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Grant Proposal

CAgriLab – Consolidated virtual living lab platform for knowledge sharing and adaption in regenerative agriculture

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Abstract

The main goal of 'CAgriLab – Consolidated virtual living lab platform for knowledge sharing and adaption in regenerative agriculture' is to establish a consolidated virtual living lab to enable real-time data sharing and collaboration amongst isolated living labs, lighthouses and farmers for exchanging regenerative agriculture knowledge and practices across diverse environments, leveraging Digital Twin (DT), dataspace, blockchain and artificial intelligence (AI) technologies.

The CAgriLab consortium is composed of four organisations from three different EU Member States (Ireland, Poland and Finland). It consists of one university of technology, one university of applied sciences, one research centre and one industrial partner. CAgriLab will leverage existing partner projects to pilot and evaluate a decentralised dataspace platform across three countries, covering different use cases i.e. living labs (Ireland), lighthouses (Finland) and farms (Poland). Three sets of DTs (three countries) will be created and connected by the platform.

This article contains an edited version of the original funding proposal. The proposal was evaluated by an International Evaluation Committee and selected for funding by the Call Steering Committee.

Keywords

virtual living labs, digital twin, knowledge and data sharing, localised regenerative agriculture, agroecological context aware query

Justification for topic choice of the funding call

The project is primarily aligned with Topic 2 of the funding call, focusing on promoting, reviving and strengthening the best practices for regenerative agriculture by establishing a digital platform (i.e. a virtual living lab). This platform will connect isolated living labs and farmers, enabling them to create and manage digital twins of their farms for enhanced data exchange, analysis and collaboration. In doing so, we connect computer science and agricultural sciences and leverage a variety of expertise. The project tailors the digital technologies (i.e. digital twin, dataspace, blockchain and AI) to address a key challenge in regenerative agriculture i.e. the location-specific nature of practices that complicates the knowledge transfer across varying soil types, climates and biodiversity. The project focuses on soil parameters by providing AI tools to quantify the data from the farms (e.g. assess the biodiversity level using the images of the farm) and then identify the farms with similar conditions to enable knowledge exchange and adaptation. The platform will provide a feedback loop to the stakeholders to enable more effective knowledge exchange, for example, a living lab may ask a farmer to provide additional data to obtain more accurate biodiversity assessment. The platform will incentivise and reward the transformation by tokenising (monetising) the stakeholders' assets to incentivise the sharing of data, knowledge and AI tools. In addition, it offers localised solutions which enable farmers to adopt and adapt successful practices that can maximise their profits, thereby leading to business innovation. The platform will enable the living labs and individual farmers to establish their own virtual labs using digital twin technologies. It will also enhance the communications between stakeholders for exchanging data, knowledge, tools and feedbacks. The project also addresses the challenges outlined in Topic 1 'Artificial intelligence (AI) Tools for Sustainable Agri-Food Systems' i.e. using AI to strengthen the circularity of agri-food systems through providing farm specific recommendations. Additionally, the project aligns well with Topic 3 'Smart decision-making and reflection systems in farming' i.e. making decisions, based on data (Topic 3A) and helping decision-makers to plan and predict crop production, based on the practices on the platform from other locations (Topic 3B). Furthermore, the project utilises distributed ledger technologies (i.e. blockchain), as specified in Topic 4 'Open Topic', to create the decentralised virtual living lab, ensuring trusted data sharing and autonomous collaboration.

Scientific excellence

Project objectives

Regenerative agriculture (RA) encompasses farming principles aimed to maintain agricultural productivity, increase biodiversity, particularly soil biodiversity and enhance ecosystem services including carbon capture and storage. RA involves diverse practices like crop rotations, cover crops, inter cropping, agroforestry and minimising tillage. However, RA practices are highly specific to local context (McLennon et al. 2021), tailored to environmental factors like climate and soil conditions, crop and livestock suitability, water availability, cultural and social-economic factors and ecosystem services. Thus, significant challenges exist in sharing and adapting the best practices and knowledge across different geographical areas.

In December 2022, the European Commission initiated the 'A Soil Deal for Europe' mission aiming to create 100 Soil Health Living Labs (LLs) and Lighthouses (LHs) to promote the transition towards healthier soils by 2030 (SOILL2030). The PREPSOIL (Preparing for the 'Soil Deal for Europe' Mission) map includes over 100 LLs and LHs across the EU (PREPSOIL consortium 2025). Furthermore, farmers may possess valuable experiences in RA. Bridging these isolated living labs, lighthouses and farmers is crucial to facilitate the discovery, exchange, replication and adaptation of RA knowledge as well as best practices.

