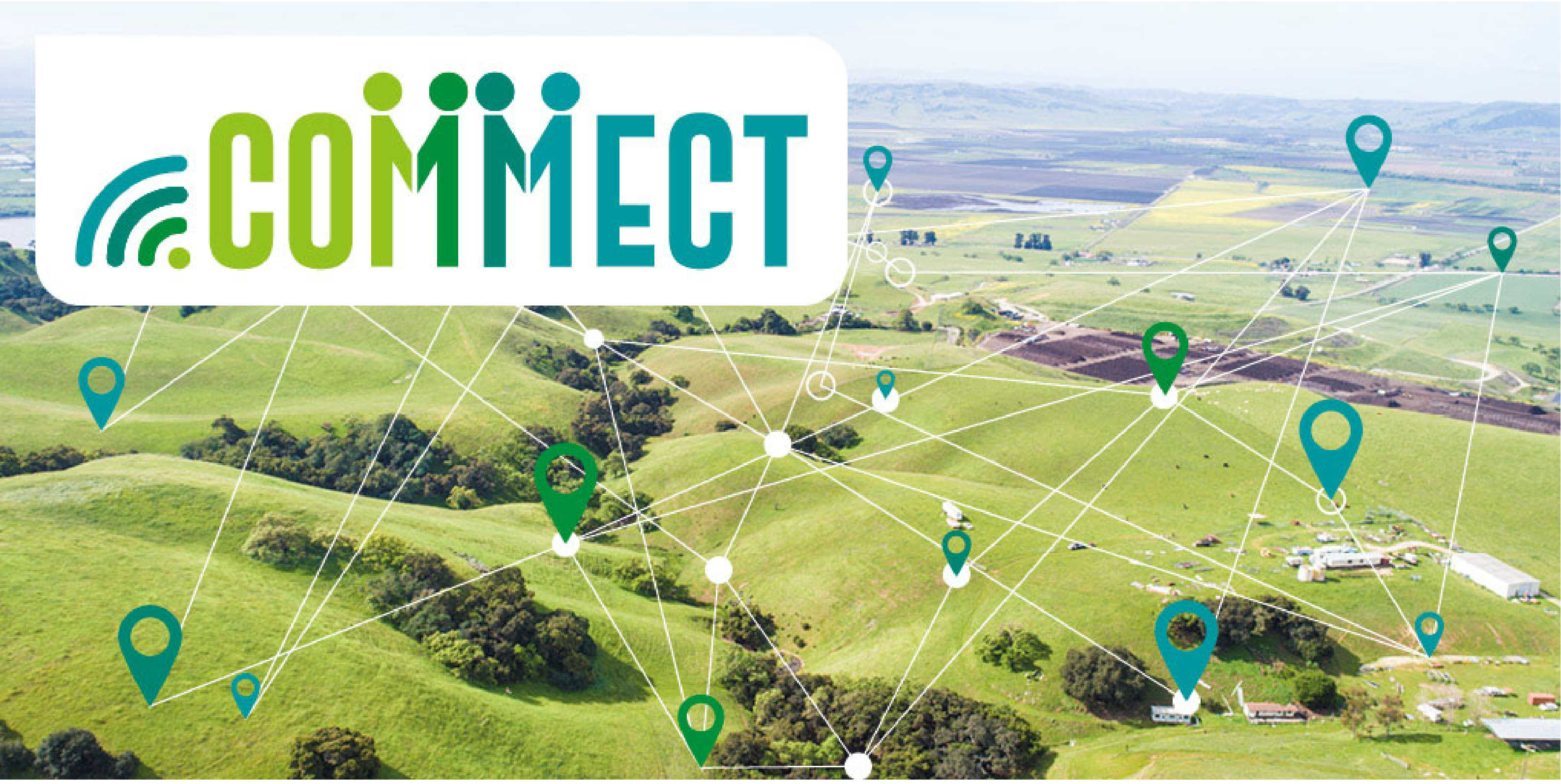
Bridging the digital divide and addressing the need of Rural Communities with Cost-effective and Environmental-Friendly Connectivity Solutions



Deliverable 1.1
Report on end-users' needs and relevant use cases

November 2023

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COMMECT

Bridging the digital divide and addressing the need of Rural Communities with Cost-effective and Environmental-Friendly Connectivity Solutions

Grant agreement No. 101060881

Report on End-Users' Needs and Relevant Use Cases

WP1 – End-User Needs, COMMECT Requirements and Architecture

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Contributors	Aalborg University (AAU), Telenor ASA (TNOR), Klosser Innovasjon AS (KI), Nederlandse Organisatie voor Toegepast Natuutwetenschappelijk Onderzoek (TNO), Luxembourg Institute of Science and Technology (LIST), Turkcell Teknolojo Arastirma Ve Gelistirme Sirketi (TCELL), Huawei Technologies (Ireland) Co Limited (HWIE), Foreningen Padborg Transportcenter (PTC), Institut Fir Biologesch Landwirtschaft an Agrarkultur Luxembourg Asbl (IBLA), Ministry of Agriculture and Forestry (Türkiye) (TOB), Drustvo za Konsalting, Razvoj I Implementaciju Informacionih I Komunikaciobih Technologija Duvanet Doo Novi Sad (DNET)

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COMMECT Project Abstract

In recent years, the importance and need for broadband and high-speed connectivity has steadily increased. The COVID-19 pandemic has also highlighted this need and further accelerated the process towards a more connected society. However, the acceleration has largely taken place in urban communities. In Europe, 13% of people are still without broadband access, and this mainly affects the most rural and remote areas [1]. Those areas are the most challenging to address since they are the least commercially attractive. COMMECT aims to **bridge the digital divide** by providing quality, reliable, and secure access for all in rural and remote areas. The **goal of extending broadband connectivity in rural and remote areas** will be achieved by *integrating Non-Terrestrial Networks with terrestrial cellular XG networks, and low-cost Internet of Things (IoT). Artificial Intelligence, Edge and Network Automation will reduce energy consumption both at the connectivity and computing level.*

A participatory approach with end-users and ICT experts working together on development challenges will be the key **to the digitalization of the sector**. To ensure the rich exchange of best-practice and technical knowledge among the actors of the agri-forest value chain, COMMECT will set up **five Living Labs across and outside Europe**, *where end-user "pains" and (connectivity) "gains" will be discussed in detail from different perspectives.*

COMMECT aims to contribute to a balanced territorial development of the EU's rural areas and their communities by making smart agriculture and forest services accessible to all. COMMECT will facilitate that by developing a **decision-making support tool** able to advise on the optimal connectivity solution, according to technical, socio-economic, and environmental considerations. This tool, incorporating collaborative business models, will be a *key enabler for jobs, business, and investment in rural areas, as well as for improving the quality of life in areas such as healthcare, education, and e-government, among others.*

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Lead Authors	Michael Nørremark (AU)
Other Authors	Melisa Maria López Lechuga (AAU), Nemanja Mišic (DNET), Senka Gajinov (DNET), Serkan Kaptan (TOB), Muzaffer Kerem Savran (TOB), Izzet Saglam (TCELL), Miriam Machwitz (LIST), Mario Gilcher (LXS), Kristina Heilemann (LIST), Jörg Pauly (IBLA), Kerstin Klemm (IBLA), Sofia Davidson (KI), Jesper Schimann Hansen (PTS)
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Executive Summary

The COMMECT project aims at empowering rural communities by using smart services that require sustainable communication solutions. A variety of branches of rural area production and nature preservation are considered in the project, such as: wine growing, olive growing, arable crop growing, forestry, preservation of natural environment and livestock transport. This report comprises the end-users needs for their business, as well as connectivity-related pain points and gains, which have been largely discussed, from different perspectives, at workshops and interviews with several stakeholders in Luxembourg, Norway, Denmark, Türkiye, and Serbia.

This report constitutes deliverable D1.1 of the COMMECT project. It presents the results of activity T1.1 'Definition of End-User needs and COMMECT use cases. The deliverable outlines the methodologies applied for gathering user needs and describes the methodologies to identify stakeholders, for the definition of the value chain of individual branches of rural and forestry area production and nature preservation, and finally for the definition and description of use cases.

The use cases that have been analysed encompass a range of communication technology applications that emphasize the integration of different terrestrial, such as Wi-Fi, LPWAN, NB-IoT, LTE-M, 4G, 5G, and non-terrestrial networks, such as aerial, and space-based networks, as well as cloud and edge computing into different sectors:

- **Seamless connectivity** and **extended coverage** emerge as a recurrent theme across several use cases. Whether it is ensuring uninterrupted connectivity for meteorological sensors, monitoring of crops and livestock transport, reliable and continuous data transmission is crucial. This connectivity enables real-time monitoring, analysis, and remote support, facilitating informed decision-making and optimizing operations in rural areas.
- Also, **digitalization and data-driven approaches** are important in the identified use cases. The creation of digital twins, digitization of agricultural activities, and big data analysis using artificial intelligence all underscore the importance of leveraging digital technologies to enhance processes and outcomes in the agricultural, horticultural, viticultural, and silvicultural sectors. By utilizing remote sensing, remote operation support, machine vision, and data analytics, the defined use cases aim to improve precision, efficiency, and situational awareness.

Table of Contents

List of Figures

List of Tables

Glossary of Terms

Term	Description
AI	Artificial Intelligence
AR	Augmented Reality
DST	Decision-making Support Tool
ECU	Electronic Control Unit
eMTC	enhanced Machine-Type Communications
FAO	Food and Agriculture Organization
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
GSM	Global System for Mobile communication
HSE	Health, Safety and Environment
ICT	Information and Communication Technology
IoT	Internet of Things
ITS	Intelligent Transport Systems
KPI	Key Performance Indicator
LL	Living Lab
LoRaWAN	Long Range Wide Area Network
LPWAN	Low Power Wide Area Network
ML	Machine Learning
NB-IoT	Narrowband Internet of Things
PEFC	Programme for the Endorsement of Forest Certification
QoS	Quality of Service
RES	Renewable energy source
SME	Small and Medium-Sized Enterprise
VR	Virtual Reality
UAV	Unmanned Aerial Vehicle

XG	Extended Generation mobile networks
4G	4^{th} Generation mobile networks
5G	5^{th} Generation mobile networks

1. Introduction

The COMMECT project aims at bridging the existing digital divide experienced by rural communities. Following a participatory approach, the project advocates for a close collaboration between the information and communication technology (ICT) experts and the end-users. This will provide all the technical experts involved in the project with a better understanding of the end-users' businesses, their needs, and the benefits they expect from digitalization. The purpose is to prompt the development of the most appropriate solutions. Five Living Labs (LLs) have been setup by the project across and outside Europe to carry out this initiative. The proposed connectivity solutions integrated in current or future ICT solutions will not only be evaluated from a technical perspective. In fact, the project will also investigate how those solutions can boost socio-economic growth of rural communities. Additionally, the environmental impact of the connectivity solutions will also be studied, providing the end-users with insights of how digitalization can support them in becoming more resilient and sustainable. To that end, the first and most important step is to gather the actual user needs and define the main use cases that should be addressed in the COMMECT project.

The first objective of this document is to describe the research methodology that has been followed to identify the needs of the different branches of rural area production and nature preservation enclosed by the five LLs. The second objective is to define specific use cases which demand for extended connectivity, encompassing several communication technologies from different terrestrial (Wi-Fi, LPWAN, NB-IoT, LTE-M, 4G, 5G), to non-terrestrial networks, such as aerial, and space networks, as well as cloud and edge computing technologies. Accordingly, this deliverable also identifies the various stakeholders in each branch and presents the different user needs and use cases that have been determined for each of the LL. Lastly, the document includes an assessment of the connectivity solution(s) that could be used to address the use cases determined across the different LLs.

As shown in Figure 1, the engagement with end-users has followed an iterative approach. Following the initial gathering of user needs, refinement has been ongoing, informed by various interviews and workshops conducted throughout the project's duration. User needs were gathered using a multi-actor approach, encompassing input from various stakeholders, experts, advisors, scientists, authorities, and other relevant parties - as depicted in Figure 1 (top). The content of this document constitutes the prior step for the identification of the COMMECT technical requirements and key performance indicators (KPIs) in deliverable D1.2. Additionally, the user needs will serve as an input for the Decision-making Support Tool (DST), further described in deliverable D3.3 *(Decision-making Support Tool).*

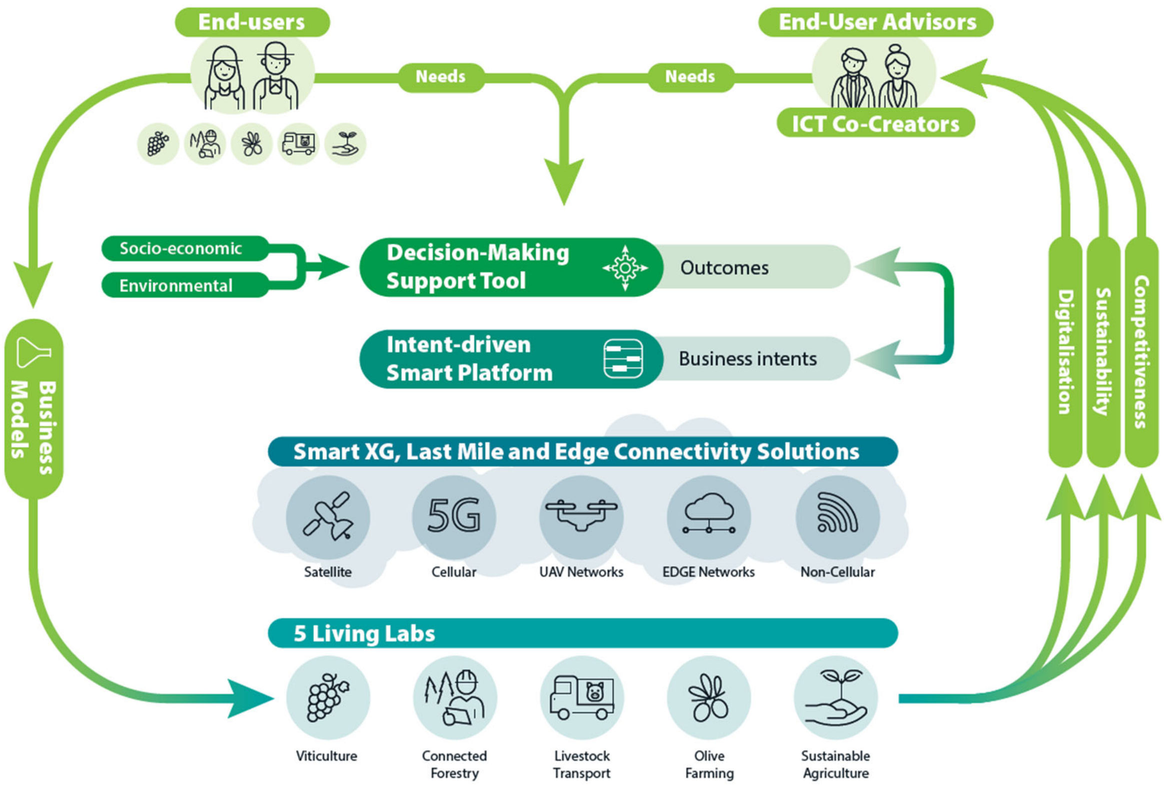

Figure 1. Overview of the COMMECT methodology.

