overview and Report Structure

D2.2 "Reference Architectures and Resources Mapping" is a report with a twofold goal; on one hand, it aims to serve as a source of information to the WPs involved in the development of the SmartDroplets solution on existing resources and reference architectures that could potentially enhance its interoperability; on the other hand, aims to provide a concrete set of examples of available, relevant solutions and to suggest potential ways of linkage between them and SmartDroplet solution. To this end, the deliverable is structured under the following scheme, featuring three main sections:

- Reference Architectures: A detailed presentation on available reference architectures – models, frameworks, features, etc. – with a specific focus on the Big Data Value Association (BDVA) and its components and on the International Data Spaces Association (IDSA).

- Common Resources: A detailed presentation of common resources – data sets, tools, etc. – that are available via open-source software, open data initiatives, or collaborative platforms.

- Prospective links with other AI, Data and Robotics Tools: A list of examples of currently existing solutions – products, relevant EU projects, etc. – and suggestions of potential linkage between them and the SmartDroplets solution.

Finally, a section on the "Next Steps" is included which provides a set of recommendations and guidelines for the upcoming action points to be taken within the further implementation of T2.2 "Building on Existing Reference Architectures & Results".

It is important to be noted that this deliverable includes the results of a process that is being and will be continued up until M18 of the project. The outcomes of it and the respective sets of recommendations will be further expanded and enriched with additional content throughout this period.

2. Methodology, Objectives and Results Transferability

The key objective of Smart Droplets projets is as follows : Smart Droplets' main objective is to advance both hardware and software capabilities during chemical applications for resource optimisation and minimisation of chemical waste. To accomplish this vision, this project will use already existing technologies (>TRL 7) developed within but not limited to the agricultural industry. Its ultimate aspiration is to deliver a complete system capable of translating large amounts of data from the field into meaningful information and impactful spraying commands to achieve the Green Deal goals.

The D2.2 Reference Architectures and Resource Mapping deliverable contributes to Smart Droplets KO#1: Innovate using intelligent (non-robotic) Data infrastructure and Digital Twins: "In Smart Droplets, data interoperability, warehousing and exploitation by AI models is crucial to support large- scale demonstrators and continuously monitor and refine big amounts of field data. Digital Twins and AI models will play an instrumental role in analyzing field data about crop growth and enemies' expansion, while recommending optimal spraying strategies, which will bring the solutions ready to practice.

And in particular to KPI1.1 Interoperable interface adapters with up to 5 third party services VMs: Selection of 3rd party services for data provision and for utilizing Smart Droplets Digital Twins. This task contributing to it by reinforcing interoperability of the Smart Droplets solution with available common resources.

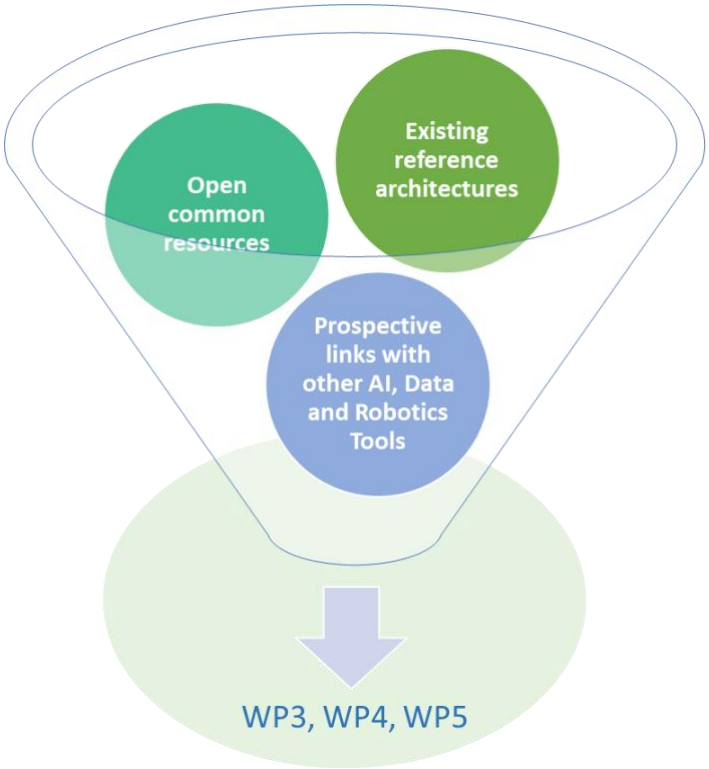

Figure 1 Results trasferability of D2.2

The review produced a set of recommendations to be fed into the Autonomous Robotic Spraying System reference architecture (WP5). The architecture aligning with relevant model architectures (from BDVA and

IDSA) and will use experiences from different platforms, extending the proposed Smart Droplets architecture.

The review was conducted by researching all available open source common resources, reference architectures, AI Data, Robotics projects preferability given for European projects and initiatives. Set of recommendations were created for Smart Droplets sollution based on delivered research to feed into the Autonomous Robotic Spraying System reference architecture (WP5). The task also contributes to other workpackadges (WP3, WP4) by supplying references to other Smart Droplets components - Digital Platform and Digital Twin Intelligence, Autonomous Robotic Spraying System and Field Deployment.

3. Reference architectures, common resources and prospective links with other AI, Data and Robotics projects

3.1. Reference architectures

Reference architectures are blueprints or frameworks for designing and implementing systems or applications that are optimized for specific tasks or domains. In agriculture, reference architectures can be used to design and implement systems that leverage technologies such as AI, data analytics, and robotics to improve crop yields, reduce waste, and increase efficiency.

The Big Data Value Association (BDVA) provides a comprehensive framework for designing, building, and deploying big data solutions in various sectors, including agriculture. Here are some of the components of the Big Data Value Reference Architecture (BDVA RA) that can be applied to the agriculture industry:

- Data sources: The BDVA RA identifies different sources of data, such as IoT sensors, remote sensing systems, and social media platforms, which can be leveraged to collect data in the agriculture industry. For example, IoT sensors can be used to collect data on soil moisture, temperature, and nutrient levels, while remote sensing systems can be used to collect data on crop health and growth patterns.

- Data management: The BDVA RA provides guidelines for managing and storing big data. In agriculture, this component can be used to manage data related to crop production, yield, soil quality, and weather patterns. The guidelines can help ensure that the data is stored securely and can be easily accessed and analyzed by farmers, agronomists, and researchers.

- Data analysis: The BDVA RA identifies various techniques and tools for analyzing big data, such as machine learning algorithms, data mining, and predictive analytics. These techniques can be applied to agriculture to identify patterns and insights that can improve crop yields and reduce waste. For example, machine learning algorithms can be used to analyze data on crop growth patterns and recommend optimal fertilizer and pesticide use.

- Data visualization: The BDVA RA provides guidelines for presenting big data in a meaningful and understandable way. In agriculture, this component can be used to visualize data related to crop growth, yield, and soil quality. Visualization techniques can help farmers and agronomists to quickly identify areas where improvements are needed and take corrective actions.