The main goal of CAgriLab is to establish a consolidated virtual living lab to enable real-time data sharing and collaboration amongst isolated living labs, lighthouses and farmers for exchanging regenerative agriculture knowledge and practices across diverse environments, leveraging Digital Twin (DT), dataspace, blockchain and AI technologies.

The specific technology objectives (TOs) include:

TO1: Develop a decentralised DT platform dedicated to promoting best practices and knowledge sharing in RA. The platform enables farmers and living labs to create and manage DTs with multimodal temporal-spatial field data and field specific practices and knowledge. It supports monetisation of DT usage, tracks the usage trajectory and pattern for analytics and enables autonomous and trusted collaboration between labs and/or farms, using DT, dataspace and blockchain technologies.

TO2: Develop low-cost AI driven tools to measure indicators of soil health and diversity towards localisation of RA practices to specific agroecological context. Utilise low-cost sensors, for example, smartphones and spectral cameras, to measure and estimate soil health parameters. Develop AI-based data correlation tools for discovering, accessing and replicating best practices in different soils, living labs and farms. The tools will encourage evidence-based adoption of RA.

TO3: Develop a standardised interoperable framework to improve knowledge exchange and reusability of effective RA practices, including establishing standardised

vocabularies and semantics, data formats and data protocols for seamless sharing and exchange of farm data. It will extend and adapt existing standards and models like AIM (based on OGC and W3C) and customise existing tools for data integration and harmonisation to ensure interoperable data feeding to DTs. Implement robust Application Programming Interfaces (APIs) aligned with standards like OGC APIs for smooth integration and functionality across diverse platforms and users.

TO4: Develop pilots to evaluate the solution by engaging living labs and farmers in Poland, Finland and Ireland.

Relation to the funding call scope

CAgriLab primarily aligns with Topic 2 of the funding call, focusing on promoting, reviving and strengthening the best practices for RA by establishing a digital twin platform (virtual living lab). Additionally, CAgriLab aligns well with Topic 1, 3B and 4. More details are in 'Justification for topic choice'.

Concept and approach

Overall concept

The overall concept of CAgriLab is to model the consolidated virtual living lab as a digital twin and model the individual living labs or farms as submodels (sub-level DTs). This process is recursive. Each individual physical item and process in the lab/farm can be represented as a DT and integrated into higher-level DTs. This concept is inspired by Asset Administration Shell (AAS), a core component in the Industry 4.0 Platform standard – RAMI 4.0 (Megow 2020).

Although AAS is designed for smart manufacturing, recent studies have shown its adaptability to agriculture (Falcão et al. 2023a, Falcão et al. 2023b). For example, agriculture service providers like weed control operators, can be modelled as factories in Industry 4.0, i.e. service providers (company) utilise various systems (production mean) to perform agriculture activities (process). However, unlike factories, the agriculture process may produce intangible outcomes, for example, directly acting on the field rather than generating products.

CAgriLab will leverage the AAS concept to create a decentralised DT interaction platform, enabling automatic interactions amongst DTs across different hierarchical levels and organisation boundaries.

Asset Administration Shell (AAS) Types

An AAS is a digital representation (digital twin) of an asset which is a physical or logical object owned by an organisation. It is identifiable, holds various aspects (submodels) and describes technical functionalities of the DT or the asset. Three types of AAS have been

defined (Belyaev and Diedrich 2019). CAgriLab will customise and implement them to support diverse lab/farm interaction patterns:

1. Type 1 – Passive AAS accessed via file formats like XML or JSON, suitable for sharing historical agriculture data.
2. Type 2 – Passive AAS accessed via Application Programming Interfaces (APIs). The DT exists as a runtime instance, supporting distributed deployment, for example, the top-level DT can reside in the cloud, whereas submodels may operate on physical devices, suitable for real-time data access to labs/farms.
3. Type 3 – Active AAS, an extension of type 2, supporting active behaviour like reacting to environment and/or asset changes, initiating communication and negotiating autonomously, suitable for intelligent interactions between labs/farms. The architecture of Active AAS (Belyaev and Diedrich 2019) contains type 2 AAS (passive API) and the active part. The Interaction Manager implements semantic interaction protocols, using a Service Requester to order services from other AAS and a Service Provider to provide services.