2. Methodology

This section summarises the research methodology that has been followed to identify the user needs of the different LLs, and to define the corresponding use cases that should be addressed. As shown in Figure 2, the following steps have been taken:

1) **Stakeholders Analysis:** the identification of the stakeholders and the end-users that are relevant to the branch of rural area production and/or nature preservation subject/theme of each LL.
2) **Data Collection:** via communication with the different stakeholders involved in each LL through the conduction of surveys, workshops, interviews, etc.
3) **Identification of user needs:** The user needs identification based on the collected data from the previous step, with the objective to extract the most relevant user needs in relation to the technical requirements, the business and the production conditions.
4) **Definition of use cases:** via the definition of the use cases that address the different user needs identified in the previous step. Note, this document includes all the identified use cases. Only a selection of them will be further investigated in the next phases of the project, and addressed in each LL.

More information about the four steps is provided in the following sub-sections, from 2.1 to 2.4. These four steps were implemented in an iterative process to gather as much information as possible during the period from September 2022 to February 2023. Frequent communication with the end-users in the different LLs is expected throughout the entire lifetime of the COMMECT project. As such, user needs will be redefined as a better understanding of them is reached, with possible changes in the definition of the use cases.

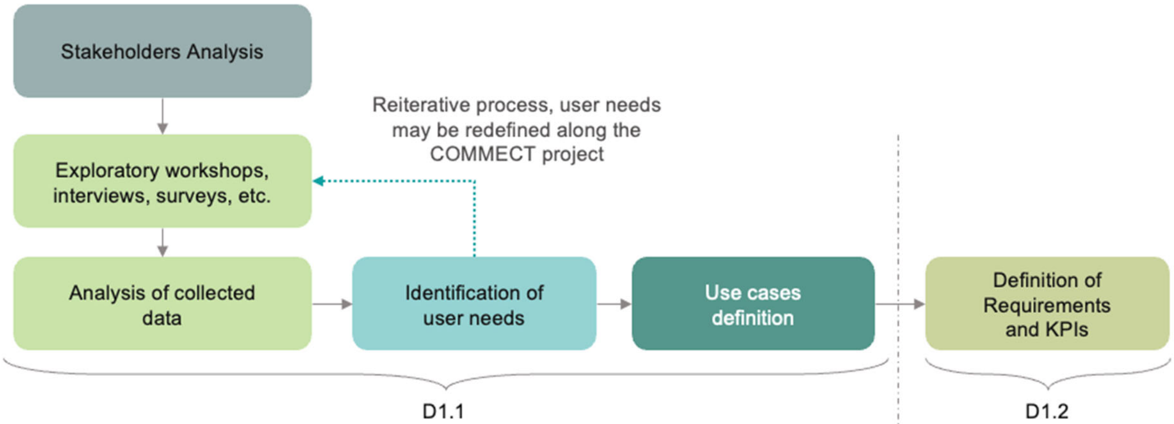

Figure 2. Research methodology followed by the COMMECT partners for the definition of user needs and use cases in D1.1.

2.1. Stakeholder Analysis

The first step in the research methodology consisted of identifying key end-users for each of the LLs. In general, it was recommended to identify essential end-users and approach them in a preliminary meeting to obtain a better understanding of the business, an overview of the value chain, and information about other potential stakeholders, experts, advisors, authorities etc. The approach for the end-user's selection was specific/customized to each LL and will be further explained in Sections 3 - 7. In many cases, existing relationships between the end-users and the LL leading partners facilitated the initial contact.

As shown in Figure 3, the end-users designation step matches the first and second phases of the Workshop Organization, which was previously described in D6.2 of the COMMECT project *(Dissemination, Communication and Exploitation Plan).*

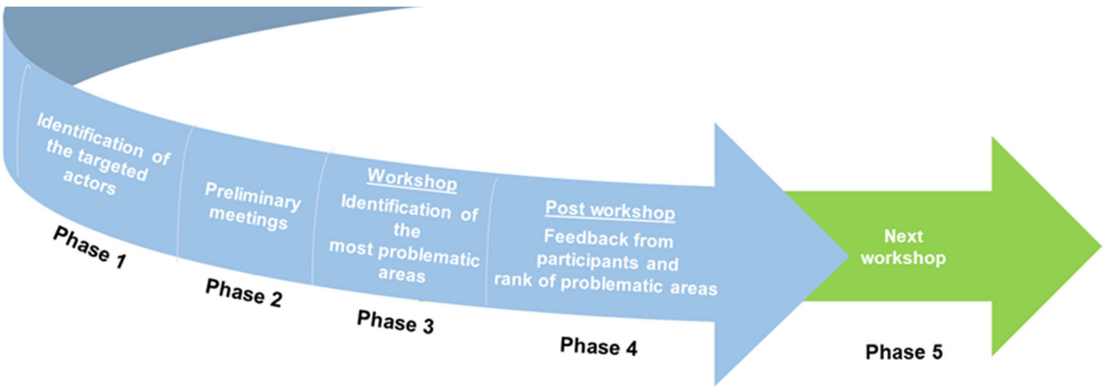

Figure 3. Phases in Workshop Organization (derived from COMMECT D6.2).

2.2. Data Collection

The next step in the research methodology involved communication with the end-users to investigate the main challenges that they are facing and how these challenges can be solved through digital solutions, enabled by deploying connectivity solutions in rural remote areas. Data collection was carried out by different means:

- Workshops with the different stakeholders involved in the LL.
- Surveys/questionnaires.
- Individual meetings, where end-users that may be competitors, can express openly their needs for their business, as well as connectivity related pain points and gains.

After the information was collected, the results from the surveys, and the notes extracted from the workshops and/or meetings, were analysed to obtain a summary of the main concerns of the end-users, paying special attention to those needs that could be covered by the design and implementation of connectivity solutions. This step matches phases 2-4 in [2], and it is reiterative in the sense of research methodology. Therefore, different workshops and meetings with the end-users will be carried out during the lifetime of the COMMECT project, collecting the necessary data for a successful implementation of the solutions that will cover the end-users' needs. This approach is depicted in Figure 3, for phase 3-4 in accordance with COMMECT D6.2.

2.3. User Needs

Once the LL organisers had the value chain in place and collected information during the workshops, interviews, and surveys with the end-users, it was possible to identify what their main needs, challenges and expectations were, and why these were occurring, and how digital and connectivity solutions could help improve or solve the identified needs. Both the data collection and analysis strategy were inspired by the recommendations in [2]. Accordingly, the third step of the research methodology was the identification of end-user needs.

Since most end-users were expected to have limited knowledge regarding quantitative wireless network requirements (like latency, throughput, reliability etc.), a more qualitative approach was taken. Most end-users know the type (e.g., video streaming, data, text message, voice call, etc.) and quantity of information they will exchange over a wireless network. Furthermore, they can understand the importance of the data and information they will receive and/or send, and the impact of lost data or unreliable connectivity or coverage can be perceived by them. Therefore, the end-users were, in relation to user needs, also asked to describe the type and importance of the information/data that a wireless network will have to transmit, and not the expected network capabilities.

To obtain a more standardized way of data collection and user needs definition, each LL was suggested to adopt the guidelines included in Appendix 6 – *Guidelines for compilation of user needs*.

Since additional workshops and surveys will be carried out during the project, the collection of end-user needs is an iterative process, and these may be redefined in future workshops or stakeholder meetings as a better understanding of them is achieved.

2.4. Use Cases Definition

The fourth step of the research methodology consisted of the definition of use cases based on the identified user needs. The use cases should enclose the root problems that are causing the user needs to be unsatisfied, explaining the gap that could be filled with ICT or other technical/digital solutions. To facilitate the process of use case definition, the LL's were provided with a list of questions and sub-questions to be answered:

1. **What is the problem that the use case solves? Which user need is it connected to?**

   Which problem(s) is the use case aiming to cover, which user needs is it addressing? What is the impact on the user if a solution would be provided?

2. **Why is digitalization/communication technology not applied already to the use case?**

   Gap analysis. Is there a solution for a specific use case? If so, how is it currently done? How could it be improved?

3. **Which stakeholders are part of the use case?**

   Which are the actors involved? Who can benefit or affected by the implementation of the use case?

4. **What is the added value of digitalization/communication technology in this use case?**

   This question not only accounts for the end-user impacted by a certain technical/digital solution, but also considers a socio-economic aspect. What is the financial impact on the business and the sector? What could be the impact for the rural communities?

Detailed information about the research methodology followed by each LL, as well as the identified user needs, and defined use cases are provided in the following sections.

3. Living Lab N.1 – Luxembourg – Digitalization of Viticulture

3.1. Characteristics of the Viticulture Sector in Luxembourg

Luxembourg's viticulture takes place on a 42-kilometer stretch between Rosport and Schengen and has a total of 1295 hectares of vines cultivated by about 450 full-time and part-time winegrowers. The wines are produced by the members of the cellar cooperatives Domaines Vinsmoselle (58% of the national production), the private winegrowers Organisation Professionelle des Viticulteurs Indépendants (28% of the production), and the wine trade (14% of the production).

The wineries in Luxembourg have based their cultivation of the vineyards, as well as the vinification and cellar management, on very good technical equipment. The winegrowers are very well educated and have great experience in all areas of viticulture. As a result, all wines from Luxembourg reach a very high level of quality and the wineries manage to market these qualities with a high added value.

As such, wine production is of outstanding local economic importance. However, plant protection and maintenance of plant health can be very challenging in vineyards. Diseases and pests often spread more easily in vineyards compared to other, non-permanent crops and are consequently difficult to suppress due to permanent cultivation. Nevertheless, intensive pesticide spraying, which is necessary to control diseases and pests, has several negative impacts, such as risk to the environment and high costs for labour time and treatments.

The use of helicopters for spraying of pesticides is very strictly regulated in Luxembourg and has lost relevance in recent years. The treated area through helicopter's spraying has declined considerably, to protect the surrounding areas from wind drift and in parallel, the acceptance of the residence decreased as well. Helicopter flights are planned weeks in advance and are not easily adjustable to the actual risks and needs. Since they are becoming less important, opportunities for precise spraying are growing and more information on the disease and pest risks is helpful and needed.

On one hand, growers face new challenges with respect to economic pressure and facing climate change, while on the other, digitalization and connectivity offer new ways to address them. In-situ sensors, UAV and satellite data provide new information on how and when to apply treatments or irrigation. This detailed information can be used to plan more targeted treatments and irrigations depending on the specific needs of the crop.

3.2. Implementation of Research Methodology

The LL Luxembourg employed a multifaceted approach to identify the potential user needs in the field of viticulture in Luxembourg. The methodology consisted of conducting interviews with 12 winegrowers and a survey with participation of 41 winegrowers to get an overview of the state-of-the-art value chain and to rank practical challenges and potential solutions. Additionally, the LL Luxembourg organized several meetings with the Administration des services techniques de l'agriculture (ASTA), Institut Viti-Vinicole (IVV), and with the partner Moosle GmbH, that is a provider and developer of MOOSLE app and cloud software for wine growers (Moosle GmbH, Germany), and finally, internally within our LL team. The interviews and survey were fundamental in understanding and ranking the most pertinent challenges.

In order to accomplish a comprehensive user-need analysis in the context of COMMECT in the viticulture domain, the LL Luxembourg followed a stakeholder-oriented approach with a focus on the first category: the winegrowers. For the definition of the use cases, two different strategies were applied to get information on the needs of wineries in Luxembourg with respect to digital decision support and digital-based management systems.

The purpose was to let different stakeholders define the needs of the users. First, the winegrowers' needs were analyzed, from the perspective of needs for digitalization, business development/opportunities and research. The specific communication strategy with end-users for the user need data collection was divided into the following three tasks:

1. Interviews were carried out with viticulture business in Luxembourg in the period December 2022 and January 2023. The interviews were based on the stakeholders' opinion about the needs for digital support in viticulture management. In each case, interviews took place with a duration of 1-2 hours, in which a previously compiled list of questions was worked through. The questions covered the topics of decision-making in downy mildew control, irrigation/management of drought stress and fertilization management. The selection of the winegrowers ensured that all types of farms that have a relevance in viticulture in Luxembourg (self-marketers, grape producers, organic farms, conventional farms) were covered.
2. Based on the interview, an additional 2-page questionnaire survey was drafted and was made available at the Luxembourg viticulture day on the 1st of February 2023, an event with approx. 150-200 winegrowers. The Viticulture Day in Luxembourg takes place annually in February and is organized and carried out by the Luxembourg Winegrowers' Association. It is the most important professional and educational event on viticulture in Luxembourg for the topics of cultivation, cellar management, marketing, and viticulture policy. The survey was done in the form of a multiple-choice questionnaire, which covered the topic of using digital data for decision making in the following details: personal data, business data, use of weather forecast systems, irrigation practice, helpful future technology. Furthermore, the questionnaire contained a "comments" field which invited the winegrowers to add their ideas, remarks, and thoughts in text. The survey was handed out in parallel to an oral presentation of the project during which active participation in the project was promoted. A user-driven approach was described and the importance and central role of the winegrowers themselves were highlighted. 41 participants took part in the survey.
3. Meetings and knowledge exchange with researchers and governmental entities: In the COMMECT project, the experiences on viticulture are tied from different disciplines. Models and methods are already used, applied, or developed within the consortium and its wider network. Thus, the LL Luxembourg organised several meetings with stakeholders like the ASTA or the IVV which are associated with the Ministry of Agriculture, Viticulture and Rural Development, to discuss with them their needs, ideas and opportunities to establish COMMECT solutions.

The applied methodology not only offered valuable insights into the difficulties encountered by the winegrowers but also shed light on the adoption rate and the interest level in using digital solutions for field management. This strategy enabled the understanding of the state-of-the-art viticulture value chain, and the determination of specific user needs that are outlined below.

3.3. Value Chain Analysis

The value chain in viticulture is composed of a multitude of stakeholders that interact and exchange information, goods and services with each other. The winegrowers are at the center of this value chain, and they are responsible for cultivating the vineyards, producing the grapes and making the wine. Around half of the winegrowers are so-called independent winemakers, who are also responsible for the sale and distribution of their wines. The second half of Luxembourg's winegrowers engage solely in grape production. The processing of grapes and winemaking, as well as the marketing of wines, is in the hands of the winegrowers' cooperative "Domaines Vinsmoselle". The wine value chain consists of six broad production stages: planting (vineyard preparation), grape production (viticulture), wine production (viniculture), bottling and distribution (logistics), marketing and sales, and consumption and recycling of e.g. glass bottles (see Figure 4).