- Data sharing: The BDVA RA provides guidelines for sharing big data securely and efficiently. In agriculture, this component can be used to build data sharing platforms that enable farmers, agronomists, and researchers to collaborate on improving agricultural practices. For example, a data sharing platform can be built to allow farmers to share data about their crop yields, soil quality, and farming practices with researchers who can use this data to develop new insights and recommendations for improving crop productivity.

The International Data Spaces Association (IDSA) is a non-profit organization that promotes secure data sharing and data sovereignty across various industries, including agriculture. While the IDSA does not have specific reference model architectures for agriculture, the following components of the Industrial Data Space (IDS) Reference Architecture can be applied to the agriculture industry:

- Connector: The IDS Reference Architecture provides a standardized approach to connecting different data sources, such as sensors, mobile devices, and cloud platforms. In agriculture, this component can be used to connect data sources related to crop production, soil quality, and weather patterns. For example, sensors can be used to collect data on soil moisture and nutrient levels, which can be integrated into a cloud platform for further analysis.

- Gateway: The IDS Reference Architecture provides a gateway component that enables secure and reliable data exchange between different data sources. In agriculture, this component can be used to ensure that data is shared securely between different stakeholders, such as farmers, agronomists, and researchers. For example, a gateway can be built to enable farmers to share data related to their farming practices with researchers who can use this data to develop new insights and recommendations.

- Broker: The IDS Reference Architecture provides a broker component that enables secure and trustworthy data exchange between different data platforms. In agriculture, this component can be used to build data marketplaces that enable farmers to sell their data to researchers, agronomists, and other stakeholders. For example, a data marketplace can be built to enable farmers to sell data related to their crop yields and farming practices to researchers who can use this data to develop new insights and recommendations.

- Trust: The IDS Reference Architecture provides a trust component that enables stakeholders to establish trust relationships with each other based on agreed-upon policies and rules. In agriculture, this component can be used to ensure that data is shared securely and with appropriate access rights. For example, farmers can establish trust relationships with researchers and agronomists to share data related to their farming practices and crop yields.

BDVA and IDSA do not have specific reference model architectures for agriculture, but they provide general frameworks and architectures that can be applied to robotic, AI povered system and integrated so ensure interoperability and functionality of the systems:

- The Big Data Value Association's Big Data Value Reference Architecture (BDVA-BDRA) is a comprehensive reference architecture for big data solutions. It provides a blueprint for designing, implementing, and managing big data solutions that are interoperable, scalable, and secure.
  The BDVA-BDRA is organized into several layers, each of which represents a different aspect of the big data solution, such as data acquisition, data storage, data processing, and data analytics. These layers are connected by a set of interfaces and protocols that enable communication and data exchange between the different components of the solution.
  The BDVA-BDRA also includes a set of building blocks, each of which represents a functional component or capability required for a complete big data solution. These building blocks are designed to be modular and interchangeable, allowing organizations to customize their big data solutions based on their specific needs and requirements.
  The BDVA-BDRA is designed to be flexible and adaptable to different use cases and industries. It is intended to be used as a starting point for organizations developing big data solutions, allowing them to leverage the BDVA-BDRA's common language and data model to create interoperable and standardized solutions.

The BDVA-BDRA is closely aligned with other reference architectures developed by the BDVA, such as the Common Big Data Architecture (CBD) and the Architecture Reference Model for AI (BDVA-ARM). Together, these architectures provide a comprehensive framework for developing big data and AI solutions that are interoperable, scalable, and secure.

- The Big Data Value Association's Common Big Data Architecture (CBD) is a reference architecture that provides a common language and data model for big data solutions. The CBD aims to facilitate the interoperability and integration of big data solutions by defining a standard architecture that can be adopted by various industries and domains.
  The CBD consists of a set of building blocks, each of which represents a functional component or capability required for a complete big data solution. These building blocks are organized into layers, each of which represents a different aspect of the big data solution, such as data acquisition, data storage, data processing, and data analytics.

  The CBD is designed to be flexible and adaptable to different use cases and industries. It is intended to be used as a starting point for organizations developing big data solutions, allowing them to leverage the CBD's common language and data model to create interoperable and standardized solutions.

  The CBD is closely aligned with other reference architectures developed by the BDVA, such as the Big Data Value Reference Architecture (BDVA-BDRA) and the Architecture Reference Model for AI (BDVA-ARM). Together, these architectures provide a comprehensive framework for developing big data and AI solutions that are interoperable, scalable, and secure.

- The Big Data Value Association's Data Management Framework (DMF) is a set of guidelines and best practices for managing and processing data in big data solutions. The DMF provides a framework for organizations to manage data throughout its entire lifecycle, from data acquisition to data processing, storage, and analysis.

  The DMF is designed to ensure that data is managed in a consistent and transparent manner, enabling efficient data exchange and collaboration across different applications and domains. The framework is also intended to ensure that data is protected, secure, and compliant with relevant regulations and industry standards.

  The DMF consists of several components, including data governance, data quality management, data privacy and security, and data storage and retrieval. These components are integrated and interconnected, enabling organizations to manage data holistically and efficiently.

  The DMF is closely aligned with other reference architectures developed by the BDVA, such as the Big Data Value Reference Architecture (BDVA-BDRA) and the Architecture Reference Model for AI (BDVA-ARM). Together, these architectures provide a comprehensive framework for developing big data and AI solutions that are interoperable, scalable, and secure, while also ensuring that data is managed in a consistent and transparent manner throughout its entire lifecycle.

- The Big Data Value Association's Architecture Reference Model for AI (BDVA-ARM) is a reference architecture that provides a framework for developing AI solutions that are interoperable, scalable, and secure. The BDVA-ARM is designed to enable the development of AI solutions that can be integrated with other systems and data sources, while also ensuring that data is managed and processed in a transparent and secure manner.

  The BDVA-ARM consists of several components, including data management, AI model management, AI execution, and application management. These components are integrated and interconnected,

enabling organizations to develop AI solutions that are modular and flexible, and can be adapted to changing requirements and environments.

The BDVA-ARM is designed to be used in conjunction with other reference architectures developed by the BDVA, such as the Big Data Value Reference Architecture (BDVA-BDRA) and the Data Management Framework (DMF). Together, these architectures provide a comprehensive framework for developing big data and AI solutions that are interoperable, scalable, and secure, while also ensuring that data is managed and processed in a consistent and transparent manner throughout its entire lifecycle.

The BDVA-ARM is intended to be a flexible and adaptable framework that can be customized to suit the specific requirements and use cases of different organizations and industries. It is intended to enable the development of innovative AI solutions that can transform business processes and create new opportunities for growth and value creation.

- The Industrial Data Space (IDS) Reference Architecture: The IDS Reference Architecture is a framework for building secure and trusted data sharing platforms. In agriculture, this architecture can be used to build data sharing platforms that enable farmers, agronomists, and researchers to share data and collaborate on improving agricultural practices. For example, a data sharing platform can be built to allow farmers to share data about their crop yields, soil quality, and farming practices with researchers who can use this data to develop new insights and recommendations for improving crop productivity.