Eclipse BaSyx, an open-source implementation of AAS, supports all three AAS types and includes a Virtual Automation Bus (VAB) to facilitate the interactions. VAB supports end-to-end communication between entities, for example, DTs, submodels, directory service and discovery service (Eclipse BaSyx 2024). It defines five communication primitives (i.e. **create, retrieve, update, delete and invoke**) for DT access, which are mapped to actual protocol operations during operation, for example, HTTP-DELETE for delete. CAgriLab will implement the primitives for decentralised DT access.

CAgriLab Architecture

AAS focuses on the DT modelling and sharing within an organisation. It lacks full definition for data sovereign, security and trust perspectives. In contrast, dataspace, for example, IDS-RAM 4.0, Gaia-X and FIWARE, are designed for challenges in cross organisation data sharing.

CAgriLab will integrate AAS DT and dataspace technologies to support DT access and interactions across organisation boundaries in agriculture settings. As the living labs and farms involve diverse stakeholders, CAgriLab adopts decentralised dataspace technologies, primarily blockchain based, to facilitate the interactions and mitigate the vendor lock-in issues in centralised solutions.

In the CAgriLab architecture (Fig. 1), each living lab or farmer can create DTs for the physical objects, for example, fields, planting machines, weed machines, plants and animals. These DTs are stored in their own dataspace or third-party storage services, discoverable and accessible through a decentralised dataspace platform. The platform includes standard dataspace components like ID and trust management, data sovereign and compliance. It also provides agriculture specific components, for example, decentralised DT catalogue for registration, AI tools to search and discover context specific DTs and AI tools for quantifying and analysing the farm data within DTs.

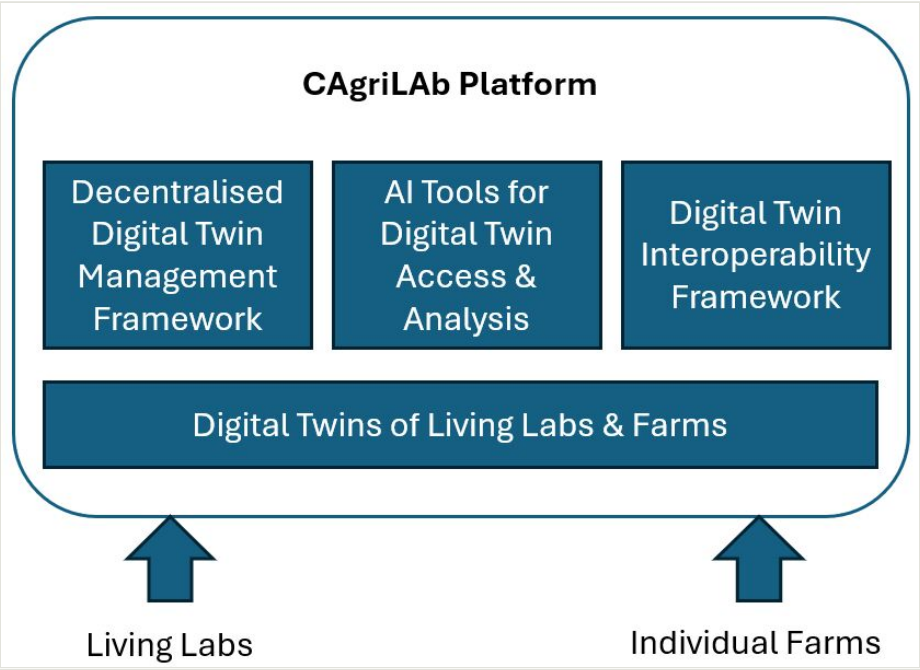

Figure 1.
CAgriLab Overall Architecture.

Fig. 2 shows a more detailed design. A smart contract-based orchestration platform will autonomously manage the interactions with DTs (from other DTs or software). The actual data transmission occurs directly between the DT consumer and provider (e.g. the dataspace connectors), with access permissions controlled by smart contracts. Each living lab or farm can set access policies for their DTs. The platform also records the data access and utilisation trajectory and pattern, helping researchers and farmers in exploring data utilisation benefits.

CAgriLab users can create three types of DTs: the two passive types and one active type discussed above. DT management functions, for example, DT cataloguing and discovery, involve two components, i.e. smart contracts and offchain functions. Balancing the two components is a key design challenge. The VAB communication primitives (i.e. create, retrieve, update, delete and invoke) will be mapped to smart contract calls and offchain communication protocols. AI tools for DT query are deployed in each dataspace to analyse local data, adhering to the bringing compute-to-data principle seen in big data and decentralised dataspaces like PONTUS-X (Gaia-X powered). CAgriLab supports using third-party resources for DT storage and analysis, subject to owner approval.