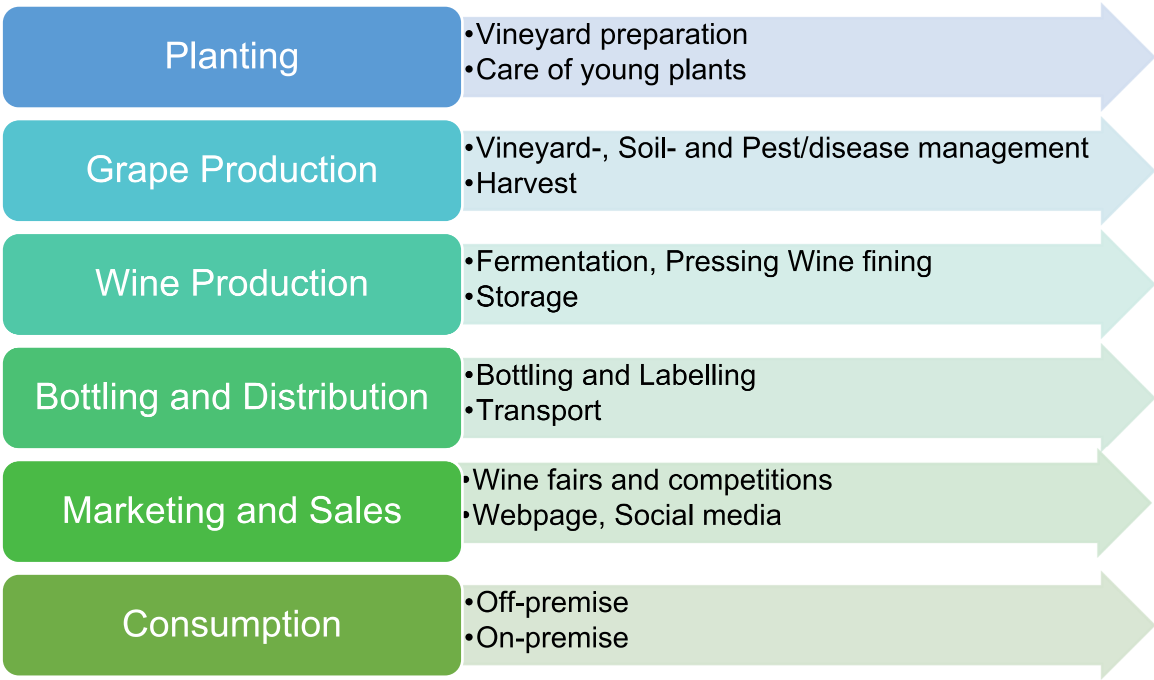

Figure 4. Value chain of wine production in Luxembourg.

As shown in Figure 4, the value chain initiates with the preparation and planting of a vineyard, with a prior decision about the location and grape variety. Plants are produced and delivered directly from the nursery and prepared for planting by machines. In the following years, the care of the young plants takes most of the time for the winegrower.

The next step is the grape production, where all actions concern the management of vineyards. This includes manual canopy management, for example pruning and defoliation. Furthermore, additional work on the vines includes soil management, weed control, pest and disease protection, and finally the annual grape harvest, which can be done manually or by a machine.

After harvest the wine production begins with fermentation and pressing of the grapes. During the stages of winemaking the wine will be filtered, fined, and then stored in the cellar in tanks or wooden barrels.

When the wine is ready for consumption it is bottled, labelled, and usually packed in cartons. The distribution can take place in different ways. The wine can be sold directly from the winery to retailers, but it can also pass by importers who then deliver it to restaurants, bars etc., or through online shops and on-site sales directly to end-users.

Marketing is getting more and more important and includes the participation of wineries in wine fairs and competitions, as well as the webpage, social media, events, and tasting on-site among others.

In the last step, the wine is consumed, which can be done on-premises like in bars or restaurants or off-premises. The last step is related to recycling of, for instance, glass bottles or other materials that can be reused during the wine growing and production etc.

3.4. Stakeholder Analysis

For grape production as well as winemaking, many upstream industries and companies play an important role. Their products, information and services are incorporated into the production process. These include the nurseries for providing the plants for establishing new vineyards, as well as the entire viticulture and machinery manufacturing industry, which provides the necessary equipment for the different production steps. Likewise, the inputs of the chemical industry (fertilizers and pesticides) enter the production process. However, these inputs and products are usually provided and distributed by the agricultural trading companies listed as Planting and Grape Production in Figure 4.

For the winemaking sector, there are also several industries (glass manufacturing companies, cork and closure manufacturers, label printers, packaging manufacturers) that are responsible for the supply materials. The marketing and distribution of Luxembourg wines is partly carried out by self-marketing wineries, by the cooperative "Domaines Vinsmoselle" but also food wholesalers, food retail companies, the specialized wine trade and catering establishments are involved listed as Wine Production, Bottling/Distribution and Marketing/Sales in Figure 4.

The LL Luxembourg divided the stakeholders into three main groups, which are of relevance for the LL viticulture theme. First, the winegrowers, which handle the day-to-day work and management of the vineyards. They are the more vulnerable group with respect to climate change impacts, disease outbreaks and economic changes and uncertainties. Consequently, the LL has an interest in learning the most relevant problems concerning their daily work, in order to understand how enhancing the connectivity in rural areas (COMMECT's key goal) can help them in the various aspects of the value chain (Planting, Grape Production and eventually all further steps of the value chain depending on the farm, Figure 4).

The second group of stakeholders are the data or instrument providers. During the analysis by the LL Luxembourg two stakeholder subgroups were identified. The first subgroup includes companies which develop instruments to measure environmental variables (like air temperature sensors or cameras for Unmanned Aerial Vehicles - UAVs) and the second subgroup provides the infrastructure for digital information to the winegrowers such as digital information management system like the widely used viticulture management information system MOOSLE [3]. The MOOSLE system offers a high level of competence and diversity in the areas of field card indexing, task planning, documentation, inventory monitoring, telemetry and the analysis of work processes and it is favored in the viticulture context. The Moosle GmbH was contacted and a collaboration with COMMECT will be further investigated. Moosle GmbH might be an interesting partner, to visualize the project's results and support with digital information as described below (use case 1.2, digital twin). These stakeholders (data and instrument provider) are linked to Planting and Grape Production stage (Figure 4).

The third group of stakeholders is referring to research and development of new knowledge. The State Institute for Enology and Viticulture (Institut Viti-Vinicole) in Remich, Luxembourg, and research organizations like LIST and other universities have a high need for digital data and information which are the basis and driver of research. There exist also combinations of research and model development with commercial stakeholders. The company GEOsens GmbH (Germany) is an IT service provider that has programmed the model VITIMETEO [4]. The consortium, which is developing and running the VITIMETEO model comprise a list of universities, and ICT and IT related companies and offered as a service from the Staatlichen Weinbauinstituts Freiburg (WBI). These stakeholders are linked to Planting and Grape Production but also to all other steps of the value chain (Figure 4).

There are many more stakeholders in the value chain like the wine sellers, retailers, and machinery producers. However, these stakeholders are not directly involved in the management of grape production, where we see the biggest potential to integrate communication and further digital solution. Thus, since they are less relevant for the COMMECT project, we will not describe them here.

3.5. User Needs

This section presents the user needs identified through the different interviews and workshops (section 3.2) with multiple stakeholders in the viticulture industry.

1A Downy mildew control

Climate change is presenting winegrowers with new challenges, including increased disease occurrence and more frequent, localized extreme weather events. For a disease like downy mildew (*plasmopara viticola*), which is one of the most relevant, leaf wetness is a key piece of information to decide on the need for spraying. Downy mildew is the grapevine disease with the greatest relevance in European viticulture and therefore also in Luxembourg. The damage caused by this fungus can go as far as total crop failure. Therefore, its control is indispensable for an economic and quality-oriented viticulture, but this can only be done prophylactically. The decision-making process and the design of plant protection measures must be carried out by considering many influencing factors. The disease severity conditions of the near past as well as the expected disease severity play an essential role. Both temporally and spatially high-resolution weather data are needed to estimate the risk. These data aid in deciding at which time and with which treatment agent the respective spraying needs to be carried out. Usually, the decision is taken based on the user's experience and/or using a downy mildew forecasting system such as VITIMETEO [4], which can predict both the vine development and the development of the fungus. The model needs air temperature, precipitation, humidity, and leaf wetness as input data. The ideal temporal resolution of the weather data would be 10 min-interval data, but the model can also calculate with a further temporal resolution of up to one hour. However, since the model can only produce forecasts based on data from 5 weather stations installed in the Luxembourg wine-growing region, the spatial resolution and accuracy of the forecasts is severely limited. There is a need to realize an improvement in the infection forecast for downy mildew through additional weather stations and specific sensors for leaf wetness. The possibility for Luxembourg to achieve a better prediction accuracy by additional leaf wetness and temperature sensors is seen as positive by GEOsens GmbH, the company running the forecast model. The data from the leaf wetness plus temperature sensors would replace the installation of a fully equipped weather station. However, the server capacity would have to be enlarged due to the increasing demand for computational resources and power supply, following the high prediction accuracy requested by end-users.

The analysis of the interviews with the winegrowers gave the following results concerning user needs in downy mildew control. When making decisions on the scheduling of spraying dates and the choice of agents, many wineries rely on their own, long-term empirical values. When using weather data, the farms resort to different sources: weather apps of different origins, weather stations of the IVV, or precipitation radars. The use of the VITIMETEO [4] forecasting model varies greatly. In some cases, the system is not used, in others, it is used as supplementary information to the wineries' own experience. However, some wineries arrange all their decisions concerning downy mildew control around VITIMETEO. The need for an increase in the network of weather stations, to ensure a higher spatial resolution of downy mildew risk and thus better site specificity, was mentioned very frequently by the participants. As plant protection remains the biggest challenge, in-field installation of sensors can give a big added value with respect to disease management. The survey showed that especially young winemakers have a high interest in using a field management system.

The precise and need-oriented spraying is saving time and treatment costs and ensures the health of plants and grapes. Thus, there is a clear economic interest. Furthermore, there is an ecological aspect since precise spraying is saving treatments and decreases leaching into the soil or water.

Another result of the survey showed that the greatest interest is in sensor-based recommendations that can be accessed directly via smartphones. The surveyed wineries also expressed the important need for improved estimation of the downy mildew infection situation using leaf wetness sensors and air temperature measurements.

Based on the results from the interviews, the user needs regarding this issue can be summarized as follows:

- Increase of the network of available weather stations to realize a higher resolution of the forecasting model VITIMETEO [4].
- Installation of leaf wetness and temperature sensors to support forecasts systems such as VITIMETEO [4], as well as to improve decision making based on experience. In contrast to weather station, these sensors are less expensive and as such allow for a higher number of installations. Furthermore, it might be easier for the winegrowers to interpret the measurement directly without further modelling of disease severity.

1B Management of drought stress

Due to climate change, longer periods of considerable drought have increasingly occurred in recent years, with the most severe drought (so far) in the summer of 2022. This drought stress causes growth depression in the vines, which can lead to severe yield losses. In addition, drought-stressed grapes show a significantly reduced formation and storage of value-giving aroma substances and show typical symptoms of grapes' sunburn. There is also an increased formation of phenols, which have a negative influence on the grape quality, and the reduced storage of minerals in the grapes can lead to major problems in winemaking.

The experience of recent years shows that old vines survive drought stress situations relatively well due to their deep root system. Symptoms of water deficiency are more likely to be seen in vines younger than 15 years. In particular, young vines aged 1-3 years must be regarded as particularly endangered. In the extreme year 2022, for example, the Luxembourg vine growers were reporting that the drought led to the withering of young vines, which could only be avoided by appropriate irrigation.

Due to limited water availability and for reasons of additional workload, only young plants up to the 3rd standing year are irrigated by the surveyed wineries. In individual cases and extreme years, irrigation of yielding plants on extremely shallow sites is also carried out. Increasingly, drip irrigation systems are installed in drought risked areas immediately after planting. To operate these systems effectively, many wineries would like to have reliable, timely information on the development of soil water contents and usable field capacity. Information which should also have a high level of site specificity that can be used for on-farm ranking of individual plots in terms of need for irrigation, but also for irrigating subplots. The interviews also revealed that there is a need to use UAV imagery to determine the vitality status of vineyards to react to drought stress. Both the soil water balance and the water consumption by greening plants and vines must be mapped and the heterogeneities within a plot must also be recorded. On this basis, irrigation systems can be established and operated effectively in a water-saving manner.

The stakeholder survey showed that high-resolution information on soil quality and soil water content is seen less important than for example the disease-relevant leaf wetness sensors that were mentioned in the previous user needs section. Irrigation does not play a big role in Luxembourg (yet) since only young plants from 1-3 years, or for yielding plants younger than 10 years need to be watered in extreme drought years.

Based on the results from the interviews, the user needs regarding this issue can be summarized as follows:

- Information system for small-scale derivation of usable field capacity.
- UAV imagery, aerial photography and satellite imagery to determine the vitality status of grapevine stands.

1C Site-specific fertilization

Adapted fertilization is also an essential factor to produce high-quality grapes. Fertilization that is too high reduces the quality of the grapes due to rotting, as does fertilization that is too low or not applied at all due to low mineral content, which results in insufficient aroma formation. The amount and timing of fertilization must be adjusted to the needs of the vineyard. Especially soil heterogeneities and spatial differences in the vitality state of the vines must be recorded with suitable tools.

Although vineyards are relatively small compared to arable land, they can still exhibit considerable heterogeneity in terms of the spatial distribution of soil substrates and the resulting soil properties and nutrient contents. The causes may be paedogenic as well as anthropogenic. For example, in the 1970s and 1980s, land consolidation and land levelling were carried out with insufficient care about and focus on soil fertility. As a result, many vineyards show a strong alternation of areas with a high thickness of humous topsoil material and areas where almost exclusively humous-poor, un-weathered raw soil material is present. Although vineyards, in contrast to arable land, have a comparatively low fertilization level, a professional and resource-saving fertilization requires addressing these substrate differences.

The evaluation of the interviews shows that most of the wineries attempt to address known soil differences and heterogeneities when applying fertilizer. The adjustment of fertilization to known heterogeneities (soil and vine stand) is done manually by varying travel speeds or settings of the fertilizer spreader. Digital information is essential for documenting the spatial variability within the vineyard, encompassing both soil composition and the arrangement of the vine stands. As an additional factor in fertilizer measurement, wineries rely solely on visually assessing the vitality of the vines. In some wineries GNSS-capable fertilizer spreaders are available.

Among the winegrowers surveyed, the lowest demand was observed for UAV images as a mean to assess vine vigour conditions when compared to previous digital support methods.

Based on the results from the interviews, the user needs regarding this issue can be summarized as follows:

- UAV imagery, aerial photography, and satellite imagery to determine the vitality status of grapevine stands.
- Determination of fertilizer requirements through digital provision of high-resolution soil information.

1D Single plant inventory

In viticulture, the practice of identifying grapevines often revolves around a simple grid-based system using rows and columns. This system benefits from relative simplicity due to the consistent spacing between plants within a vineyard, which typically have similar row and column spacings. However, this grid-based identification falls short when higher spatial accuracy is required or when inconsistencies, such as missing or dead plants, disrupt the pattern.

Identifying the exact stem positions of wine plants can significantly enhance various sectors of the wine value chain, particularly those directly interacting with the plants. For researchers, having exact stem positions can provide valuable insights when rating plants. It allows for precise, individual-based data collection, which can lead to more accurate findings in studies of disease resistance, plant vigour, fruit quality, and other viticulture research areas. For wine growers, this level of accuracy in plant identification and documentation can improve plant development monitoring. It can guide precision agriculture techniques, including irrigation and harvesting, or targeted application of treatments. Additionally, detailed spatial information can also contribute to improved vineyard management strategies. For example, it can aid in planning for plant replacements, optimizing vineyard layout, and even informing decisions about harvesting and pruning based on individual plant health and productivity.