- The European Interoperability Reference Architecture (EIRA): The EIRA is a standardized approach to designing and implementing interoperable IT systems across different public administrations in Europe. In agriculture, this architecture can be used to build interoperable systems that enable farmers to exchange data with different stakeholders, such as government agencies, industry associations, and researchers. For example, a system can be built to enable farmers to report their crop yields to government agencies for regulatory compliance purposes, while also allowing researchers to access this data for developing new insights and recommendations.

Overall, while BDVA and IDSA do not have specific reference model architectures for agriculture, their general frameworks and architectures can be applied to the agriculture industry to design, develop, and deploy data-driven solutions that can improve agricultural practices and increase productivity.

Some other reference architectures in agriculture that can be found and are used globally:

- Precision Agricultural Connectivity Taskforce (PACT) Architecture: PACT is a standardized architecture that enables the integration of various sensors, devices, and software tools to collect and analyze data on soil moisture, temperature, and other environmental factors. This architecture allows farmers to make data-driven decisions and optimize crop yields.

- Global Open Data for Agriculture and Nutrition (GODAN) Reference Architecture: GODAN is a global partnership that promotes open data policies and standards for agriculture and nutrition. Its reference architecture provides guidelines for creating and sharing open data sets in agriculture, with a focus on interoperability and standardization.

- Open Ag Data Alliance (OADA) Reference Architecture: OADA is an open-source project that provides tools and services for sharing and managing data in agriculture. Its reference architecture defines a common framework for managing data across different types of farming operations and data sources.

- Agricultural Data Application Programming Interfaces (APIs) Reference Architecture: This reference architecture defines a common framework for building APIs that can be used to access and share

agricultural data across different systems and applications. This architecture promotes interoperability and data sharing in agriculture.

- FarmOS Reference Architecture: FarmOS is an open-source farm management system that enables farmers to manage their operations and data in a single platform. Its reference architecture provides guidelines for designing and implementing a modular, extensible, and interoperable system that can be customized to meet the needs of different types of farms.

These reference architectures are designed to promote interoperability, standardization, and data sharing in agriculture, with the goal of improving productivity, sustainability, and food security.

3.2. Common resources

Common resources are open resources of shared tools, datasets, and others that can be used by different stakeholders in agriculture. These resources are typically made available through open-source software, open data initiatives, or collaborative platforms, and they can help farmers, researchers, and other stakeholders in agriculture to make better decisions, optimize their operations, and improve productivity and sustainability. These common data resources include:

- European Soil Data Centre: The European Soil Data Centre (ESDAC) is an initiative that provides access to a wide range of soil data and information for Europe. It includes databases on soil properties, soil erosion, and soil biodiversity, as well as mapping tools and analysis services.
- Agro-Environmental Indicators: The European Commission's Joint Research Centre (JRC) has developed a set of agro-environmental indicators that can be used to assess the environmental performance of agriculture in Europe. The indicators cover a range of environmental factors, such as soil quality, water quality, and biodiversity.
- The European Centre for Medium-Range Weather Forecasts (ECMWF), and the Intergovernmental Panel on Climate Change (IPCC): Provides climate data that can be used to track historical weather patterns and predict future climate trends.
- Eurostat: Eurostat is the statistical office of the European Union and provides a wide range of agriculture-related data, including crop production, livestock populations, agricultural prices, and trade statistics.
- Copernicus: Copernicus is a European Earth Observation Programme that provides satellite imagery and other data related to climate change, land use, and environmental monitoring. The programme offers free and open access to its data.
- European Environment Agency (EEA): The EEA provides a range of environmental data related to air and water quality, biodiversity, and land use. The agency's data can be used to inform agricultural practices and improve sustainability.
- Joint Research Centre (JRC): The JRC is the European Commission's in-house science service and provides a range of data and tools related to agriculture, such as crop yield forecasting, soil erosion risk assessment, and climate change adaptation.
- European Drought Observatory (EDO): The EDO is a platform that provides drought-related data and information for Europe. The platform can be used to monitor drought conditions and inform water management and irrigation decisions.
- Farm Management Information Systems (FMIS): FMIS platforms provide farmers with tools to manage their operations, such as crop planning, soil analysis, and yield forecasting. Some FMIS platforms, such as Agroptima and FieldBee, also provide integration with IoT sensors and weather data.

- Agro-Weather Data: Agro-Weather Data provides weather-related data for agriculture, such as temperature, humidity, rainfall, and evapotranspiration. The platform offers data for various European countries, including Germany, France, Italy, and Spain.

These data resources provide a wealth of information for farmers, researchers, and other stakeholders in the agriculture industry and are open sources. By integrating these data sources into smart farming platforms, stakeholders can optimize their operations, reduce waste, and improve sustainability.

3.3. Prospective links with other AI, Data and Robotics Tools

There are some prospective links with other AI, Data and Robotics Tools that have been developed through different projects and initiatives. Smart Droplets Solution might find alliance, intercompatibility links and good practice examples amongst these initiatives. Smart Droplets Solution were separated into three components: AI, Digital Farm Twins, Deep Learning component, Retrofit Spraying, DIS intelligent spraying and Autonomous Navigation, Data Storage component. For each component the detailed research was conducted. Overview of the findings presented below:

SmartDroplets Solution	Resource Name	Type of solution	Website
AI/ Digital Farm Twins/ Deep Learning	**FarmTelemetry**	Applications oriented on precision farming, farm telemetry, sustainable agriculture.	https://www.lesprojekt.cz/en/nase-aplikace/
	365Farmnnet	Agriculture management and planning applications	https://www.365farmnet.com/en/
	InGreens	Platform for management	http://www.ingreens.in/insurtech.html
	AgTwin	Platform, which creates digital twins of farm properties using real-time data	https://agronomeye.com.au/
	Azure FarmBeats	Data integration and aggregation platform in the cloud	https://learn.microsoft.com/en-us/azure/industry/agriculture/overview-azure-farmbeats
	Precision Farming Network & xFarm	Precision technology for total tracking of agricultural activities	https://www.pfnetwork.eu/en/; https://xfarm.ag/?lang=en
	CropX	Software application	https://cropx.com/
	Beriqo	Deep learning and satellite imagery.	https://www.beriqo.com/
	Dataloop	Machine learning solutions for agriculture practices	https://dataloop.ai/solutions/precision-agriculture/
	Anolytics	Machine learning solutions for agriculture practices	https://www.anolytics.ai/
	Cropin	AI solutions for agriculture	https://www.cropin.com/