CAgriLab Pilots

CAgriLab will leverage existing partner projects to pilot and evaluate the platform across three countries, covering different use cases, i.e. living labs (Ireland, from TUS

SOILCRATES project), lighthouses (Finland, organic farming lighthouse at HAMK Mustiala campus) and farms (Poland, provided by CGFP). Three sets of DTs (three countries) will be created and connected by the platform.

Start and target Technology Readiness Level (TRL)

Decentralised DT and Interoperability Frameworks: aim for TRL 6, building on TRL 7 foundational technologies.

AI tools: start at TRL 3 and target TRL 5.

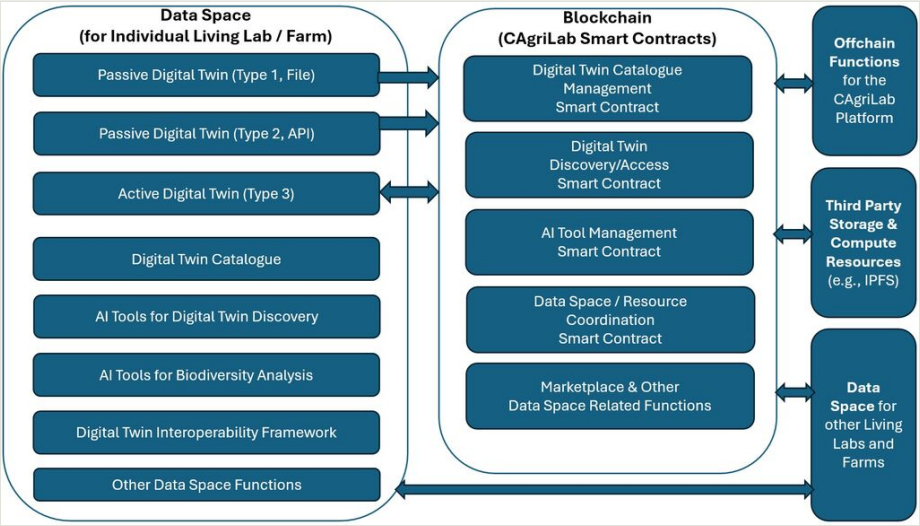

Figure 2.
CAgriLab Detailed Architecture.

Ambition

Decentralised Digital Twin (DT) Framework

Current Landscape: DT has been applied to different agriculture sectors, for example, crops and livestock farming (Purcell et al. 2023), as well as for various purposes, for example, monitoring, prediction and prescription (Verdouw et al. 2021). Existing works address specific vertical issues, for example, irrigation management system (Alves et al. 2023) and urban agriculture (Ghandar et al. 2021), but lack comprehensive frameworks for agriculture DT modelling and data exchange. Falcão et al. (Falcão et al. 2023a, Falcão et al. 2023b) propose a centralised agriculture dataspace framework combining AAS DT with IDS-RAM dataspace to improve service quality by data exchange between service providers (e.g. weed control) and farms.

CAgriLab Innovation: CAgriLab focuses on sharing of RA best practices and knowledge. The DT modelling, discovery and exchange framework is designed for this purpose, i.e. integrating best practices and knowledge in DTs besides the collected field data. CAgriLab will track the DT usage pattern and trajectory, which will form a part of the knowledge. It employs a decentralised architecture using blockchain to ensure platform accessibility for diverse stakeholders (e.g. living labs, farmers) without vendor lock-in issues.

AI Tools for DT Discovery and Analysis

Current Landscape: There is growing interest in adopting digital technologies in agriculture to focus on ecosystem roles and effects, beyond just increasing yields. These endeavours, often termed 'digital regenerative agriculture' (O'Donoghue et al. 2024), face important challenges, from a lack of clearly defined conceptual framework to difficulties in monitoring physical parameters. A key challenge is expanding the evidence base for various resuscitated and innovative regenerative practices, which need to be transparent, accessible and participatory (by primary practitioners). Advances in AI and Internet of Things (IoT) technologies have enabled data intensive smart farming (Xu et al. 2022). However, enhancing engagement with the primary producers requires integrating data sources, analysis methods and communication protocols (Gebresenbet et al. 2023).

CAgriLab Innovation: Implementing AI tools using ubiquitous technologies (e.g. smartphones, apps, machine vision) to lower the threshold for farmers to participate in data collection and expanding the evidence base. Two central themes will be piloted in CAgriLab: data collection/aggregation (Nevalainen et al. 2022) and information discovery (Tzachor et al. 2023). The innovation lies in integrating the collection, aggregation and discovery in a single platform that prioritises cost effectiveness and ease of adoption.