With these potential benefits of exact stem position, we can develop more specific user needs:

- Highly accurate stem positions: Users require techniques capable of determining the exact stem position with a positional error of no more than 5 centimetres. These techniques should be cost-effective, efficient, and adaptable to different vineyard configurations and sizes.
- Data Integration: Once obtained, the stem position data needs to be integrated into a format that can be easily accessed and understood across various platforms. This could include Geographic Information System (GIS) platforms, vineyard management software, or research data analysis tools. The integration process should maintain data accuracy and ensure the data is readily available for use in decision-making processes.
- Scalability and adaptability: The methods used to acquire and integrate stem positions should be scalable to accommodate vineyards of different sizes. Moreover, they should be adaptable to changes in vineyard layout due to plant growth, replacements, or redesign.

1E Leaf Level Symptom Mapping

Past research projects showed that in viticulture the precise geolocation and orientation in UAV image data is challenging due to the row structure and the fast and wide growth of the plants. In theory, UAV image data could be sufficient to map leaf level symptoms in a vineyard, but in practice the distinctive traits of vineyards make it difficult to differentiate between healthy vine leaves and the surrounding vegetation or between symptomatic vine leaves and other background pixels. In aerial or satellite imagery, with much larger pixel sizes, the confusion of ground/leaf pixels is not the issue, but rather that all pixels are mixtures of leaf and background pixels. Lastly, as described in user need *1D Single plant inventory*, plant inventories and ground truth data are usually defined by just point coordinates, with relatively low spatial accuracy, which makes it very difficult to link expert ratings of plant diseases with image features. To summarize, there are three main problems which make it difficult to link image data and ground truth:

1. Pixels from operational satellites are mixtures of many leaves and background which could be anything ranging from vegetation to nearby roads.
2. Pixels from UAV based research instruments can usually not directly be identified as leaf pixels.
3. Ground truth data is usually point based and cannot be directly linked to pixels in the imagery.

Leaf level symptom mapping could be of great potential use for winegrowers directly. If provided quickly after data acquisition, they could use the maps to verify any identified symptoms and intervene directly. Additionally, they could adjust their future management strategies in terms of irrigation, fertilization, application of pesticides and more. Researchers, on the other hand, could use high precision symptom maps to validate and improve monitoring and modelling algorithms. Since the geolocation of a given symptom would be much more precise, it can be directly linked to other image-based instruments and used to train classification and regression models.

Taking the above considerations into account, we can define the specific points regarding the user needs associated with leaf-level symptom mapping as follows:

- Symptom mapping with high spatial accuracy: For a given symptom, the occurrence must be available in a spatially explicit way (e.g. as raster or vector data) with a geolocation error of less than 5 cm.
- Timely integration: Spatial data needs to be integrated and available for the user within 2 hours.

1F Local pattern analysis

UAV data does not give information on leaf symptoms, but they are a valuable source for the analysis of local patterns like patches of downy mildew or differences in temperature due to different elevation or canopy densities. For winegrowers but also researchers these patterns are of great interest because the aerial view gives unseen information on, e.g., big difference of temperature within one field.

Consequently, we define the following specific detail for the user need:

- Acquisition and analysis of UAV data for selected times of interest like drought events

1G Regional spatial information on vegetation vitality

As previously mentioned, extreme weather events and droughts have become more frequent. Moreover, there is significant spatial variability in their appearance, particularly influenced by the hilly landscape and varying hill orientation. These factors play a crucial role in determining the consequences for vine stress symptoms and severity. In the future, irrigation is expected to play a larger role, but water will become (or is already) a scarce resource. Therefore, it is crucial to have regional patterns and timely information on the status of plants for regional planning, such as water distribution. Moreover, regional information is essential from a research perspective to better understand recent and upcoming trends, as well as the occurrence of local differences.

To provide such regional information we define the following details for the last user needs:

- Analysis of very high to high spatial resolution (3-10m) satellite data (Sentinel-2 or Plante Scope) for selected times (like the drought in 2022) to analyse differences in vine vitality and regional pattern of the Mosel region.
- Calculation and interpretation of vegetation indices

3.6. Use Cases

In this section the use cases are derived and described based on the users' needs identified in the LL Luxembourg. Constant exchange with winegrowers, and other actors of the value chain will allow fine-tuning the use cases, during the next steps of the project (starting from the implementation of the use cases in the LL). At this stage, two use cases have been defined: (1) In-field Monitoring of Microclimate and Crops in Vineyards (2) Creation of a digital twin of the vineyard, which will be both explained in detail in the following two sub-sections.

UC 1.1 In-Field Microclimate and Crop Monitoring in Vineyards

The first use case aims to assist plant protection (as per user need *1A Downy mildew control*) in selecting the most suitable timing, dose rate, and treatment for disease control. UC 1.1 will primarily focus on digital solutions for protecting against downy mildew infections and spread, which are related to leaf wetness. Currently, plant protection is mainly planned based on experience and systematic interval spraying. However, with climate change and increasing extreme weather events, along with very local precipitation and thunderstorms, achieving adequate or optimized plant protection is becoming more and more challenging. This challenge has been identified by winegrowers under user need *1A Downy mildew control*.

To support the winegrowers plant protection practices, the Luxembourg LL has identified the need of installation of cost-effective devices in the fields to provide wine growers with relevant information. Specifically, there is a need to install leaf wetness and temperature sensors that measure the most relevant parameters for the development of downy mildew symptoms. For some sites, a full weather station should be installed for detailed calibration of downy mildew growth models. However, leaf wetness is the most important and the most variable information to model and estimate the disease development. Additionally, the possibility to integrate radar information on precipitation should be investigated. High spatial and temporal resolution data is essential for winegrowers to apply good practices in their vineyards. Information from a weather station located several kilometres away may not accurately represent the precipitation that occurred on the winegrower's parcels. However, local weather data is exactly the information needed to apply plant protection in the most efficient way. Non-adequate spraying has the consequence of either potential yield and quality loss or risk of higher impact on the environment if vineyards are sprayed unnecessarily.

As an example, a total of five weather stations are currently in operation and spaced over a length of 42 km in the Luxembourg wine-growing region, for which the VITIMETEO [4] model provides forecasts for the infection process and risk regarding downy mildew. This means that one single model represents a rather large area with a complex and heterogeneous microclimate (hilly slopes along the Mosel River), which is not sufficient for precise plant protection. If the spatial resolution is increased by commissioning additional sensors and weather stations, the heterogeneities of the soil and the relief should be considered. High costs for full weather stations are currently limiting the availability of more data, and therefore, it is a task to limit some sites to the most important sensor (leaf wetness) and the development of a data transfer solution. On the one hand, winegrowers are direct stakeholders. On the other hand, the sensor provider, the modelling consortium for providing monitoring services (VITIMETEO developers), and potentially Moosle GmbH (MOOSLE developer) could incorporate real-time information into their systems, making them potential stakeholders as well. Additionally, there are socio-economic impacts for various stakeholders. Sensor providers may access a new market, service providers like Moosle GmbH could integrate pertinent features into their systems, and individual winegrowers can optimize plant protection treatments intelligently. This means that the winegrowers are informed when they must act in terms of applying plant protection and even more relevant, when they do not need to. This ideally saves the grapes and keeps them healthy while also avoiding the application of plant protection when, for example if a local rainfall did not target their fields even though it was forecasted or recorded by the closest weather station. Finally, this does not only save costs and time for the grape producer but also reduces the impact on the environment by reducing the fungicide applications during the actual period.

The region can be divided into two geological areas: The area from Schengen to Wormeldange is characterized by loamy, heavy Keuper soils and a flatter and more even terrain. At this location and due to the natural conditions, a weather station can represent a rather large area. This means that a moderate increase of sensors will be sufficient for reliable forecasts. The second part of the Luxembourg wine-growing region is located from Schengen to Wasserbillig and is characterized by shell limestone soils. The vineyard fields are placed on steeper terrain, partly terraced. The terrain is hilly and more fragmented. To achieve reliable forecasts on a small scale, more measuring points (weather stations, sensors) are needed for this part in comparison to the first mentioned. An increase of measurement point by approximately three times could help achieving better forecast resolution in the Schengen-Wasserbillig region.

The vineyards are deployed on a large and mountainous area where terrestrial cellular network coverage is spotty/not always available. Seamless connectivity and extended coverage are main demands to ensure constant data collection from the field. There is a need to transfer data at least hourly to the remote server, where the model estimating of the disease pressure is running. Connectivity for the sensors installed in the field can be provided by Low Power Wide Area Network technology (LPWAN) IoT technology, in particular LoRa (Long Range), and LoRaWAN (LoRa Wide Area Network), which support the deployment of private networks. The in-situ data collected at the gateway from several sensors and weather stations in the vineyards can be transmitted to the remote server either by using available terrestrial cellular network connectivity or by satellite backhauling network.

UC 1.2 Digital Twin for Digitalized Management of Vineyards

A digital inventory of a vineyard has many advantages with respect to planning, management, requested reporting, balancing, to just mention some. High spatial resolution remote sensing data can become very valuable for the winegrowers. A full digital representation of a site is called a “digital twin” and the creation of such a digital twin is the second use case of the Luxembourg LL.

The involved stakeholders for such use case are the winegrowers but also researchers, which can run simulations, using the digital replica. Furthermore, governmental organisation which are responsible for reporting or companies who sell machineries or treatments can make use of a digital twin. A first workshop, held on March 16th, 2023, in Remich (targeting remote sensing in viticulture as a seminar in the context of a course on gentle pruning, and jointly organised by IBLA, LXS and LIST) showed that the winegrowers have interest in interpreting these data and motivated them to look for reasons behind different patterns which became visible from this perspective. This use case is about applying wireless networks to achieve the following digital solution objectives:

1. Provide an accurate baseline inventory of the vineyard, including stems classified in old, young, and missing plants. This inventory is then used in conjunction with imagery provided from other sensors.
2. Providing images of the canopy/the leaves which can be analysed visually or automatically with a machine learning algorithm.

The use case focusses on enabling the rapid availability of disease maps, which can then be directly verified by experts, before they use the data to advise wine growers. The goal is to greatly reduce the time these experts spend to check individual leaves for symptoms. Many sensors have come to the market the last decade; however, the data transfer is still under constraints, especially due the huge volume of data from consistent data streams. However, if an image is acquired for example from a camera on the tractor, it would be helpful to analyse the data directly at the edge, and based on the local processing, provide insights to the machine for precise spraying. The same is true for drought stress. Once the drought stress is recognised as critical, water-stress related data must be made available as soon as possible, so an appropriate irrigation schedule, at plant-level can be planned. As a first result, it is most relevant to support an irrigation strategy to distribute (the partly rare resource) water in the most efficient way. However, fertilization might be a topic in the future, to save fertilizer but also to homogenise the vineyards.

Vineyards have some unique traits compared to other crop types, which impede the ability to monitor large fields from a UAV perspective. Compared to a lot of other perennial crops, they are smaller, and they do not have a circular shaped canopy like trees have. As most of their leaves are arranged in row structures with interspaces, they do not have a closed canopy like annual grain crops such as wheat. A large percentage of aerial photos are of mixed landcover, ranging from the actual vine canopy, covering soil areas, to a lot of secondary vegetation between the rows. From the human perspective, leaf-level rating of plant health is often difficult to conduct in a spatially explicit and accurate way. GNSS-based geolocation is generally not accurate enough to track the data collection of ground truth in a way that later this ground truth can be referenced to aerial imagery. For practical reasons, field data is often collected just referencing specific row and plant identifiers, which can then be related to inventory data with geolocation. This geolocation, however, is often not very precisely measured, but rather based on estimations relying on equidistant rows and plant positions.

Consequently, there is a need for spatially accurate vineyard geometry, which is one component of the digital twin. A digital twin in viticulture would be a virtual representation of a real-world vineyard, created using data from various sources, such as sensors, weather stations, and imagery from different sources like cameras, UAVs or satellites (Figure 5). Very high spatial resolution satellite data are available nowadays providing detailed spatial information on plant status like decreased pigment (e.g., chlorophyll) concertation, which is a symptom for diseases like downy middles, or information on plants' drought stress. The digital twin should also include information about soil conditions, climate, water usage, and other factors that affect grape production.

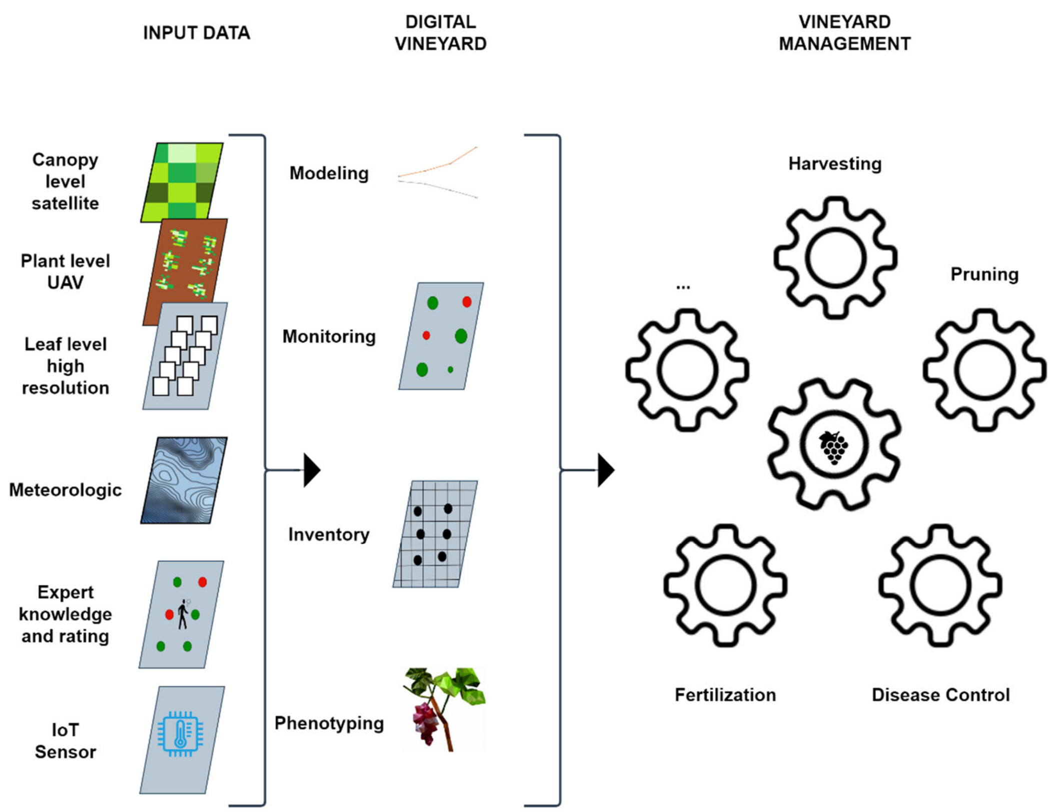

Figure 5. Schematic overview of the creation of a digital vineyard (digital twin).