	SWAMP	Smart Water Management Platform	Smart Water Management Platform | SWAMP Project | Fact Sheet | H2020 | CORDIS | European Commission (europa.eu)
	Asterix	Weeding robot for precision farming reducing herbicide usage by 95%	NTNU Open: Asterix: Robotic weed control in row crops
	COGNAC	Fraunhofer Lighthouse Project "Cognitive Agriculture	Fraunhofer Lighthouse Project "Cognitive Agriculture (COGNAC)" - Fraunhofer IESE
	FarmMaps	Open web-based data service platform for advanced precision farming	https://www.farmmaps.net/en/
	agroNET	Farm management platform	https://digitalfarming.eu/
	watchITgrow	Online platform that supports growers to monitor crops.	https://watchitgrow.be/en
	Flexigrobots	Flexible robots for intelligent automation of precision agriculture operations	Flexible robots for intelligent automation of precision agriculture operations | FlexiGroBots (flexigrobots-h2020.eu)
Retrofit Tractor/ DIS - intelligent spraying	**AGXEED**	Autonomy AgBots	https://www.agxeed.com/#
	JOHN DEERE	Autonomous tractor	https://www.deere.com/en/news/all-news/autonomous-tractor-reveal/
	Autonomous Tractor Corporation (ATC)	Autonomous tractor kits/sprayer	https://www.autonomoustractor.com/
	FiledBee	Retrofit tractor kits	https://www.fieldbee.com/
	Hol Spraying Systems	Weedsprayers/AgBot - Autonomous machine	https://holsprayingsystems.com/products/hss-fruit-agbot-autonomous-machine/
	BLUEWHITE	The Autonomous Platform and tractor robot kit	https://www.bluewhiterobotics.com/technology/
	Bilberry	Real-Time Spot Spraying	https://bilberry.io/how-does-it-work/
	Carbon Bee Agtech – Smart Striker	Real-Time smart Spot Spraying	https://carbonbee-agtech.fr/#technology
	BLUE RIVER Technology	See&Spray	https://bluerivertechnology.com/
	Bosch/BASF	Smart Spraying	https://www.smartfarming.ag/smart-spraying_en.html
	ECOROBOTIX	Tractormounted Smart Spraying	https://ecorobotix.com/en/
	TRIMBLE. Agriculture	Crop protection & spraying	https://agriculture.trimble.com/en/solutions/crop-protection

	WEED-IT	Tractormounted precision spraying	https://www.weed-it.com/
	GREENEYE Technology	Selective Spraying (SSP) system integrates to any agriculture sprayer to enable the precise spraying	https://greeneye.ag/
	Asterix	Weeding robot for precision farming reducing herbicide usage by 95%	NTNU Open: Asterix: Robotic weed control in row crops
	COGNAC	Fraunhofer Lighthouse Project "Cognitive Agriculture	Fraunhofer Lighthouse Project "Cognitive Agriculture (COGNAC)" - Fraunhofer IESE
Autonomous Navigation/Data Storage	**ALAV**	Autonomous Lightweight Agricultural Vehicle	https://cordis.europa.eu/project/id/970619
	IoF2020	Internet of Food and Farm 2020	Internet of Food and Farm 2020 - IoF2020
	Asterix	Weeding robot for precision farming reducing herbicide usage by 95%	NTNU Open: Asterix: Robotic weed control in row crops
	Autonomous robots for the agri-food sector	Robot systems that use self-learning and other machine learning approaches.	https://www.wur.nl/en/research-results/research-funded-by-the-ministry-of-lnv/expertisegebieden/kennisonline/autonomous-robots-for-the-agri-food-sector.htm
	AgriRobot	The AgriRobot solution scans in 2D and 3D providing redundancy and a strong data base for detecting obstacles in the field.	https://agrirobot.ai/
	Cognitive Pilot	AI-based crop-harvesting assistant	https://en.cognitivepilot.com/products/cognitive-agro-pilot/
	Agtonomy	A hybrid autonomy and tele-assist platform for agriculture vehicles.	https://www.agtonomy.com/
	ROBS4CROPS	Robots for protecting crops	https://robs4crops.eu/
	ROMI	RObotics for MIcrofarms	https://romi-project.eu/
	AgroDataCube	Big Data collection for Agri-food applications	https://agrodatacube.wur.nl/
	RoboTech Vision	Mobile robots with AI elements	https://robotechvision.com/
All components	**ATLAS**	**Agricultural Interoperability and Analysis System** -	ATLAS - AGRICULTURAL INTEROPERABILITY AND ANALYSIS SYSTEM (atlas-h2020.eu)

incorporating Tools		The goal of ATLAS is the development of an open interoperability network for agricultural applications and to build up a sustainable ecosystem for innovative data-driven agriculture	
	Farm21	Farming technology platform	https://www.farm21.com/
	AI-on-Demand	Knowledge and services for AI community	https://www.ai4europe.eu/
	Digital Industrial Platform	The platform of open-source software tools and technologies	https://robmosys.eu/wiki/community:industrial-platform

Table 2. Robotic solutions and iniciatives that can have interoperatability with Smart Droplets project

3.3.1. AI, Digital Farm Twins, Deep Learning Tools

FarmTelemetry: FarmTelemetry specializes in optimizing agricultural operations by reducing energy consumption required to power machinery, transport inputs and outputs, and providing insights into individual farmer's fields. It accomplishes this by generating Digital Twins that establish the relationships between machinery and fields, enabling real-time monitoring of machinery fleet and energy consumption of crops on specific fields. Additionally, FarmTelemetry evaluates the economic efficiency of crop management treatments and analyzes tractor trajectories, taking into account site-specific soil conditions.

Potential integration/interoperability process - Interoperability could be achieved through Digital Twins technology.

365Farmnnet: 365FarmNet is an award-winning software that automates and streamlines documentation in the field and is stable, providing transparency into work processes and costs for farms of any size. By meeting requirements and cutting costs, it frees up time for farmers to spend on the field rather than in the office.

Potential integration/interoperability process - Interoperability could be achieved through Agricultural management software and datasets.

InGreens: Ingreens is developing a platform that integrates and analyzes data from various sources, allowing for real-time monitoring and intelligent recommendations. The company has already provided a range of software-as-a-solution (SaaS) tools that add value to farmers' operations, such as using satellite data to calculate precise farm yield information. This information is used to determine farm insurance premiums and settle claims with minimal potential for disputes.

Potential integration/interoperability process - Interoperability could be achieved through platform architecture and datasets, software tools.

AgTwin: AgTwin employs high-resolution farm maps and modeling techniques to generate digital twins that depict various data points, such as water flow and soil moisture profiles. While farmers have access to vast amounts of data, integrating and applying it to their specific farms has been a challenge. Agronomeye, however, enables farmers to leverage this data in a more practical, engaged manner.

Potential integration/interoperability process - Interoperability could be achieved through Digital Twin and a Platform technology.

Azure FarmBeats: Azure FarmBeats is a business-to-business service that is accessible through Azure Marketplace. It facilitates the consolidation of agricultural data from various providers, enabling users to create artificial intelligence or machine learning models based on integrated data sets. By using Azure FarmBeats, agricultural businesses can focus on their primary value-adding activities, rather than dedicating time and resources to data engineering tasks.