DT Interoperability Framework

Current Landscape: Agriculture data are generated by diverse systems and platforms from various technology providers, hindering data integration and exchange across these different sources, formats and models. These interoperability issues limit the potential for leveraging data to create value and develop smart services/applications for decision-making. Additionally, DTs need to receive data from diverse data systems that may span administrative boundaries and require prior agreements. Hence, interoperability is crucial to harvest data across those systems. Interoperability can be addressed from different aspects, for example, technical (connectivity), syntactic (formats), semantic (data models) and organisational, as well as legal aspects.

CAgriLab Innovation: CAgriLab will create a common information model to address semantic interoperability in agriculture. This model, akin to a lingua franca, defines data elements and their meanings for seamless information exchange across diverse agricultural applications. CAgriLab will leverage existing standards, for example, Agriculture Information Model (AIM) and those from Agriportal (the primary ontologies and semantic artefacts catalogue for agri-food), to cover the needs of the project pilots

and components. CAgriLab will also extend linked data and knowledge graph technologies for data harmonisation and standardised access, ensuring interoperable data feeding to DTs.

Impact

Added value of transnational collaboration

Data from local agricultural fields often lacks interoperability, hindering comprehensive data analysis, like comparison of soil measures. Moreover, the context-specific nature of regenerative agriculture (RA) amplifies these challenges. The transnational effort will address diverse agri/soil conditions across countries, share best agricultural practices and raise awareness amongst living labs, lighthouses and farms in Ireland, Finland and Poland. Each organisational strength complements the other and this data-driven approach to provide information for sustainable agricultural operations can only be conducted through a transnational project (see Section 'Consortium as a whole'). The consortium connects regional stakeholders along the agri-food production chain (i.e. researchers, farmers and an industrial partner) from northern, western and Central and Eastern Europe, which includes a broad regional coverage. The objectives of the transnational collaboration include:

TCO1: Establishing a digital platform connecting stakeholders across EU Member States.

TCO2: Ensuring local sites data accessibility following FAIR (findable, accessible, interoperable and re-usable) principles.

TCO3: Facilitating remote collaboration to promote the development and adoption of RA practices beyond the limitations of local knowledge silos.

Expected impacts: Scientific benefits and economic benefits

Scientific benefits. CAgriLab addresses the growing need to explore digital twins (DTs) in agriculture sectors, aiming to advance current agricultural use cases (Verdouw et al. 2021, Singh et al. 2022). It will investigate novel use cases, based on interoperable data from various agricultural fields. Soil conservation, one of the main goals of RA practices (Schreefel et al. 2020), will be studied via data-driven approaches. CAgriLab will leverage the consortium expertise to build solid data-driven use cases in Ireland, Finland and Poland.

Economic benefits. CAgriLab contributes to agriculture and a healthy food system, as outlined, for instance, in the European Green Deal (European Commission 2019a), the Kunming-Montreal Global Biodiversity Framework (Convention on Biological Diversity 2022) and the United Nations Sustainable Development Goal (SDG) 2 (Zero Hunger) (United Nations 2015). Furthermore, CAgriLab contributes to Europe’s Digital Decade

policy programme through the digital transformation of businesses (European Commission 2019b). The expected impacts (EI) include:

EI1: Strengthening RA best practices and knowledge-sharing by creating a collaboration platform in the food sector.

EI2: Enhancing business innovations in RA and food sector, with open platform and data for reuse by innovators.

EI3: Fostering links between research organisations and farms.

EI4: Strengthening the micro-environment in the participating farms through a focus on RA.

EI5: Providing environmental impact evidence in agriculture using shared data and artificial intelligence (AI) analysis, for example, data from Earth observation of agrifields and weather stations.

EI6: Lowering entry barriers for users (e.g. farmers) to participate in RA and the project with low-cost and ubiquitous measurement devices.

Significance of the project results and user benefit

CAgriLab will connect user groups that would otherwise be isolated. This research will be conducted in a user-friendly way by involving stakeholders along the development of the platform. We plan events to engage with potential users and provide additional feedback channels to ensure continuous collaboration. The open data-sharing approach of the platform enables connections between business partners, farmers, public authorities and policy-makers from several countries.

Strategic significance for partners

The strategic significance and the exploitation plan for each partner is shown below.