Using this data, the digital twin could provide a simulation of the growth and development of the vines in real time, allowing growers to monitor and optimize their operations. For example, the digital twin could predict how the vines will respond to different irrigation schedules or fertilizer applications, helping growers to make more informed decisions. Consequently, a digital twin can support all the described user needs, but the use cases will elaborate mainly on the user needs *1D Single plant inventory*, *1E Leaf level symptom mapping*, *1F local pattern analysis* and *1G Regional spatial information on vegetation vitality*. Furthermore, *1B Management of drought stress* and *1C Site-specific fertilization* can be planned and managed with the support of the digital twin, but stakeholders rated these user needs with less relevance for the winegrowers compared to the other user needs.

The digital twin of a vineyard could contain:

- **Stem positions** which could then be used enhance manual plant ratings with accurate geolocations.
- **Canopy masks** which could be used in UAV monitoring to extract pixel values and relate these to ground truth data.
- **Special information** on single plants like disease symptoms.
- Information on **vitality** or **plant age** which might be used for site specific irrigation or fertilization.
- **Regional information** on **vitality** for planning on a large scale like the distribution of water in water-scare periods.

Disease detection could provide spatially explicit mapping of disease symptoms which are mostly visible on a leaf level. These maps could then be used to calibrate UAV based models or be immediately verified by researchers/farmers on the field. Furthermore, these digital representations could be used to integrate IoT data and other external sources, to facilitate process-oriented decisions like the application of fungicides, as well as the operation of heavy machinery and robots.

Information acquired with remote sensing devices can be of great benefit to winegrowers as well as service providers and researchers. The remote and bird's eye perspective from UAVs or satellites can provide valuable information for adapted management that may not be possible from a human's perspective in the field. One example is a smart irrigation, which can be adjusted according to the spatially varying needs of the plants, which may be due to topography and hill slope exposition. Additionally, variability within the field due to the replacement of old and dead plants with new plants can cause different water requirements due to less developed roots. Furthermore, the direct identification of disease symptoms or analysis of general heterogeneity in the field is also valuable information.

Remote sensing data can be acquired on different scales:

- Close-to-canopy images can provide detailed images of a variety of plant phenological features, where even small stems and leaves can be clearly identified. Further than that, leaf details like yellow and brown spots can be distinguished and used to detect a wide variety of plant diseases.
- UAV-based imagery usually has a pixel size of multiple centimetres, meaning that information is gathered on canopy and not leaf level. Pixels are usually a mixture of several leaves and background. Consequently, issues with plant health show a decreased vegetation signal, but it is usually not possible what the exact cause of the decline is.
- Satellite-based images usually have pixel sizes of several meters. They can also be of great benefit to monitor plant health, but each pixel is a mixed signal of background plus leaves from potentially many different plants. Therefore, it is not only difficult to tell what exactly causes the decline in plant health, but also which plant exactly is affected.

All these sensor types have advantages and disadvantages and can provide crucial information for the vineyard cropping system. In conjunction with ground truth collected by field work, internal information provided by IoT systems, external information produced by national and international service providers, these products can be used to build informed decision support systems for all cropping interventions applied by machinery and field workers. One major advantage of this decision support system could be the timely and site-specific integration, which means that the information must be collected from all the numerous different data sources to the decision maker as fast as possible. Therefore, an effort must be made to improve interoperability of data sharing between individual parts.

Geospatial feature detection as a basis for digital twins

Most vineyard inventory databases do not have geospatial information on a single plant level. Since one field can contain many hundreds of individual plants, it is generally too labour-intensive to measure the exact position of individual stems, and furthermore, the extent of the canopy of individual plants and rows. An image-based feature detection and spatial projection approach is proposed. It should rapidly map plant locations and further characteristics, and therefore to provide a baseline geometry for the digital twin (Figure 6).

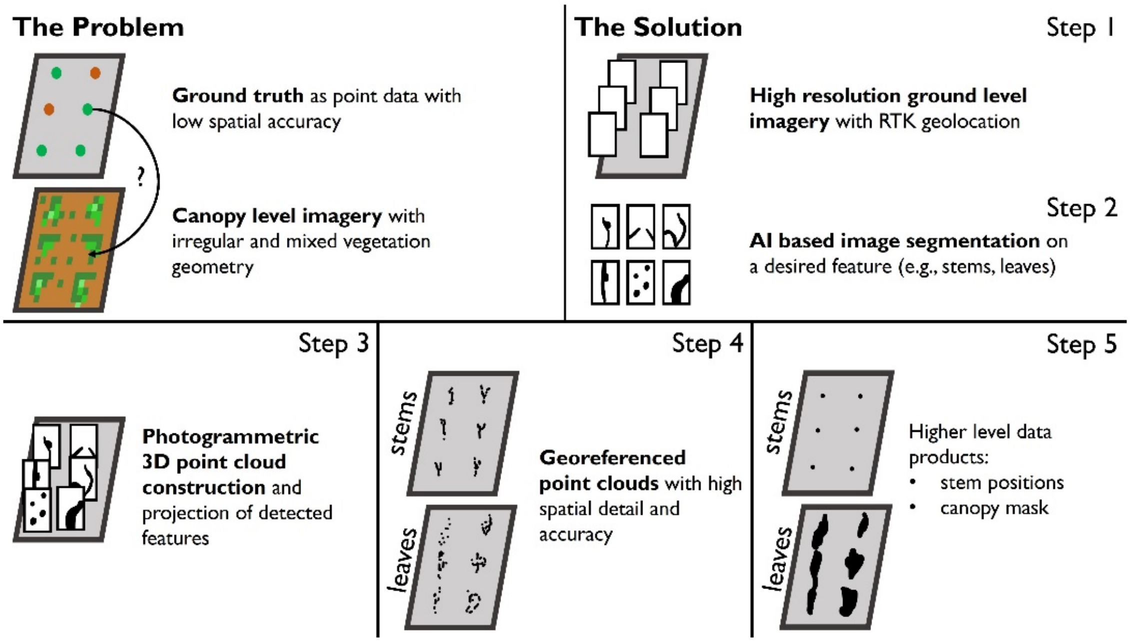

Figure 6. Creation of the geometric basis of the digital twin.

The system itself consists of a smartphone, which continuously records ground level imagery as well as GNSS antenna and receiver, which continuously records the exact submeter accuracy position of the camera. These images are then segmented by state-of-the-art algorithms, and desired arbitrary (e.g., stems, leaves, diseases) features are classified. By means of photogrammetry, these features are then projected on a 3D dense point cloud, where higher level products, like stem positions and leaf masks can be derived from. This system could be mounted on a tractor and therefore rapidly map entire vineyards in detail, without any additional human labour required.

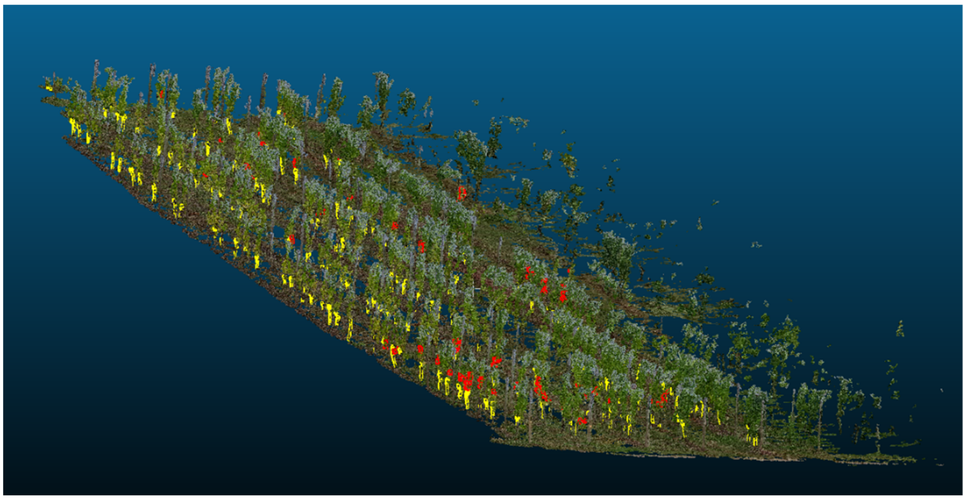

Figure 7. A 3D representation of a vineyard, including stems in yellow, and leaves with esca symptoms in red.

Figure 7 highlights the potential of such a system in the field. In addition to a rapidly mapped 3D representation and documentation of the current state, arbitrary features can be mapped explicitly. The image shows detected stems in yellow, which could be aggregated to accurate plant positions. Furthermore, leaves with potential disease symptoms are highlighted in red. Such predictions could then be used to verify esca on the field if they would be available in a timely manner.

While the data acquisition itself is conducted in the field, the data processing is computationally demanding, and usually solved with the use of high-performance cloud computing. Uploading the data from the phone is done via a wireless network and could greatly benefit from enhanced on-site connectivity, for instance by 5G and satellite Wi-Fi backhaul. The data volume is around 200 MB per row in 1920*1080p resolution. Since a single tractor can cover over hundreds of rows per day, this severely limits the ability to upload the data on the field.

4. Living Lab N.2 – Norway – Connected Forestry

4.1. Characteristics of The Forestry Sector in Norway

Forestry and the forest industry (sawing and value creation of logs) is one of the oldest industries in Norway. In 2020 the total volume of logging was 12 Million m^3 [5]. Comparable figures from Sweden, Norway's neighbouring country, was 70 Mill. m^3, a country with a different topography, characterized with a much flatter terrain. Kongsvinger, where this LL is located, is the second largest (approximately) municipality in Norway when it comes to the volume of logging per year (m^3) [5].

The regional cooperatives (of Norwegian Forest Owners Federation) cover almost the whole of Norway and represent around 30,000 family forest owners [6], with a market share of approximately 80% of the logging market. For most of the family forest owners, the forest is one of several sources of incomes. The forest industry is an important creator of value in the rural areas of Norway. In addition to the material value from forestry and forest industry, the forest is a ground for outdoor life and biotope for many flora and fauna species. Processing timber creates large economic value, and the value of the logs increases approximately 10 times before it reaches the customer as a product [7]. In 2017, the turnover from forestry and the forest industry was 56 billion Norwegian Krone (NOK), of which 8.3 billion NOK originated from forestry. The number of employees in the forestry and forest industry constituted 27,000 work years in 2017 [7].

Today, the forest industry is as relevant and as important as ever. With a general focus in society on sustainability, more and more buildings are being constructed with wood due to it being a greener option compared to concrete, bricks, and steel. Demand is high for the correct type and quantity of timber. Furthermore, the focus on precision and taking care of the surrounding areas in the forest is strongly emphasised now due to protecting biotopes and cultural monuments. The use of mapping forest and individual trees and GNSS positioning have been the prevalent way to manoeuvre around the forest but with the development of, amongst others, satellite and UAV technology, there is a lot of unlocked potential.

4.2. Implementation of Research Methodology and Data Collection

The LL Norway pursued an agile and iterative approach to the development of innovative connectivity solutions [8] and [9]. Figure 8 is an illustration of the iterative process for developing innovative connectivity solutions by the LL Norway.

Figure 8. Iterative approach for development of innovative (5G) solutions for the Forestry LL.

By following the methodology set out in the COMMECT project (see Methodology chapter) the LL Norway has identified and analysed the value chain through primarily desk-based research but also through existing knowledge of some stakeholders that were contacted with specific questions. The LL partner Klosser Innovation has previously worked on projects with some stakeholders in the value chain and as such had prior knowledge exchange with several of the stakeholders and the end-users. This knowledge exchange was supplemented with data and information collected during the first workshop. The decision to stay within a geographical restricted area (South-East of Norway) was made to ensure a consistency of participants throughout the project. Frequent dialogue with the major stakeholders helped identify if there were any major differences across the country. However, it was determined that this was not likely the case since the industry struggles with the same challenges regardless of region.

Identifying the forestry related needs and solutions arose from the collection of the data done during the first workshop.

The LL Norway decided to set out an iteration of uncovering the needs and solutions of the LL stakeholders and end-users. Identifying the forestry related needs and solutions came from the data collection achieved during preliminary interviews before the first workshop, during the first workshop and through in-depth interviews with four stakeholders after the first workshop.

During the preliminary interviews, six stakeholders from different parts of the value chain were asked to identify different problems that could be solved by better connectivity. Roughly 20 stakeholders from different parts of the Norwegian forestry value chain in the region of Kongsvinger in Norway participated on a workshop late October 2022.

During the workshop, an introduction to the industry was given. After that, the stakeholders joined groups to discuss the needs pertinent to forestry and therefore relevant to the Forest LL. Three main questions were proposed for the group members to respond to during their 80 minutes discussion timeslot:

1. What are the most important problems/challenges (pick #5) that digitalization can help solve for the forest value chain?
   - How are these problems/challenges solved today?
2. What type of effects will digitalization have on the identified problems/challenges?
   - Cost efficiency/value creation and profit, or health, safety, and environment (HSE), or improved climate and environment effects?
3. Who are the most important stakeholders affected by the problems and challenges?
   -Where are they found in the forest value chain?

The output of the discussions were documented in a template with the same structure as in the guidelines (Appendix 6 – Guidelines for compilation of user needs). The workshop identified problems and challenges, which in turn were interpreted as needs. Solutions were discussed, but only briefly.

After the workshop, the LL Norway conducted in-depth interviews with four different stakeholders. The purpose was both to confirm that COMMECT partners connected to the LL Norway had a correct understanding of the value chain and the problems concerned to lack of connectivity and to get more information for the use cases.

4.3. Value Chain Analysis

Tentative findings from the workshop show that forestry goes through steps spanning over 60-100 years (from planting to logging) and following transport and sawing of the logged timber for portfolio of different wood products (Figure 9).

Figure 9. Forestry supply chain activities. Activities after sawing are not included.

In the first phase, planting, new trees are planted right after timber is cut. Planting is mostly done by manual labour hired by the forest owner(s). Many plants do not survive after they are planted, hence there is a need for qualified labour for the planting. The quality with which this phase is performed affects all later phases. For example, putting the plants correctly into the ground and in the right place is crucial. 15% of the plants wither after the first 1-2 years, which can be weather dependent, most often due to temperature and drought, but also because of pests. In 2021, 39,4 million plants were planted in Norway, up 70.5% compared with the decade before [5].

After planting comes caring for the young forest (young stand improvements) with a clearing saw, removing forest/deciduous trees around planted trees, or sown trees sowing too tightly. This is also most often performed by hired labour from the forest owner(s) or the Forest owner's association. Here it is important to invest in the right trees, i.e., to select those that have the greatest chance of survival and are of high quality.

Once the young forest has been nursed, it is necessary to complete a thinning process, this involves using smaller forestry machines to take out trees that are least suitable to be used in timber products such as planks. Trees that have been thinned ends up as pulpwood that goes to the paper industry and chipboard. In the thinning the same type of forest machines is used for logging in general, but smaller in size. It is important to have an experienced machine-operator because they pick out the bad trees (e.g., the trees that will be less valuable for further growth) according to their visual assessment. This process is maintained by the forest owners/association but completed by the operator. In the future, it may be interesting to learn more about individual trees in advance – to support the operator in their decision making.