Potential integration/interoperability process - Interoperability could be achieved through AI and machine learning models.

Precision Farming Network & xFarm: PFN was established to integrate digital services with the equipment of its partners. Precision Farming Network has filed a patent application for a system that monitors equipment activities in the field, which is also available to xFarm users. This is accomplished using a groundbreaking digital twin, a digital representation of each piece of machinery that facilitates the creation of new digital services to meet the demands of precision agriculture.

Potential integration/interoperability process - Interoperability could be achieved through Digital Twin, datasets and digital services.

CropX: CropX is a user-friendly dashboard, accessible through both mobile and desktop applications, and provides recommendations that incorporate data from various sources, such as soil sensors, satellites, crop models, and field characteristics.

Potential integration/interoperability process - Interoperability could be achieved through data and data management.

Beriqo: Beriqo provides frequent updates on field conditions that support optimal crop management for maximum productivity, including water management and crop performance.

Potential integration/interoperability process - Interoperability could be achieved through datasets and Platform.

Dataloop: Computer vision models have the potential to enhance several farming applications, including crop and produce monitoring, livestock management, and aquaculture. However, developing such applications entails working in unstructured, unpredictable, and highly dynamic environments, with constantly changing terrain and target objects. Additionally, preparing agricultural data requires specialized knowledge and expertise during analysis and implementation. Dataloop addresses these challenges by integrating automated active learning and data processing capabilities, along with a human-in-the-loop workforce to validate the data.

Potential integration/interoperability process - Interoperability could be achieved through Platform and datasets.

Anolytics: Anolytics specializes in producing training data for machine learning applications in the agriculture industry. Agricultural data annotation and labeling services aim to overcome the obstacles associated with automating agricultural processes. The labeling platform is compatible with all agricultural workflows and formats, and the Anolytics team of labeling experts can handle all aspects of agricultural data annotation and labeling from start to finish.

Potential integration/interoperability process - Interoperability could be achieved through AI and machine learning technology, datasets and data management, labeling platform.

Cropin: Cropin is solving complex problems across the agriculture value chain. Building a global real-time ag-ecosystem intelligence platform.

Potential integration/interoperability process - Interoperability could be achieved through the platform technology.

SWAMP: The SWAMP project focuses on the development of Internet of Things (IoT) methods and strategies for smart water management in the precision irrigation sector. The project conducts pilot programs in Italy, Spain, and Brazil to test these approaches.

Potential integration/interoperability process - Interoperability could be achieved through IoT -based smart applications, Big Data, Software Platform, Integration of different technologies and tools (sensors, drones etc)

Asterix: The Project aims to develop, test, and market the Asterix weeding robot, which is a cost-effective and eco-friendly solution for the precision farming industry. The autonomous robot, which is lightweight, is specifically designed to combat weeding challenges while drastically reducing herbicide usage by up to 95%. With a patented ultra-high precision nozzle system, Asterix uses machine learning to distinguish between crop and weed appearance, allowing for the targeted application of herbicides exclusively to weeds. This feature enables the use of environmentally friendly weeding agents in both conventional and organic farming practices. The Asterix robot is expected to reduce global herbicide usage by 186 million liters over the first 5 years after its launch, while also reducing the cost of weeding operations by at least 550€ per hectare per year, and mitigating the health and environmental impact associated with traditional weeding methods.

Potential integration/interoperability process - Interoperability could be achieved through AI, machine learning tools and Big Data.

COGNAC: Fraunhofer Lighthouse Project “Cognitive Agriculture” is constructing an "Agricultural Data Space," which will serve as a significant development in digitized agriculture by utilizing innovative automation concepts and new sensor technology to create a data-driven agricultural ecosystem.

Potential integration/interoperability process - Interoperability could be achieved through IoT, Data Space and decision making.

FarmMaps: FarmMaps provides precision farming services and components, including the grower's croppings scheme and weather and rainfall data. These components are fully integrated and share their data and newly generated map layers with other applications on the FarmMaps platform.

Potential integration/interoperability process - Interoperability could be achieved through the Platform and data management.

agroNET: Farm management platform for improving crop production and animal breeding thus enabling transparency and traceability across the food supply chain.

Potential integration/interoperability process - Interoperability could be achieved through Farm management platform.

watchITgrow: WatchITgrow utilizes a range of data sources, including satellite imagery, weather information, soil data, and IoT data, in addition to field data provided by the growers. By utilizing cutting-edge technologies such as big data analytics and machine learning, this data is integrated to deliver more customized and timely recommendations to farmers.

Potential integration/interoperability process - Interoperability could be achieved through IoT, Big Data analytics, machine learning, AI.

Flexigrobots: The FLEXIGROBOTS project, intends to create a platform that can facilitate the construction of multi-robot systems with heterogeneous capabilities. By utilizing existing robots for various tasks, the platform is expected to increase flexibility and generate high-value data from different sources and sensors. This development is anticipated to enhance operational autonomy and precision, while simultaneously reducing costs and promoting robotics investment.

Potential integration/interoperability process - Interoperability could be achieved through IoT, Big Data analytics, machine learning, AI.

3.3.2. Retrofit Tractor and DIS - intelligent spraying Tools

AGXEED: AgXeed's autonomous robotic solutions provide farmers with the opportunity to focus on their core competencies, such as managing resources and cultivating crops, by saving them time. AgXeed provides technologies for automated weeding, seeding and spraying.

Potential integration/interoperability process - Interoperability could be achieved through agricultural machinery operational systems, sensoric systems and LIDAR technology.

JOHN DEERE: Equipped with six pairs of stereo cameras, the John Deere autonomous tractor is capable of detecting obstacles in 360 degrees and calculating their distance. The camera images are fed into a deep neural network, which analyzes each pixel in just under 100 milliseconds to determine if the tractor should continue moving or stop if an obstacle is detected. The tractor also constantly monitors its position in relation to a geofence, ensuring that it operates within the designated area with an accuracy of less than an inch.

Potential integration/interoperability process - Interoperability could be achieved through agricultural machinery operational systems, sensoric systems and LIDAR technology.

Autonomous Tractor Corporation (ATC): The tractor solution is guided across the field using a Laser Radio Navigation System (LRNS) that employs lasers and radio signals. GPS serves only as a backup due to concerns about signal loss, drift, and the possibility of hacking since it lacks encryption. Artificial intelligence software is utilized to execute tasks, and the operator trains the software to do so. Two small domes on top of the tractor contain the proprietary AI software responsible for driving, operating, and making safe decisions.

Potential integration/interoperability process - Interoperability could be achieved through agricultural machinery operational system, AI, software.

FiledBee: Precision farming technology of retrofit tractor kits. Tractor autosteer and manual guidance systems. Smartphone based professional solutions: FieldBee tractor GPS system utilizes smartphones and an Internet of Things (IOT) architecture, thus making the products affordable, modular and updatable.

Potential integration/interoperability process - Interoperability could be achieved through agricultural machinery operational system, AI, software, IoT.