Technological University of the Shannon (TUS) is partner of various agriculture projects, for example, Horizon Europe SOILCRATES and the Co-Centre for Sustainable and Resilient Food Systems (SUREFOOD). CAgriLab will increase TUS capacity in RA and strengthen and expand our collaborations with European partners in the field. It will enhance TUS capability in developing DT technologies in agricultural settings, gaining expertise in living-lab set-up, fostering innovation in these areas. CAgriLab will strengthen collaboration of TUS innovation centres, for example, ShannonABC (for BioTech) and COMAND (for InfoTech), to jointly develop digitisation solutions for farms and food industries. CAgriLab is aligned with the Food Vision 2030 Strategy of Ireland (Department of Agriculture, Food and the Marine 2022) to promote and increase awareness of RA under Irish conditions.

Poznan Supercomputing and Networking Center (PSNC) participates in various agriculture projects like SUSPOT for data modelling, ILIAD for ocean DTs and eDWIN for plant protection and farm management. The core mission of PSNC is to advance scientific excellence via reliable and cutting-edge e-Infrastructure. PSNC leads Digital Innovation Hubs for HPC and cyber security and hosts a living-lab space, supporting innovation of companies (SMEs). CAgriLab extends PSNC expertise and innovation capacity in RA and agriculture DT deployment, enhancing service offerings and strengthening and expanding its collaborations with national and European partners. It can help increase the competitiveness and growth of farms and agri-related businesses, specially at the regional level, with the knowledge and services for RA and agriculture DTs. It will promote and increase awareness of RA practices that foster the health of degraded soils by restoring their organic carbon, resulting in a wide range of environmental and societal benefits. It will enable sharing and promoting these best practices in Poland, contributing to environmental health and conservation.

Häme University of Applied Sciences (HAMK) addresses in its strategy responsible and innovative AI utilisation. HAMK's SmartBio key research ecosystem focuses on primary sources of food production in fields, including the food industry. The Finnish Kanta-Häme Region has been recently selected together with other regions as a EU Regional Innovation Valley (European Commission 2024) with a focus on digital transformation and food security. CAgriLab will be aligned with these challenges. DT is a technology of 'digitally enabling industries'. In 2018, this sector "produced EUR 27.4 billion worth of products and services for Finland's national economy and created EUR 12.5 billion of value added for Finland (Lukkarinen and Tuomaala 2024)". CAgriLab contributes to the green transition and digitalisation as outlined in the Finnish Roadmap for Research, Development and Innovation (Government of Finland 2021). It is aligned with the national strategy for implementation of the Common Agricultural Policy (CAP) in Finland (European Commission 2022), because agriculture DTs contribute to food security, farm competitiveness, increased environmental and climate ambition.

Potulicka Foundation Group (CGFP). The project solutions and the use of a farm management information system (FMIS) will support decision-making (enable more informed decisions) in farm management, optimise sowing, fertilisation, plant protection and harvesting, improve soil health and enhance machinery equipment operational efficiency. The use of FMIS will increase the practical value of the project. The project results will contribute to sustainable agricultural practices, consistent with national and international environmental regulations and standards.

Interaction with ongoing activities

CAgriLab will benefit from and contribute to various ongoing activities (with partners involved in most of the activities, see Table 1):

1) Platform user related initiatives, for example, living labs in EU projects (SOILCRATES, SOIL2030 etc.), to gather requirements, develop pilots and identify users.

2) Stakeholder engagement and training related activities, for example, AgriNext and Agretain (Erasmus+), to leverage their innovative teaching methods and learning materials for broad accessibility.

3) Dissemination related activities, for example, OGC Agriculture Information Model (AIM) Standard Working Group, to contribute to the standardisation of semantic data models in agriculture.

4) Technology related activities, for example, agri data interoperability (SUSPOT, AgrifoodTEF); agri data marketplace (Datamite); DTs (ILIAD); dataspace – IDSA (International Dataspace Association), DSSC (Dataspace Support Center), Common Agriculture European Dataspace, to leverage and contribute to these efforts.

Table 1.

Ongoing Projects and Contribution to CAgriLab.