Then there is the logging phase, that involves felling of trees and making them ready for second circulation (new growth). Efficient forestry machines cut down 150-200 m^3 per day (up to 140 trees per hour) It is one machine that cuts and another machine that transports trees to trucks. There are also hybrid forestry machines. Fertilization of forests usually occurs every 10 to 20 years before logging. It increases the volume of trees, and consequently harvest value. Fertilization takes place by helicopter, forestry machines and by hand, often by hired and/or contracted machines and labour. Logging takes place according to specifications from the buyer of forest/sawmills (length and quality levels). The goal is to optimize the value at the end of the tree's lifetime. Attention should be drawn to the fact that the requirements may change over time, e.g. current environmental requirements could differ in the future.

The actual logging is performed using machines from machine manufacturers such as John Deere and/or Ponsse, but often performed by external operators and contractors, hired by the forest owners/association. The logs are measured for the first time during this process before they are cut into different lengths. After the logging is completed, the transportation of the timber from the forest to the sawmills is done by external transportation companies, usually by truck. The pulpwood is also transported by train or ship, since the factories using the pulpwood and are highly specialised in this are in different parts of Norway and Sweden. This is where the timber is then sold from the forest owner/association to the producers of wooden materials and other products of pulpwood. Also, during this stage, the logs are measured at autonomous measuring stations throughout Norway on their way to the sawmill.

4.4. Stakeholder Analysis

The identified stakeholders and end-users of the forestry value chain comprise the five main groups described below.

The first group are organizations of forest owners. They offer small and large forest owners services throughout all the steps of the value chain, planting, care, thinning, logging, transport, and sawing. Further, they assist forest owners with certification, technology, advise on financial topics, real estate development etc. They do not perform the thinning or logging itself but hire external contractors to do it. However, they are still responsible for ensuring that the job is done in accordance with all regulatory and environmental standards and laws. There is a high risk for the organization of forest owners if something goes wrong that has a negative environmental impact. Beyond harming their reputation, it can also put their license at risk.

The second group are contractors offering the service of thinning and logging the forest. The logging is primarily outsourced to independent machine contractors, and they often lease forest machines from the machine vendors/suppliers. They own or lease the machines and are responsible for all operations connected to the actual thinning or logging. They are independent contractors, and they own the data that is connected to and generated during the logging and thinning process.

The third group are suppliers of forest machines for cleaning, cutting, and bringing forward logs to trucks for further transport to sawing mills. For example, Ponsse and John Deere forestry, they sell or lease out machines and then provide support and maintenance for them (on site and remotely).

The fourth group are organizations offering education and training in the forestry sector, i.e., planning, economy, ecology and certification, forest operations and techniques etc.

Finally, the fifth group of stakeholders are providers of third-party (wireless) technology for exploitation of production data from the forest machines, like UAVs, Augmented Reality (AR)/Virtual Reality (VR) technology, camera technology and software.

The Figure 10 provides an overview of the roles and interest of the main stakeholders listed above and other stakeholders involved in the various parts of the forestry value chain.

Figure 10. Forestry value chain and connected roles and interests of forestry stakeholders.

4.5. User Needs

2A Connectivity solutions for forestry operations.

Improved connectivity solutions for forestry work are considered necessary, especially in relation to logging and transport activities. These activities are temporary during the year, and typically occur during a period of 2 months or more. Currently, the lack of connectivity is causing less productive workflows and potential economic losses as well as increases health and safety risks. Today, 4G connectivity and coverage is challenging in several places and performing, e.g., remote operations, such as expert help from another location in real time, is non-existing, due to insufficient connectivity, that cannot support the necessary data transfer.

Connectivity is especially needed during logging operations, and during the planning and reporting afterwards, which adds up to a total period of 1 week or even 1-month. Better precision will also increase the margin of withdrawal for forest owners, as GNSS positioning with sub meter accuracy requiring reference data via mobile internet connection will be significantly more accurate than the current >15 m margin when withdrawing trees and timber. Better connectivity in connection with planting and field processing (as part of the "tree life cycle online" goal), may also be appropriate. Alternatively, ICT solutions must extract data locally/edge (e.g., from the machine) and upload it when there is coverage.

2B Digitalization.

There is a need for more digital support in the Forest process steps. The value chain is the same as it was 50 years ago, but the separate parts of the chain are more efficient than before. Sawmills are already good at extracting the maximum value of the timber, which means that that part of the value chain is already optimized. The greatest efficiency gains that can still be attained are along the way before the timber reaches the sawmill. A lot of effort is required to move from stump to sawmill. The profit margins are very small, 5-10 NOK extra per m^3 of timber is regarded as a large margin. Smarter forestry will save costs, reduce the possibility of misunderstandings regarding what trees should be logged, reduce inefficient logistics and increase use of data from the forest chain. Timber is treated as bulk goods (length and volume) with less focus on differentiation on quality and price (i.e., primary, and secondary products), which means that forest owners do not get paid for quality. It is a low-cost industry with low margins. Quality is first determined when the timber arrives at the sawmill. It is then the sawmills that take the risks and benefits of varying quality. There is significant potential for various parties to save and earn through more effective timber utilization and greater recognition of quality during logging.

Digitalization should ideally begin with the planting of a tree and continue throughout its life cycle, documenting its health status. However, since the process from planting to sawing takes 80 years, it may not be feasible to digitalize the entire life cycle. Nonetheless, having more information about each individual tree's profile before logging can be very beneficial. Scanning the forest and collecting data that can serve as historical data and be used as a basis for future analysis would be highly valuable and contribute to real-time decision-making support.

2C Improving data flow between stakeholders and end-users.

Being able to standardize data across the value chain, with only one entry point, would be extremely valuable. Today data silos are a big challenge. Varying levels of digitalization per activities in the value chain makes it difficult to collaborate across the stakeholders/levels of the value chain. The intended goal is to have a better flow of data between the stakeholders. Streamlining the forestry industry requires that many parts of the value chain cooperate. Forest owners' associations are often cooperatives, where issues are raised locally and regionally, the industry is promoted, and there is a community to relate to.

2D Need for digitalisation of the forest PEFC and CO_2 certification.

There is a need for an easy upload of data and measurements in line with industry CO_2 requirements. The introduction of the Programme for the Endorsement of Forest Certification (PEFC) [10], which tells the end-user that "this timber product is from a sustainable forestry and controlled sources", has become increasingly important in the forestry industry and is likely to become a requirement. To obtain PEFC chain of custody certification, a forest owner or company within the forest supply chain needs to fulfil certain key requirements. A forest PEFC certified forest owner or company within the forest supply chain also needs to keep records to prove that their forestry is managed in line with challenging environmental, social and economic requirements. There is currently some support for record keeping and checking of environmental requirements in parts of the value chain where PEFC's is considered. This is the reason why the forest owners and PEFC audit authorities want to increase the usage of digital information. Most of the timber that is cut in Norway is certified through the Norwegian PEFC Forest Standard. In the future, it is expected that "everyone" must follow this certification, otherwise they will be banned from the industry ("whip"). When considering the environment in the forest it also includes how the forest floor is worn down through the forestry operations. These operations must be adapted to wet areas/water maps. Unfortunately, it may seem that today, some are more concerned with cost efficiency than certification.

2E Operator Safety

It was identified that it is important to provide safer working conditions for the machine operator. The operator is exposed to fatal injuries when working (often alone) sitting inside, but also being outside and around the forestry machines. With no or little network coverage, communication options are few or non-existing (pending). Operating in tough terrain also consists of a certain level of strain injuries to the operator's body.

2F Documentation – Protected Areas

There is a need for better documentation (e.g., mapping) of the forests close to protected areas (with diverse species). In situations where forestry work is performed close to protected areas with rare flora and forest species, there is a requirement that the operator documents that these operations are done in accordance with the regulations of these areas, hence without exceeding the boundaries/limits and damaging the terrain and vegetation. This documentation is submitted after each forest operation is completed.

4.6. Use Cases

Based on the user needs, the LL Norway identified three main use cases, that are connected to three areas tied to the value chain, as illustrated in Figure 11. These three use cases are related to several of the steps in the value chain.

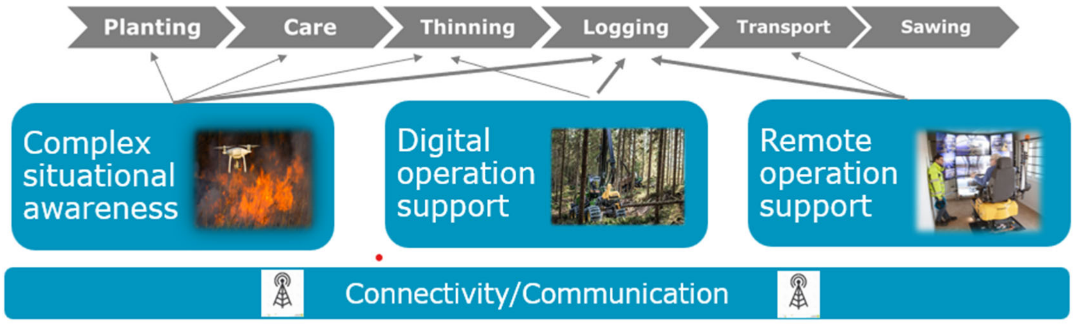

Figure 11. The forestry use cases (middle row) connected to the value chain (top row). The bottom row is showing that connectivity is required for each use case and across the forestry value chain.

UC 2.1 Remote operational support from expert for forest machine operator.

This identified use case accommodates for the situation where one forest operator is guided and supported by another expert remotely or the machines are remotely controlled (end-to-end communication). This includes VR, sensors, and digital cameras mounted on forest machine, UAVs, etc. The remote support is connected to the activities: thinning and logging, i.e., an expert from the forest operator company is giving advice to the operator who is in the forest and supporting the decision-making on a remotely basis. Further, support related to maintenance, detecting, and repairing engine errors or other machine errors will also be explored. In the mentioned situations, an expert from the vendor, who is located nationally or internationally, supervises the operator via online camera(s) with support from an AR setup at the vendors location. This would enable the possibility of providing the machine operators with direct access to immediate support when maintenance is needed. The use of remote control and operator support is limited in forestry, in particular because of the poor performance of cellular network in the forest areas.

This use case is tied to the user needs: *2A coverage and communication*, *2B digitalisation*, and *2F operator safety*. The main stakeholders are Forest owners, the Forest owners' associations, companies providing operators, forest machine producers and transport companies.

An extensive possibility to control remotely an entire fleet of machinery and personnel, thus limiting the possibility of incidents and decreasing expenditures. Using automation during the logging process is one possibility in this use case e.g., via remote/self-driving machines compared to automation of tasks performed by the operator (who make mistakes, logging errors) today, often these mistakes are made due to not having sufficient information or data about the surrounding forest or the operators are not experienced enough to make the decisions. Remote assistance (from experts located elsewhere) e.g., when repairing forestry machines, can take place via the mobile network and someone could override the controls and make the decisions the operator is struggling with. Harvesters can also be "docking stations" for UAVs with video analysis/LIDAR of forest, terrain around logging fields. The topography is an important factor for the efficiency of remote cutting, flat terrain is preferable in comparison with more rugged terrain. The size of a football field is cut in one day with the current solutions on site by operators. Automation of logging is challenging but can provide some advantages, such as increased efficiency and reduced errors. One solution that provides the operator with more information whilst performing the logging is using VR glasses that can read the profile of the single trees (this is a future solution).

This use case will help reduce the number of errors made in the thinning and logging process, in relation to what areas of the forest and what trees should be cut. It is often down to the experience of the machine operator, how well and correct this is done, and since the industry suffers from recruitment issues, there are not enough experienced drivers out there. This problem would be solved by enabling them access directly to remote experts that can provide immediate assistance. Further this use case reduces the downtime of the machine and as such decreases the financial losses occurred during that time.

An increase in digital solutions and connectivity can address several challenges in this use case. Such as the operators being alone inside or outside the forest machines during the period when cutting the logs, often for up to 12-14 hours a day. The difficulty with such long and strenuous days is that the operators become exhausted. In addition, the operators cannot comply with the regulation of maximum hours allowed for a working day. The consequence is that the operators must take shifts, which require hiring more operators, which by experience unfortunately consists of less experienced personnel. Another issue connected to this is that the newly recruited operators are in general left to themselves in the woods, potentially without having all the necessary competency. Being able to use digital camera technology, for educational and training purposes on site in the forest will increase the quality of the entire logging process, including how to drive and manoeuvre around the terrain, as well as increase the sense of security for the operator. Another potential problem alleviated by this use case is that those working alone in the woods are quite exposed if there were to be an accident and there is no connectivity enabling them to get in touch with someone.

There are various ways to reduce the risk of injury to operators and minimize errors associated with the use of machinery in logging activities. These include remote steering activated through 5G, the use of AR/VR tools, 3D models that map the forest, and direct assistance to operators during logging activities such as cutting and transporting logs to nearby forest roads. The current lack of real-time logging services causes delays in production and is not cost-effective. Additionally, the absence of real-time connectivity poses a risk of injury, especially in cases of forest fires or other emergencies where the operator needs to contact someone remotely as soon as possible. It is yet to be determined which of these solutions can be implemented now or within this project. However, a benefit overall of addressing this use case is that it could lead to an increase in recruitment to the industry and an improved working environment for the operators. There is also an increase in value through that the correct parts of the forest are chopped during the thinning process and less damage is done on the surrounding terrain.

5G is useful for this use case because it promises a single solution for several key industrial requirements, namely guaranteed throughput, guaranteed response-time, scalability in number of nodes for large sensor networks, indoor and outdoor position information, as well as information security related to issues such as privacy and authentication. For remote operation, it is especially important that the response times are predictable, and sufficiently small. This is one of the issues that 5G through its slicing mechanisms is expected to solve.

UC 2.2 Complex Situational Awareness services in the Forests

This use case aims to provide emergency personnel (police, ambulance, fire and volunteers) with real-time digital information of a critical situation (accident, fire, landslide, flood) occurring in the forest. It is connected to user needs *2B Digitalisation* and *2F operator safety*. The involved stakeholders are machine operators, contractors, forest owners/association, authorities, and UAV producers.

The added value of digitalisation and technology here is addressing the situations where operators are subjected to accidents and injuries or where real-time situational awareness is needed. The use of UAVs (with mounted 5G antennas) to distribute real time video to e.g., smart phones or other devices of emergency personnel's (police, ambulance, forest fighters, municipality) will provide the necessary situation awareness to handle the situation effectively. In this use case, the objective is to ensure the smooth functioning of the core forest LL stakeholders as described initially. However, for further needs assessment and trials, there is a need to involve additional stakeholders. The COMMECT partners connected to the LL Norway have identified some suppliers who have developed a UAV technology that enables the analysis of machine tracks and provides a certain level of support.

UAVs can provide real-time situational awareness in forestry by capturing various data sources such as high-resolution imagery, infrared imagery, environmental data, GNSS positioning data, and LiDAR data. These data sources can enable forestry operators to respond quickly to changing conditions and make informed decisions about forest management and emergency response. The high-resolution imagery and LiDAR data can provide detailed analysis of forest features, while the environmental data and GNSS positioning data can provide important context for situational awareness. The use of UAVs for real-time situational awareness can improve the efficiency and effectiveness of forest management and emergency response in the forestry industry.

Data analytics techniques such as image analysis, machine learning, spatial analysis, statistical analysis, and predictive analytics could be used to analyse data captured by UAVs for real-time situational awareness in forestry. These techniques can provide valuable insights into the forests condition and support informed decision-making by forestry operators. By analysing the data captured by UAVs in real-time, forestry operators can respond more quickly to changing conditions, improve the efficiency and effectiveness of forest management and emergency response, and make more informed decisions about forest sustainability.