Hol Spraying Systems: The AgBot 2.055W3 & CF2000-AB autonomous machines has multiple functions, including crop protection, weed control, liquid nutrition application, as well as mowing and shredding prunings. Additionally, the tank can be refilled in a controlled and unmanned manner. With the help of a task card, the machine can be instructed precisely what to do by issuing commands, allowing the AgBot 2.055W3 & CF2000-AB to perform its designated tasks efficiently.

Potential integration/interoperability process - Interoperability could be achieved through agricultural machinery operational system, AI, software, IoT.

BLUEWHITE: Bluewhite is a single operator that can operate and oversee a fleet of autonomous vehicles, such as tractors, robots, or drones. The system provides optimal planning and a variety of actionable insights, including timing sprays and harvest decisions, that are accessible at any time. The design is vehicle agnostic, and the self-driving tractor market kit can convert any existing tractor into a fully autonomous one. To ensure real-time situational awareness with no downtime, multiple sensors, ultra-high precision navigation, and robust AI models are utilized.

Potential integration/interoperability process - Interoperability could be achieved through agricultural machinery operational systems, AI, software, IoT, sensoric systems.

Bilberry: The sprayer booms are equipped with high-definition RGB cameras, which are suitable for use with any size of sprayer. These cameras provide complete coverage of the treatment area and capture real-time field data. Computers mounted on the sprayer collect images captured by the cameras and analyze the field's status, offering a personalized assessment of vegetation and weed growth among the crops. A user interface display is installed in the cab, enabling the operator to configure and control the detection process, monitor detections and system status, and send real-time orders to the nozzle controller.

Potential integration/interoperability process - Interoperability could be achieved through sprayer-tractor systems, AI, software, IoT, sensoric systems.

Carbon Bee Agtech – Smart Striker: The Smart Striker by Carbon Bee has adopted a more advanced technique for targeted spraying by integrating three distinct sensors.

Potential integration/interoperability process - Interoperability could be achieved through real-time decision making, sensor - sprayer system.

BLUE RIVER Technology: Blue River had gained recognition for its See & Spray system, which was designed for lettuce crop thinning, prior to the acquisition. The system operates at low speeds to achieve sub-2cm accuracy, identifying unwanted plants and administering a harmful salt solution. However, it was the system's capability to use AI and machine learning to make real-time decisions in the field, rather than its specific application in lettuce thinning, that persuaded Deere to invest in the company. Following the acquisition, efforts have been focused on modifying and enhancing the system for use on large-scale sprayers.

Potential integration/interoperability process - Interoperability could be achieved through real-time decision making, sprayer -tractor system, AI, machine learning.

Bosch/BASF: The Smart Spraying Solution by Bosch/BASF is a comprehensive approach to weed control in agriculture, developed by combining the agronomic and digital knowledge of xarvio with the software and system integration expertise of Bosch. The solution utilizes reliable hardware from Bosch's mass production to deliver an effective and integrated approach to weed management in the field.

Potential integration/interoperability process - Interoperability could be achieved through a smart sprayer system.

ECOROBOTIX: Smart spraying for ultra-localised treatments of your row crops, pastures and lawns.

Potential integration/interoperability process - Interoperability could be achieved through a smart sprayer system.

TRIMBLE. Agriculture: Trimble's precision solution monitors the application and flow of materials in real-time, allowing for improved accuracy and efficiency of inputs. It provides precise application of herbicides, pesticides, and fungicides.

Potential integration/interoperability process - Interoperability could be achieved through a smart sprayer system.

WEED-IT: WEED-IT utilizes spot spraying mode to target all living green material on fallow land, which helps to increase moisture availability, minimize competition, and reduce herbicide resistance. This technology enables precise spraying, using minimal chemicals, making it an ideal option for managing risks and weeds. Additionally, WEED-IT is one of the few manufacturers that can offer dual spraying technology, allowing for low and high application rates with just one spray line.

When in cover mode, WEED-IT functions as a conventional sprayer, with the ability to continuously vary the rate through pulse width modulation. The WEED-IT Quadro system employs advanced communication speeds, allowing for variable rate application, weed and biomass mapping, and the use of application maps.

Potential integration/interoperability process - Interoperability could be achieved through a smart sprayer system.

GREENEYE Technology: Greeneye leverages artificial intelligence and deep learning technology to transform pest control in agriculture. Instead of the current practice of spraying pesticides broadly and wastefully, Greeneye enables precise and selective spraying, leading to a more effective pest control process.

Potential integration/interoperability process - Interoperability could be achieved through a smart sprayer system.

Asterix: The Project aims to prototype, pilot, and commercialize Asterix, our cost-effective and environmentally friendly weeding robot, for the global precision farming sector. Asterix is a lightweight and autonomous robot that provides a unique solution to weeding challenges while significantly reducing herbicide usage by 95%. The robot incorporates a patented, vision-based, ultra-high precision nozzle system that relies on a state-of-the-art machine learning platform. This platform is trained to differentiate between the appearance of crops and weeds, allowing Asterix to apply herbicide only to weeds and not to crops or soil. As a result, novel and environmentally safe weeding agents can be used in both conventional and organic agriculture. The adoption of Asterix is expected to reduce herbicide usage in the global farming sector by 186 million liters in the first 5 years after the Project. Moreover, it will significantly reduce the health and environmental impact of agricultural weeding operations and cut their costs by at least 550€ per hectare per year.

Potential integration/interoperability process - Interoperability could be achieved through a smart sprayer system.

COGNAC: Fraunhofer Lighthouse Project “Cognitive Agriculture” is constructing an "Agricultural Data Space," which will serve as a significant development in digitized agriculture by utilizing innovative automation concepts and new sensor technology to create a data-driven agricultural ecosystem.

Potential integration/interoperability process - Interoperability could be achieved through IoT, Data Space and decision making.

3.3.3. Autonomous Navigation and Data Storage Tools

ALAV: Whether operating as a single unit or as part of a fleet, the ALAV can carry out all cultivation cycle operations independently and safely, thanks to its precision robotics technology. Moreover, the ALAV operates below the irreversible soil compaction threshold, avoiding further soil degradation in contrast to increasingly heavy conventional machinery. This results in healthier crops and higher yields. The ALAV is equipped with a cloud-based operating portal, a road-compliant transportation module, and is designed as a platform that can be linked with conventional implements already in use by farmers. As an autonomous system, the ALAV eliminates labor shortages during seasonal peaks and offers significant savings for farmers in terms of both labor and operational costs.

Potential integration/interoperability process - Interoperability could be achieved through autonomous navigation system, data and data storage.

IoF2020: The IoF2020 project is dedicated to accelerate adoption of IoT for securing sufficient, safe and healthy food and to strengthen competitiveness of farming and food chains in Europe.

Potential integration/interoperability process - Interoperability could be achieved through autonomous operation system, data-driven farming.