Acronym (ordered alphabetically) | Project Partner | Title | Funder | URL	**Contribution to Project Development**
AGRETAIN | **TUS** | Regenerative sustainable food chains through market gardening | Project | European Commission (ERASMUS+) | https://erasmus-plus.ec.europa.eu/projects/search/details/101140260	Expertise on vocational education and training (VET) programmes, flexible learning processes, and gamification.
AgrifoodTEF | **PSNC** | European Testing and Experimentation Facilities for Agrifood Innovation | Project | European Commission and European Funds for a Modern Economy (Poland) | https://agrifoodtef.eu/	Services for agri-data modelling and alignment with standards, data harmonisation services.
AgriNext | **TUS** | Agricultural and Rural Incubator and Platform for the Exchange of Competences | Project | European Commission (ERASMUS+) | https://erasmus-plus.ec.europa.eu/projects/search/details/101056023	Expertise on vocational education and training (VET) programmes, flexible learning processes, business incubators and development.
AIM | **PSNC** | Agriculture Information Model | Standard Working Group | N/A | https://github.com/opengeospatial/aim-swg	Semantic model for agri data, leveraging and aligning standards.
Datamite | **PSNC** | Monetization, Interoperability, Trading & Exchange | Project | European Commission (Horizon Europe) | https://doi.org/10.3030/101092989	Services for data harmonisation, agriculture marketplace, data spaces.
Digi4CSA | **HAMK** | Digital Solutions to Foster Climate-smart Agricultural Transition | Project | Research Council of Finland | https://www.hamk.fi/en/projects/digi4csa-ilmastoviisasta-maataloutta-tukevat-digitaaliset-ratkaisut/	Expertise on climate-smart agriculture.
eDWIN | **PSNC** | eDWIN Advisory Platform | Project/National Platform | Centrum Projektów Polska Cyfrowa | https://www.edwin.gov.pl/	Services for farmers, delivery at national level, data sources for the project.
FiON | **HAMK** | Field Observatory Network | Business Finland, Research Council of Finland, Ministry of Education and Culture of Finland, Ministry of Agriculture and Forestry of Finland and the Maj and Tor Nessling Foundation | https://www.fieldobservatory.org/	Expertise on data collection and analysis from agricultural fields.
FoodSec | **HAMK** | Smart Food Security | Project | Ministry of Education and Culture of Finland | https://www.hamk.fi/en/projects/smart-food-security-foodsec/	Expertise on agri-food systems.

Acronym (ordered alphabetically) | Project Partner | Title | Funder | URL	Contribution to Project Development
FUN-C | **HAMK** | Revealing the links between fungal necromass properties, microbial community composition and soil microbial carbon stocks | Project | Research Council of Finland | https://www.hamk.fi/en/projects/fun-c/	Expertise on soil science.
HiiletBio | **HAMK** | Enhancement of Soil Carbon Sequestration Through Agricultural Practices: Implications for Soil Biodiversity | Project | Finnish Cultural Foundation | https://www.hamk.fi/en/projects/hiilet_bio/	Expertise on soil science.
HIKKA | **HAMK** | Carbon and growth for the clay fields of Southern Finland | Project | Ministry of Agriculture and Forestry of Finland | https://www.hamk.fi/en/projects/hiilta-ja-kasvua-etela-suomen-savipelloille-hikka/	Expertise on soil science.
ILIAD | **PSNC** | Digital Twins of the Oceans | European Commission (Horizon 2020) | https://doi.org/10.3030/101037643	Semantic interoperability, data harmonisation services based, metadata models, development of digital twins.
LuoVaMix | **HAMK** | Improving yield stability and climate sustainability of organic farming by mixed cropping and autumnsown protein crops | Project | Ministry of Agriculture and Forestry of Finland | https://www.hamk.fi/en/projects/luovamix/	Expertise on agriculture.
OpenAgri | **PSNC** | Democratising digital farming through tailored open source and open hardware solutions | Project | European Commission (Horizon Europe) | https://doi.org/10.3030/101134083	Agriculture data model, alignment with standards, semantic interoperability, data harmonisation.
PoliRuralPlus | **PSNC** | Fostering Sustainable, Balanced, Equitable, Place-based and Inclusive Development of Rural-Urban Communities' Using Specific Spatial Enhanced Attractivenes Mapping ToolBox | Project | European Commission (Horizon Europe) | https://doi.org/10.3030/101136910	Semantic interoperability, building blocks, data harmonisation services, alignment and generation of standard API.
ResilMesh | **TUS** | Situation Aware enabled Cyber Resilience for Dispersed, Heterogenous Cyber Systems | Project | European Commission (Horizon Europe) | https://doi.org/10.3030/101119681	Expertise on Edge Computing and Machine Learning, Trust.
RUN-EU | **TUS, HAMK** | Regional University Network European University | Network | European Commission (ERASMUS+) | https://run-eu.eu/	Expertise on regional development.
SFC-FTF | **CGFP** | An innovative plant production management system with emphasis on optimisation of machine operation, fertilisation and protection of soil biodiversity | Project | EU CAP | https://www.cgfp.pl/projekt-sfc-ftf-zrealizowany-w-ramach-dzialania-wspolpraca-programu-rozwoju-obszarow-wiejskich-na-lata-2014-2020/	Weather, soil, yield, precise fertilisation and plant protection within the farm data; expertise in agriculture.
SOILCRATES | **TUS** | SOil Innovation Labs: Co-Regenerating And Transforming European Soils | Project | European Commission (Horizon Europe) | https://doi.org/10.3030/101157354	Provide data of the living labs to create the living lab digital twins; expertise on soil sensory data collection and analysis.
SUREFOOD | **TUS** | Co-Centre for Sustainable and Resilient Food Systems | Project | SFI, UKRI, DAERA, Industry | To be announced	Expertise on blockchain and AI for food system tracking and modelling.
SUSPOT | **PSNC** Transparency and sustainability in the potato processing chain from F2F through innovative data sharing | Project | National Centre for Research and Development (PL) | https://www.psnc.pl/projects/suspot/	Expertise on data sharing, data models, data space technologies.
UVIDI | **HAMK** | The Development of Digitalization and Competences for Regenerative Farming in Häme Region | Centre for Economic Development, Transport and the Environment Häme | https://www.hamk.fi/en/projects/uvidi-uudistavan-viljelyn-osaamisen-ja-digitalisaation-kehittaminen-hameessa/	Expertise on regenerative agriculture.