Currently, not many digital solutions are implemented because there is no possibility to fly UAVs in the necessary areas due to the communication requirements not being met. Progress in this area has been made, but it can be significantly improved to cover the user needs.

The 5G cellular technology stands out as an ideal candidate for preserving reliable and seamless connectivity that are demanded by the use case. The technological features for using a UAV for real-time situational awareness in forestry is the use of edge computing and nomadic 5G networks. Edge computing involves processing data locally on the UAV or other edge devices, rather than transmitting it to a centralized server for processing. This can reduce latency and improve real-time decision-making by allowing forestry operators to quickly analyse the data and respond to changing conditions. Another feature is the integration of machine learning algorithms on the UAV or other edge devices, which can enable the UAV to identify patterns and anomalies in the forests condition in real-time. Additionally, the use of swarm UAVs, which operate in coordinated groups, can improve the coverage and efficiency of UAV-based data collection.

UC 2.3 Digital decision support for forest machine operators

The aim of this use case is to enable the forest operator to be guided and supported with digital tools in order to improve efficiency and decision making during the logging and thinning process. That is, no external expert support. This use case can include the following technical and methodical components:

- Digital maps, AR, IoT sensors, cameras mounted on forest machine/UAV etc.
- Digital maps with online updated information that will assist in preventing the operator from driving into "forbidden" areas and smart tracks. UAVs and cameras that provide information on the health of trees, e.g., diseases and pests. Digital supervision during thinning and logging. Digital supervision (e.g., AR) detecting and repairing engine errors etc.

This use case helps solve the problem connected to the need for better precision and reducing errors in the thinning and logging stage to increase profitability as well as protecting historic monuments and biotopes. This use case is tied to the user needs: *2A coverage and communication*, *2B digitalisation*, *2E need for* CO_2 *certification* and *2G documentation-protected areas*. The involved stakeholders are forest owners, operators, forest owners' associations and machine operators.

The above mentioned technical and methodical components exist in some level already, but the readiness level is not sufficient to cover all the user needs. The machine operators have maps and some images to base their work and operations on, but they are far from comprehensive enough due to lack of sufficient data and connectivity. As for CO_2 certification, since this is something relatively new to the forestry business, not all members of the value chain are paying close attention to it because it is not yet demanded or regulated by law.

The added value of the digitalisation provided by this use case consists of a tool/system that provides the forest owner/association of forest owners and the machine operator with real time data, enabling them to improve the decision-making processes. This will enable the operator to better select the logs to thin/care or cut, and which routes to take in the woods. The type of relevant information includes (but is not limited to): where the tree is located, when it is logged, whether there is rot in the tree and the value of tree. This type of information created for every tree, can be used for planning and optimizing production.

Today, data from the available and digitalised maps, as well as UAV pictures and laser scanning are used. This data has been improved over the years. This makes it easier to determine the price for the logging/thinning task. The laser scan can give a good estimate of volume. This helps both the operator and forest owner when writing a tender for the work to be done.

More frequently updated data will improve the stakeholders' revenues and ensure that the environmental standards are upheld (including avoiding driving on historic sites, reducing the risk of cutting the wrong logs, and documenting tracks). Such information can be presented to the operator through real time streaming from cameras, as well as UAVs taking overview pictures (making online 3D models), creating online maps with different layers of information, combined with AR/VR headsets. Today the logging and the driving route is based on data from maps where there are safety margins included against the areas where you should not drive or cut. The driving route and which trees to log is mostly up to the machine operator. The operator uses maps such as terrain maps to evaluate the best route. The technology could be better connected/integrated.

Currently, there are no implemented systems offering visual or digital assistance in the logging process. Enhancements, such as information from sensors around the machinery, are deemed beneficial for decision-making. Features like visual support, consistently updated real-time values, and more accurate logging aligned with end-buyer requirements would be highly advantageous. In activities like thinning trees, decision-making holds greater significance due to its long-term economic impact. It necessitates strategic choices to retain the best trees, fostering their growth for increased future value.

It is possible to get this kind of information using cameras that can generate a complete overview and generate model 3D images and maps, but this requires access to better data. The more one knows about the single tree (profile/position) before cutting it, the more likely it is that there will be a reduction in the number of incidents of cutting rare biotopes.

Further, it will enable smart routing, facilitating them to avoid driving through rare biotopes and destroying cultural monuments, as well as reducing the fuel consumption and CO_2 emission along with reduced degradation of the soil/forest floor. A full support system in digital decision making connected to what order to log the trees and what route to drive etc could be planned more automatically. This could be incorporated into the maps, which is not done currently.

In essence, several major stakeholders from the value chain would benefit from the operator having frequently updated data as well as more data on the trees they are about to cut as well as assistance in the decision-making processes especially during the logging process but also before.

5. Living Lab N.3 – Denmark – Connected Livestock Transport

5.1. Characteristics of the Livestock Transport Sector

Livestock transport is a vital element in the supply chain of animal breeding and production. The structural transformations of the downstream industry of pig production creates a need for longer transports of animals, as farm size continue to increase, as farm density decreases, as costs of meat processing increase in Denmark, and as national and international trade of pig genetics has become a business. According to a review report by the European Court of Auditors [11] about 34.9 million pigs were transported between EU member states and 0.5 million pigs to or from non-EU countries on average over the years from 2017 to 2021. In 2021, more than 31 million pigs were exported from Denmark to more than 25 different countries in Europe [12].

To ensure animal welfare during livestock transport, regulations defined by the EU and the country where the transportation is occurring should be met. Some of these regulations require communication of digital data as well as paperwork between the livestock transport units and the operational centre all along the transport route. When pigs are moved between consignor farm and consignee farm, the transport must always be registered in the Pig Movement Database [13]. In addition, as it will be shown in the following sections, the livestock trading process could strongly benefit from further digitalization.

5.2. Implementation of Research Methodology

The Danish LL aims at achieving a better understanding of the end-users' needs by interviewing the different stakeholders involved in the livestock trading and transportation processes. To collect the user needs and achieve a good understanding of the livestock trading process, the Danish LL followed a collaborative approach with the involved end-users and stakeholders. Starting with desk research, and by having discussions with the main stakeholders (well known to the LL leader), the identified other stakeholders (suppliers, farmers, etc.), which were later categorized into interest groups, (as explained in the stakeholders' analysis section).

Once the most relevant stakeholders were identified, the Danish LL created a questionnaire based on the guidelines in Appendix 6. It included questions that would allow the LL partners to identify the end-user's needs, how these needs are currently addressed or not, how they could be addressed with communication technologies, and why it is not done already. Multiple interviews, lasting between 60 to 90 minutes, were carried out with at least one representative of the different groups of identified stakeholders, where the questionnaire was shared and discussed with them. The interviews provided insights into both the present and future user needs for the whole livestock transport sector, focusing specifically on the digitalization aspects and the value that it could create.

The user needs and application scenarios that were identified during the interviews are summarized in a table presented in Appendix 3 and will be further explained in the following sections. By analysing the collected user needs, and identifying similarities between them, a series of use cases were defined, which will be introduced in the following sections.

In the last stage of the research methodology, the list of identified user needs, and use cases were shared with the different stakeholders to make sure that the understanding obtained by the LL partners was correct, and the COMMECT project will be addressing relevant end-users needs for their business, as well as connectivity related pain points and gains.

5.3. Value Chain Analysis

There are series of EU as well as national regulations that need to be followed by the livestock transport traders and the different stakeholders involved in the process. The fulfilment of many of these regulations require access to wireless network. To provide a better understanding of the regulations and the need for connectivity, this section briefly explains the livestock transport value chain and provides a list of the most relevant stakeholders.

Figure 12 shows, in a temporal step-by-step manner, a typical livestock trading process. Detailed information about this process can be found in the DANISH transport standard [14].

The Danish LL deals primary with the value chain of trading and transport of pigs. The value chain initiates by a process for washing and disinfecting the truck, trailer, and compartment units. The typical elements of a vehicle for transport of pigs are shown in Figure 13. After disinfection, regulatory authorities will inspect the transport units and approve if it is ready for a new transportation. This is the first point where connectivity is required since the transport vehicle is not allowed to leave the disinfection area until the approval is uploaded to the corresponding database.

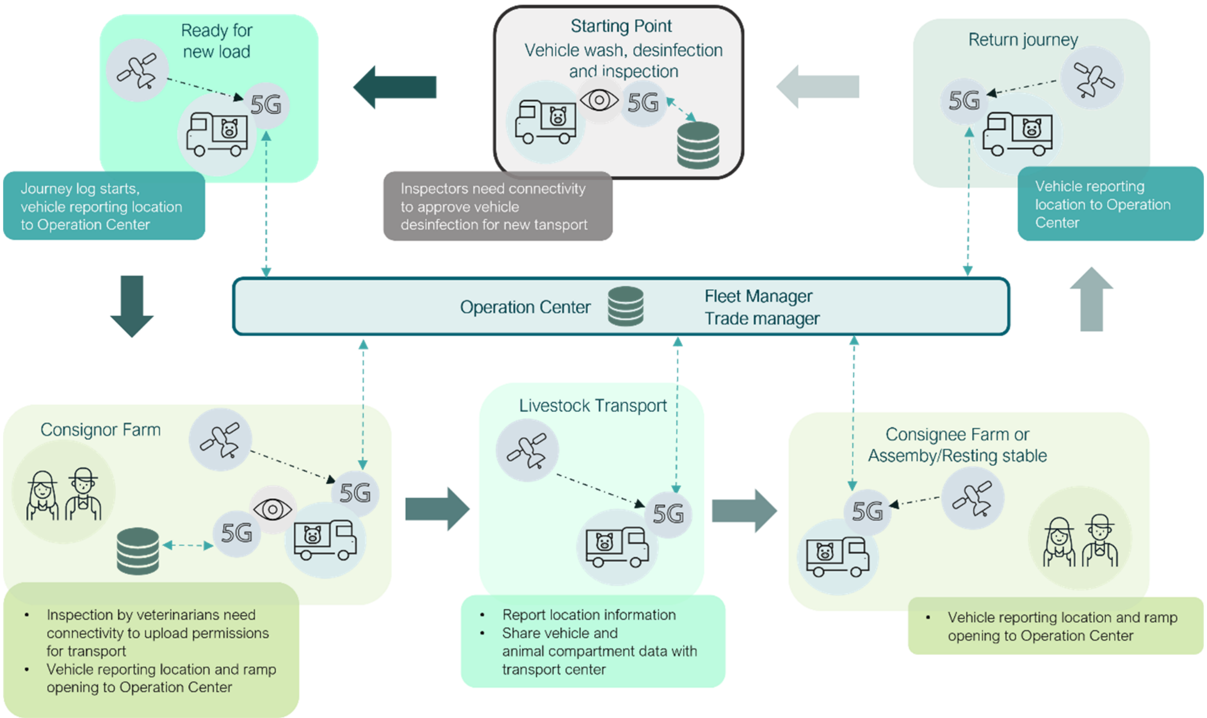

Figure 12. Livestock transport step by step.

Once the journey starts (i.e., the moment that the truck leaves the disinfection facilities to go for a new livestock load), it is important that the regulations imposed by both the Council Regulation (EC) No 1/2005 (2008) *[15]* and the country where the truck is registered are followed. In the case of Denmark, these regulations are imposed by the Danish Agriculture and Food Council and described in the DANISH Transport Standard *[14]*. The regulations and standards can be summarized as follows:

- Livestock transports carrying out long journeys between Member States of the EU must submit a journey log drawn up by the organiser of the transport. The log should contain relevant information regarding the journey (identification of the animals and the persons in charge of them, place of departure and destination, checks carried out during the journey, etc.).

- Trucks should avoid driving through areas considered of high risk of African swine fever infection.
- Truck's location must be reported along the trip with a frequency of maximum 15 minutes.
- Additionally, during the journey, there should be:
  - Monitoring of current location of the vehicle.
  - Monitoring of current animal compartment temperature.
  - Monitoring of a vehicle backdoor status (Figure 13b).
  - Automatic alerting in case of events defined as hazardous/unwanted.
  - Possibility of accessing historical data.
  - Generating reports on the parameters such as the travelled distance, journey time, temperature, etc. (cf. journey logs).

The above regulations should be followed as long as the truck is *"on route",* i.e., it is on the way to pick up a new livestock load, in the process of transporting it to a new farm, or after unloading the livestock while driving towards the disinfection centre. Some of these regulations suggest the need for seamless connectivity along the route, so that information can be constantly reported to the operation centre. Therefore, in order to fulfil them, livestock transport units are usually equipped with:

- Monitoring devices on board of the trucks including various sensors to real time control the compliance of the livestock transport environment with transport legislation (Figure 13b).
- Communication device to allow exchange of location and monitoring data between the vehicle and the hauler remote logistic operation centre. ICT infrastructure collecting and processing the data.
- For tracking and controlling transports from the transport logistics centre a web-based user interface is utilised.

Often a complete logistic service package for livestock transport includes software and hardware. It supports a variety of information services, such as vehicle/trailer parameters monitoring and reporting, basic alarm functionality, basic report generation, on-line access to data, historical data access, as well as the installation of the monitoring system in the trucks. These packages are offered by manufactures of trailers, trailer/truck ancillary equipment and logistic software tools. The solutions typically contain a GNSS receiver, a GSM modem and antenna, and a terminal for the cabin computing and displaying the compartment conditions recorded by the multiple sensors.

(a) (b) (c)

Figure 13. (a) DTL A/S vehicle - Trailer from Cuppers Carrosserieën BV, Netherland.

(b) Monitoring system. (c) Livestock loading/unloading ramp.

When the truck arrives to a farm to load or unload the livestock, the farmer needs to check that the truck's license plate is registered in the database that contains the livestock-transporting authorized trucks. Additionally, a veterinarian should approve the authorization and upload it to the corresponding database before the trading process continue and it is possible to proceed with transportation. This part of the trading process is represented by *Consignor and Consignee Farm* boxes in Figure 12. There is a regulatory demand for connectivity at the loading and unloading locations during inspections by authorities.

5.4. Stakeholder Analysis

The livestock transport value chain involves stakeholders from very different sectors, and the partners leading the Danish LL strived to involve all of them in the process of identifying the end-user needs for the COMMECT project.

Companies fully dedicated to the transport of livestock are considered the main stakeholder of this LL, especially those providing long-term transports (i.e., more than 8 hrs). Within this stakeholder category, different actors have been identified. First, the truck drivers, who are involved in almost all the steps of the value chain and are responsible of complying with the regulations.

The drivers, as well as their loads and routes, are managed by the hauliers, which, in some cases, can also be the traders of the livestock. The main responsibilities of the hauliers are to pick up and deliver livestock while maintaining its quality in the transportation, so that the same quality of livestock in the origin is delivered at destination. They also support their truck drivers for an efficient transport, reducing the journey time, and avoiding the need of resting stops where the animals need to be unloaded and reloaded.

In the endpoints of the value chain, there are the farmers, who have the role of selling and buying high quality livestock breed. For the Danish LL, the focus will mainly be on the trading of piglets (15 – 50 kg pig weight) that originate from Danish breeds and exported to both EU and non-EU countries.