Asterix: The Project's main objective is to create a cost-effective and eco-friendly weeding robot, Asterix, for the global precision farming industry, by prototyping, piloting, and commercializing it. Our autonomous, lightweight robot is the only product on the market that effectively tackles weeding challenges while reducing herbicide usage by 95%. Asterix's vision-based, patented, ultra-high precision nozzle system is based on an advanced

machine learning platform trained to distinguish between intertwined crops and weeds. It applies herbicides only to weeds, not to crops or soil, allowing the use of innovative and environmentally safe weeding agents in both conventional and organic farming. In the first five years of the project, Asterix will prevent the use of 186 million liters of herbicides in the global farming industry, reducing the health and environmental impact of weeding operations and lowering their costs by at least 550€ per hectare per year.

Potential integration/interoperability process - Interoperability could be achieved through autonomous navigation systems, data, data storage and a platform.

Autonomous robots for the agri-food sector: The objective of this project is to build proficiency in robot systems that employ self-learning and other machine learning techniques, enabling them to operate in dynamic, unstructured environments that involve numerous interactions between robots, humans, plants, and animals. The project emphasizes both technology and the ethical and social considerations of robot innovation in real-world settings.

Potential integration/interoperability process - Interoperability could be achieved through autonomous navigation systems, data, data storage and a platform.

AgriRobot: AgriRobot's safety solution utilizes technology derived from self-driving cars and last-mile delivery robots, which have been modified to function in an agricultural setting, taking into account factors such as plants, weeds, livestock, and machine operators. They employ off-the-shelf self-driving vehicle components, in conjunction with established core technologies in perception and computer vision.

Potential integration/interoperability process - Interoperability could be achieved through autonomous navigation systems, data, data storage and a platform.

Cognitive Pilot: AI-based crop-harvesting assistant with 3 different autonomous driving modes.

Potential integration/interoperability process - Interoperability could be achieved through autonomous navigation systems, data, data storage and a platform.

Agtonomy: The Agtonomy platform reduces the expenses associated with repetitive tasks like mowing, spraying, and precision weeding. Our solution offers increased capabilities and enhanced safety features compared to traditional tractors. The technology is tailored specifically for use in agriculture and land maintenance. Moreover, the Agtonomy platform facilitates data-driven services that empower local farmers to make ongoing enhancements while dealing with budget constraints and seasonal obstacles.

Potential integration/interoperability process - Interoperability could be achieved through autonomous navigation systems, data, data storage and a platform.

ROBS4CROPS: ROBS4CROPS aims to accelerate the adoption of high-tech robotics and automated technologies in the European food and farming industry, acting as a vital catalyst for innovation. Leveraging existing agricultural machinery, standards, and best practices, the project seeks to develop a flexible and modular fully autonomous system that can be tested at a large scale through partnerships with commercial farms and business leaders in France, Greece, Spain, and the Netherlands over a period of four years. By reducing farmers' reliance on hired labor, increasing safety, and decreasing the use of inputs and overall carbon footprint of food production, ROBS4CROPS is poised to deliver significant benefits to the industry.

Potential integration/interoperability process - Interoperability could be achieved through autonomous navigation systems, data, data storage and a platform.

ROMI: ROMI is aiming to create a lightweight and open robotics platform specifically designed for microfarms. The platform will assist these farms with tasks such as weed reduction and crop monitoring, resulting in reduced manual labor and increased productivity. The weeding robot developed by ROMI will save farmers 25% of their time, and will be complemented by a drone that provides more comprehensive information at the crop level.

Together, these tools will create an integrated, multi-scale view of crop development that will help farmers increase their efficiency in harvesting. ROMI will adapt and expand existing land-based and airborne monitoring tools to handle the unique complexities of small fields with mixed crops and complex layouts.

Potential integration/interoperability process - Interoperability could be achieved through autonomous navigation systems, data, data storage and a platform.

AgroDataCube: This platform (managed by WUR) aims to provide a collection of open data pertaining to Agri-food applications. It is still a work in progress, so the website and platform will be updated more in the future.

Potential integration/interoperability process - Interoperability could be achieved through data, data storage and a platform.

RoboTech Vision: RoboTech Vision develops robotic platforms designed for different environments and tasks, on which it deploys its intelligent software.

Potential integration/interoperability process - Interoperability could be achieved through data, data storage and a platform.

3.3.4. All components incorporating Tools

ATLAS: The main goal of ATLAS is to create a digital service platform for agriculture applications that will promote sustainable and innovative data-driven agriculture practices. The platform will address the issue of lacking interoperability in agriculture by enabling the flexible integration of agricultural machinery, sensor systems, and data analysis tools. It will offer hardware and software interoperability layers that will enable the collection and sharing of data from various sensors and analysis tools. The benefits of data-driven agriculture will be demonstrated through pilot studies conducted using the ATLAS platform, and a network of end-users, service providers, researchers, and policy makers, known as "Innovation Hubs," will be established to promote digital agriculture across the agricultural value chain. ATLAS will also attract innovative companies through seed funding to provide their services on the platform. The knowledge gained from the pilot studies will be used to define the next generation of standards for data-driven agriculture.

Potential integration/interoperability process - Interoperability could be achieved through all components

Farm21: Farm21 is a farming technology platform that allows farmers to optimize their operations through data-driven insights. By collecting and analyzing data from various sources such as weather forecasts, crop yields, soil conditions, and market prices, the platform enables farmers to make informed decisions on when to plant, fertilize, irrigate, and harvest their crops.

Potential integration/interoperability process - Interoperability could be achieved through all components

AI-on-Demand: AI4EU is a collaborative platform that aims to accelerate the development and adoption of artificial intelligence (AI) in Europe. It is a three-year project funded by the European Union under the Horizon 2020 research and innovation program.

Potential integration/interoperability process - Interoperability could be achieved through all components

Digital Industrial Platform: The development of the industrial platform is part of the RobMoSys project, which is a European Union-funded initiative aimed at advancing the field of robotics and automation. The platform is built on a set of open-source software tools and technologies that enable developers to create and integrate new components and systems easily.

Potential integration/interoperability process - Interoperability could be achieved through all components.

4. Recommendations

The Smart Droplets project is focused on the development of an intelligent, modular system. To ensure the success of this project, it is essential to consider existing reference architectures, common resources, and other robotics projects and initiatives, particularly those developed by the Big Data Value Association (BDVA) and the Industrial Data Space Association (IDSA).

Here are some recommendations that could be fed into the Smart Droplets project solution reference architecture:

- Incorporate the principles of the BDVA's Big Data Value Reference Architecture (BDVA-BDRA) and the IDSA's Industrial Data Space (IDS) architecture to ensure that the Smart Droplets system is interoperable and can seamlessly integrate with other systems and data sources.

- Utilize the BDVA's Common Big Data Architecture (CBD) to define a common language and data model for the Smart Droplets system, ensuring that data is consistent, standardized, and can be easily shared across different applications and domains.

- Explore the use of robotics and automation technologies, such as the Ai-on Demand and the ATLAS, which are widely used in the robotics industry and can enable seamless integration of the Smart Droplets system with other robotic systems and processes.