Partner on-going projects and international networks

CAgriLab partners are involved in multiple national and EU projects and networks that can contribute to CAgriLab. Examples include innovative learning process for farmers (AgriNext), regional development (RUN-EU), agri-data modelling (AgrifoodTEF), agri-dataspace and marketplace (Datamite), ocean DTs (ILIAD), agri-data collection and analysis (FiON), soil science (HiiletBio), farm management (SFC-FTF), living labs (SOILCRATES) and food supply chain trace (SUREFOOD). More details are presented in Table 1.

Commercialisation plans

CAgriLab aims to create an open source platform for DT sharing in RA. The team will collaborate with the Eclipse Foundation to create an Eclipse Project. The generated data, software, publications and presentations will all be openly available. CAgriLab will be commercialised by platform usage with a software-as-a-service approach. The offered services include publishing, searching, utilising, analysing DTs and the DT usage pattern and trajectory. The resulting platform will be based on solid use cases that have been evaluated at three local sites and can be scaled up to other agricultural fields. The service provided will offer a competitive advantage, based on the expertise gained on DT usage pattern and trajectory analytics, ease of use, cost-effectiveness and a common information model. During the project, we will be in close contact with user groups to provide information for the development, leveraging the research and innovation communities of the partners. The commercialisation and exploitation plan for each partner has been presented in the Section 'Strategic significance for partners'.

Quality and efficiency of the implementation

Consortium as a whole

The CAgriLab consortium is composed of four organisations from three different EU Member States (Ireland, Poland and Finland). It is a well-balanced consortium with both relevant expertise and strong presence and knowledge in the ICT and agriculture field. The consortium has been carefully chosen to match the desired outcomes of the project. It consists of one university of technology, one university of applied sciences, one research centre and one industrial partner. The consortium, therefore, comprises a well-blended mix of academic, industrial and practitioner skills to ensure the DT (TUS, PSNC), dataspace (TUS, PSNC), AI algorithms (HAMK, TUS), blockchain (TUS, PSNC), regenerative agriculture (all consortium partners) and relevant services are covered.

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Grant title

CAgriLab – Consolidated virtual living lab platform for knowledge sharing and adaption in regenerative agriculture

Hosting institution

Technological University of the Shannon (Ireland, coordinator); Häme University of Applied Sciences (Finland); Poznan Supercomputing and Networking Center (Poland); and Potulicka Foundation Group, CGFP Sp. zo.o. (Poland).

Ethics and security

This project focuses on developing software systems including the decentralised interoperable digital twin framework and the AI tools. It does not collect personal data. However, as the project will develop AI tools to assess biodiversity, based on images from the agriculture fields, the images may accidently contain humans. In addition, the project will involve human participants while collecting user requirements and during the dissemination and communication process. Task 1.5 (Research, Data Management, Ethics and Privacy) will handle the data management plan and the ethical aspects for the activities involving human participants to ensure privacy and General Data Protection Regulation (GDPR) compliance throughout the project. The images containing humans will be anonymised before analysis and publication. The user requirement collection process will be anonymous and no personal data will be recorded. Task 1.5 will ensure privacy and GDPR compliance throughout the project.

Conflicts of interest

The authors have declared that no competing interests exist.

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