- Leverage the BDVA's Data Management Framework (DMF) and the IDSA's Data Usage Control (DUC) architecture to ensure that data generated by the Smart Droplets system is managed, controlled, and protected in a secure and transparent manner, while also enabling efficient data exchange and collaboration.

- Consider the principles of the BDVA's Architecture Reference Model for AI (BDVA-ARM) to enable the Smart Droplets system to incorporate artificial intelligence (AI) and machine learning (ML) capabilities, which can enhance the system's ability to adapt to changing conditions and optimize production processes.

By incorporating these recommendations into the Smart Droplets project solution reference architecture, the project can ensure that the system is interoperable, secure, and scalable, while also leveraging existing reference architectures, common resources, and other robotics projects and initiatives to drive innovation and enhance the system's capabilities.

Here are some recommendations that could be fed into the Autonomous Robotic Spraying System reference architecture in coherence with existing reference architectures, common resources, and other robotics projects and initiatives:

- Interoperability: The Autonomous Robotic Spraying System should be designed with interoperability in mind, so that it can seamlessly integrate with other systems and data sources, such as those provided by Eurostat, Copernicus, and FMIS platforms. The Industrial Data Space (IDS) architecture, which

focuses on secure and standardized data exchange, could be a useful reference for achieving interoperability.

- Data privacy and security: The Autonomous Robotic Spraying System should be designed with data privacy and security in mind, so that sensitive data related to agricultural operations is protected. The IDS architecture could be a useful reference for implementing secure and trusted data exchange.
- IoT sensor integration: The Autonomous Robotic Spraying System should be able to integrate with IoT sensors to collect real-time data on soil moisture, temperature, and nutrient levels. The OpenIoT platforms could be a useful reference for integrating IoT sensors into the system.
- Autonomous navigation: The Autonomous Robotic Spraying System should be designed to navigate autonomously through fields, avoiding obstacles and ensuring accurate spraying of crops. Different European Robotics Platform could be a useful reference for designing autonomous navigation systems.
- Machine learning and AI: The Autonomous Robotic Spraying System should be designed to leverage machine learning and AI to optimize spraying schedules and reduce waste. The BDVA architecture could be a useful reference for designing data-driven decision-making systems.
- Integration with existing machinery and equipment: The Autonomous Robotic Spraying System should be designed to integrate with existing machinery and equipment used in agriculture, such as tractors and harvesters. The John Deere Operations Center could be a useful reference for integrating with existing agricultural machinery.

These recommendations can help ensure that the Autonomous Robotic Spraying System is designed in a way that is interoperable, secure, and optimized for data-driven decision-making. By leveraging existing reference architectures, common resources, and other robotics projects and initiatives, the system can be designed to meet the needs of stakeholders in the agriculture industry.

5. Conclusions and Next Steps

The aim of D2.2 was to present the current status of an ongoing process regarding the available resources, reference architectures, relative initiatives, products and projects from which the SmartDroplets solution could be enriched and benefitted by in terms of its interoperability. The focus was divided amongst three main aspects:

- the existing reference architectures;
- the available common resources and
- the prospective links with other AI, Data and Robotics tools.

A detailed description of all the above mentioned aspects has been provided, while for the last aspect - prospective links with other AI, Data and Robotics tools - a further distinction is implemented based on the three main features of the SmartDroplets solution (AI, Digital Farm Twins, Deep Learning Tools, Retrofit Tractor and DIS - intelligent spraying Tools and Autonomous Navigation and Data Storage Tools). Based on the current findings, a set of recommendations that could be fed into the Autonomous Robotic Spraying System reference architecture has been provided, while a set of “next steps” action plan both towards the continuation of T2.2 as well as towards the utilization of the current information by the rest of the consortium is provided below:

- examine the utilization of the recommendations that have been provided by the D2.2;
- identify the solutions that could be integrated to/by the SmartDroplets solution or that could enhance its interoperability and define the most suitable way of linkage between them;
- establish a communication with the initiatives/projects that a potential linkage has been identified;
- continue the research process of review of relevant initiatives in AI, Data and Robotics, and other programs (DIHs, pilots, data platforms, and other projects) and enrich the set of recommendations throughout the duration of the T2.2.

6. References

1. Big Data Value Association (BDVA). (n.d.). **Big Data Value Reference Architecture (BDVA-BDRA)**. Retrieved from https://www.bdva.eu
2. Industrial Data Spaces Association (IDSA). (n.d.). **Industrial Data Space Reference Architecture**. Retrieved from https://www.internationaldataspaces.org
3. European Commission. (n.d.). **Copernicus Earth Observation Programme**. Retrieved from https://www.copernicus.eu
4. European Soil Data Centre (ESDAC). (n.d.). **Soil Data and Information for Europe**. Retrieved from https://esdac.jrc.ec.europa.eu
5. European Commission Joint Research Centre (JRC). (n.d.). **Agro-environmental Indicators**. Retrieved from https://ec.europa.eu/jrc/en
6. European Drought Observatory (EDO). (n.d.). **Drought Monitoring Platform for Europe**. Retrieved from https://edo.jrc.ec.europa.eu
7. Trimble Agriculture. (n.d.). **Crop Protection and Spraying Solutions**. Retrieved from https://agriculture.trimble.com
8. FarmMaps. (n.d.). **Precision Farming Services and Data Platform**. Retrieved from https://www.farmmaps.net
9. IoF2020 Consortium. (n.d.). **Internet of Food and Farm 2020 Project**. Retrieved from https://www.iof2020.eu
10. ROMI Project. (n.d.). **Robotics for Microfarms**. Retrieved from https://romi-project.eu
11. Blue River Technology. (n.d.). **See & Spray Technology**. Retrieved from https://bluerivertechnology.com
12. FlexiGroBots. (n.d.). **Flexible Robots for Precision Agriculture**. Retrieved from https://flexigrobots-h2020.eu
13. AgriRobot. (n.d.). **Safe and Efficient Robotics for Agriculture**. Retrieved from https://agrirobot.ai
14. Asterix Project. (n.d.). **Robotic Weed Control Solutions**. Retrieved from https://ntnuopen.org
15. Bosch Smart Spraying. (n.d.). **Integrated Weed Control Solutions**. Retrieved from https://www.smartfarming.ag
16. Azure FarmBeats. (n.d.). **Cloud-Based Data Integration for Agriculture**. Retrieved from https://learn.microsoft.com/en-us/azure/industry/agriculture/overview-azure-farmbeats
17. European Environment Agency (EEA). (n.d.). **Environmental Data and Monitoring**. Retrieved from https://www.eea.europa.eu
18. AgroDataCube. (n.d.). **Big Data Collection for Agri-food Applications**. Retrieved from https://agrodatacube.wur.nl
19. ATLAS H2020 Project. (n.d.). **Agricultural Interoperability and Analysis System**. Retrieved from https://www.atlas-h2020.eu