High quality of livestock transport is controlled by the inspectors from authorities and the industry self-regulation (i.e. industry monitoring its own adherence to legal, ethical, or safety standards). Every livestock transport must be controlled by veterinarians (animal health and registration of individuals) and inspectors (cleaning and disinfection status). The inspectors are using digital platforms for checking and typing information before the individual transport units are allowed to proceed to the next step in the value chain.

Manufacturers and providers of livestock trailers, tracking and IoT solutions, logistic software tools, remote control systems, machine vision etc., are typically the ones providing the already existing digital solutions in the livestock trading sector. However, as it will be explained in the following sections, these solutions cannot be fully exploited due to the lack of connectivity in rural areas.

5.5. User Needs

Interviews with the different stakeholders led to the conclusion that livestock transport could strongly benefit for further digitalization, where an increased cost efficiency can be achieved while maintaining animal welfare and livestock quality. They envision a smarter livestock trading, with the transport units connected to the operational centre all along the process. This would allow constant sharing of extensive information, and individual decisions could be made depending on the vehicle's location, the health status of the onboard livestock, or other indicators. More specific user needs were identified and are further described in this section.

3A Improved Navigation Systems

According to EU legislation, there is an 8-hour limit for livestock transport, which can be exceeded if upgraded vehicles are used. After that limit, animals should be unloaded, rested, watered, and fed for at least 24 hours in a staging point. Additionally, to protect the animals' health, the Danish Transport Standard established risk infection areas through which the livestock transports should not drive. If this occurs, a quarantine penalty is added to the usual 48-hour quarantine that is recommended after disinfection of the vehicle.

The drivers and haulers request guidance systems that allow them to minimize the livestock transport time, avoiding waiting for 24 hours in a staging point and passing through high-risk infection areas. The existing navigation systems are not only not optimized for livestock transport (with integrated risk infection areas avoidance) but sometimes lack traffic information due to lack of connectivity, and do not prevent the transport unit from running into a traffic jam.

Since any deviation from the original, planned, and registered transport route in the journey log should be reported and justified to the regulatory authorities, drivers and haulers indicate that it would be also useful to have automatization of this information. They would like to dispose of Intelligent Transport Systems (ITS) that integrate information about traffic conditions and risk infection areas, provide access to traffic cameras, and inform about optimized route with an update frequency that is synchronized with traffic incidents and changes. The ITS could also share the information about the location of livestock transports with both the road authorities/police, which could prioritize the livestock transport and escort it out of the traffic jam, and the regulatory authorities, to facilitate the justification for the deviation compared to the original transport route plan (cf. journey log).

3B Stable connectivity for Livestock Transport to non-EU Countries

When transporting livestock between EU member states, if there are any incidents, or the reporting regulations are not fully met due to a lack of coverage in the transport routes, it is politically considered as a duty of the member states to provide a proper coverage. However, if the livestock is transported to a country outside the EU, the truck driver and/or the haulier, will be solely held liable for any incidents and lack of reporting.

Some of the non-EU countries where livestock may be transported have very poor cellular coverage, and the roaming costs might be very high. Therefore, some of the interviewed stakeholders stated the need for an alternative technology that can provide continuous and stable coverage along the route, even if this route goes beyond the EU borders. This would allow them to prove that they followed the regulations and animal welfare was ensured during the transport in the case of a relevant incident or upon request of regulatory authorities.

3C Frequent Journey Logs Reporting

In the livestock transport process, the *fleet management software* oversees the planning and optimizing of the transport tasks for each transport unit (pick-up in departing farm, transport route, and delivery in destination farm). This software is typically integrated with the administrative systems of both The Danish Agriculture and Food Council and other regulatory authorities, so that information about the trade (license plate of the transport unit, number of pigs being transported, planned and performed route, etc.) is automatically transferred to their databases, as required by regulations.

Having constant information of the vehicle's location and health status of on-board animals (CO_2 levels in the cabin, temperature, water levels, weight, etc.) along the transport, can not only help optimizing the fleet management but would also facilitate meeting the regulations and justifying route deviations to the regulatory authorities. Currently, vehicle's location information is transmitted during the transport with an interval ranging between 10 and 30 minutes, and hauliers claim that this information is sometimes not getting through due to the poor connectivity in some areas of the transport routes. This leads to a manual reporting of the location after the transport has been completed. For the same reason, and since it is not required by regulatory authorities to share that information during the route, sensors information is only reported at the end of the transport. However, hauliers would like to dispose of that information while livestock is being transported to improve the decision-making process while maintaining animal welfare.

Therefore, the hauliers request seamless connectivity that allows for more frequent logging and transmission of location and sensor data from the livestock transport units to the operation centre database.

3D Data-driven Solutions for Livestock Transport

By collecting sensor, location, and other data, the whole livestock trading process could benefit from data-driven decision-making approach. The stakeholders would like there to be more intelligent and automated solutions for the trading process, which is currently mostly designed by humans according to the limited information that they are able to gather before, during and after a livestock transport. This would allow for easier and higher individualization of the proposed route and tasks according to the vehicle's location and the animals' conditions.

Precision Livestock Farming (PLF), a concept that allows real-time monitoring of animals, has many benefits, and ensures optimal use of the farm resources, animal welfare, etc. Livestock monitoring and data-driven support systems that use both real-time data and expert knowledge would be very helpful for the decision-making in the different stages of the livestock industries, including transport [16].

The data acquired can also be used for the development of novel services and business models. The stakeholders interviewed by the Danish LL partners expect to increase quality, efficiency and sustainability of livestock transport through data-driven solutions. For instance, the inspectors are interested in efficiency measures in relation to the authority inspections, the control of the journey log, the counting pigs, and other tasks, without compromising the reasons for inspection. These measures to increase efficiency could be sensors, machine vision and automation of manual procedures, not only during the physical inspection, but also to reduce the need for the manual digitalisation (i.e. typing) of observation data.

3E Automated Counting of Pigs, Illness Detection and Weighing.

According to legislation, pig counting must be carried out before, during and after transport in the depart, staging and delivery locations with a low error rate. The farmers, inspectors and the hauliers struggle to manually do the counting and would like to have automated solutions. This would reduce their workload and would provide higher control on the number of animals, making sure that the trade occurs as agreed. It is important that the correct number of pigs is loaded in relation to regulations and trade contracts. Pigs are therefore counted by the truck driver when loading and again during unloading. Practice shows that there is often a difference between the counts, which is why the count needs to be improved by automation located around the trailer ramp.

Initial studies using the latest methods in artificial intelligence indicate that it is possible to create an automatic counting system with equivalent or higher precision than manual counting. In fact, it is already possible to find commercial solutions that provide this service. These systems typically send the images recorded by the camera to an (edge and/or cloud) computing platform for them to be processed. They have high data rates requirements since the cameras need to stream with high frame rate (≥ 24 fps) and medium resolution. After the images are processed, the system returns the information extracted from them (number of pigs counted, their health status, and other information). For both sending the video and receiving back the results of the analysis, connectivity is required. However, these solutions are currently not used in many farms since the poor coverage does not allow to fully exploit them.

When preparing digital images or videos of pigs for transport, it is important to not only count them but also individually scan them for signs of illness and estimate their weight. It is important that this is done during the movement or the residence of pigs in the delivery room. A delivering room is an area in the farm stables where the livestock is placed prior to the arrival of the livestock transport. All pigs are directed from the stable pens into the delivery room to avoid any contamination from the livestock transport and other factors having effect on the risk of contamination. The pigs in the delivering room are not allowed to return to the stables due to spreading of any contamination. Due to the regulation of maximum load on trucks and trailers in general, the livestock trailers provide a weighing system to make sure that the vehicle is not overloaded. If overload is registered during the loading process, pigs must be unloaded and returned to the farm. However, as mentioned earlier, these pigs are not permitted to return to the farm stables. In the event that these pigs cannot be sold elsewhere, they will be culled. This situation, although rare, can be very costly due to human errors at the farm level. Proper monitoring systems can prevent these errors.

Additionally, the data recorded and extracted by these solutions, should be uploaded to the databases of certain regulatory authorities, so that the livestock movements between countries are registered. This further motivates the need for connectivity in the farms and staging locations.

3F Low-cost Tool for High Resolution Coverage Analysis

As previously mentioned, the use of wireless tools and IoT-based solutions in the transport centres, or in loading, staging and unloading locations, requires good connectivity solutions. Some stakeholders claimed that, despite being assured by the telecom operators that there is good coverage in their area, after purchasing certain solutions that require stable connectivity, they experience coverage issues. This does not allow them to fully exploit the tools or IoT solutions that they have already invested in. Therefore, the stakeholders would like to dispose of a tool that allows them to evaluate the coverage in their premises before they decide to implement a solution that requires stable connectivity.

There are already services providing coverage analysis at what the stakeholders consider a very high cost. Therefore, they would like a low-cost user-friendly device that allows them to test the coverage in the area without the need for contracting costly external services.

3G Automatic License Plate Recognition

Only certified livestock transport vehicles should have access to the farms, and they can only enter the premises if the documentation is correct (e.g., the vehicle went through proper disinfection and was authorized for a new transport). In order to provide access to the vehicle, the farmers must manually check the license plate in the database and assess if the vehicle is allowed to perform the livestock transportation.

The manual control of vehicles entering a farm poses a risk of human error. Incidents resulting from such errors can have a negative economic impact on farmers and livestock trading companies. Therefore, the farmers expressed the need for a license plate scanner that automatically checks the corresponding database(s), checks whether the vehicle is allowed or not to access the farm, and opens the boom gate if the return information is positive. This solution would improve efficiency for the farmers, traders, and haulers, and it would ensure quality in the whole livestock trading process. The check of the certifications associated to a certain license plate in the corresponding database, requires access to the internet. Like the issue mentioned in user need 3*E Automated Counting of Pigs, Illness Detection and Weighing*, connectivity may also be required for edge-cloud processing of the video image. There are already some companies providing this or a similar service. However, the lack of broadband connectivity in many farms challenges the use of these solutions.

5.6. Use Cases

The following use cases have been extracted from the above-described user needs. As it is further explained below, multiple needs can be addressed by a single use case.

UC 3.1 Monitoring of Livestock Transport along Rural Routes

The first identified use case addresses the need for constant monitoring of the livestock transport unit expressed by different stakeholders. Reporting of vehicle location and sensor data information from each mobile transport unit on the road transmitted to the operation center within and beyond EU member states was requested during the interviewing process. Additionally, truck drivers would like to have internet access to download useful data for route optimization (load route maps including current traffic conditions, weather forecast, disease risk infection areas, etc.).

This use case addresses needs *3A Guidance systems that can provide safe and reliable livestock transportation*, *3B Safe livestock transport to non-EU countries*, and *3C Frequent journey logs reporting.* The stakeholders triggering this use case through the discussion of their needs are mainly livestock transport drivers and haulers (including personnel at the remote operation center).

The use case is expected to increase logistic efficiency by enhancing real-time monitoring of the performance of sub-components of the transport of livestock. That is, from the consignor to the consignee of livestock, and to record/tracking via online transmission of regulated and standardized welfare parameters of livestock transports to a database at the remote operation center governed by the hauler.

Another value is seamless updating of route planning for the truck driver’s navigation, which is especially crucial in rural areas with road infrastructures that has limits for large semi-trucks with trailers. It is important for the truck drivers that updated maps can be uploaded to the navigation system showing live traffic information, weather forecast, and fuel prices in real time, which is not possible with offline navigation systems for truck drivers. The navigation, fleet management and remote monitoring systems are in general mature technologies. It is a matter of improved stability of systems, improved security, and enhanced user experience from the remote operation center.

The added values brought through novel communication technology are new features that provide an increased availability of connectivity, increased throughput, and reduced latency of data packets, while retaining or lowering the costs of livestock transport. Specifically, the network service should be used to stream raw sensor and GNSS positional data from the vehicle to the remote operations center and to stream essential services to improve navigation and efficiency of the livestock transport efficiency (i.e., ITS systems).

Currently, the trucks transporting livestock send their location data according to the regulations defined by the DANISH Transport standard (with intervals of up to 30 min.). State-of-the-art livestock transport telemetry systems are based on 2G technology and currently transferring over 4G, whenever available. However, the stakeholders interviewed during the first stage of the COMMECT project claimed that they usually experience poor connectivity. The use case demands seamless connectivity and extended coverage, which guarantee the needed transmission capacity independent of other connected devices.

UC 3.2 License plate recognition

As mentioned in user need *3G Automatic License Plate Recognition*, whenever a new truck arrives to the farm for loading/unloading the livestock, there needs to be an online check of different websites to confirm that the certificates for that truck are in place (i.e., according to the DANISH regulations). This check is performed by the farmers, and it requires them to have online access to the databases.

Tests for automation of this process (license plate scan, database check for the certificates associated to that license plate and automatic boom barrier lifting) have been previously carried out at some farms of Denmark. However, the solution was cloud-based, and the images of license plates of both the truck and the trailer were recorded and sent via the available cellular network to the cloud, where the image processing and check of the DANISH database was performed. The biggest challenge observed during these tests was the low throughput provided by the cellular network available on the testing location.

The stakeholders that are part of this use case are IoT specialized Small and Medium-sized Enterprises (SMEs), haulers, drivers, inspection personal, and farmers.

The added value of the proposed technologies and digitalization comprised by this use case is in the reduction of cumbersome and fatiguing manual work tasks, which can lead to errors. The automation of these processes will reduce labor time for both drivers, haulers, and inspection personnel. To realize this, sufficient connectivity, high data transmission throughput, reduced latency to support live streaming of images and videos need to be provided.

UC 3.3 Monitoring of Livestock Loading/Unloading processes

The user need *3E – Automated Counting of Pigs, Illness Detection and Weighing,* mention the standard and legal procedure of counting the exact number of pigs that is loaded or unloaded in departure and destination locations, respectively. The measure of weight of pigs and the detection of illness is also important tasks to be done before loading takes place. The three tasks are currently done manually by the farmers, and its complexity can lead to errors. Therefore, the stakeholders claimed the need for a computer-vision solution that automatizes this process with cameras having the field of view on the trailer ramp and in the delivering room. The technologies for counting and weight estimation have been partially developed since there are several commercial systems for monitoring pigs in sections inside pig stables, as well as many scientific publications for image processing procedures for recognizing and tracking each individual pig in a herd. It consists of a number of cameras, illumination lights and communication technology for either live streaming of several images per second to a cloud platform that performs the advanced identification of pigs, or an edge computing solution performing the pre-processing of images and producing relevant data packages transmitted to be displayed on a web interface. Therefore, as for the previous user need, the technology exists for monitoring pigs from above, but it is lacking proper wireless connectivity. However, the scanning for illness should be from either the side or from under the pig, because as for example Umbilical hernias in pigs occur when abdominal connective tissue fails to close around the umbilical ring (~belly button or navel).

There are several reasons why the technologies and digitalisation mentioned above are not applied already. It is often not a possibility to get fibre-optic cable broadband in rural areas in Europe. The extent of Very High-Capacity Network (VHCN) was 37.1% on average in EU countries in 2021 [17] which levers the need for at least 5G broadband cellular networks for services that include for instance cloud-based computer vision as envisioned in this use case.

The stakeholders that are part of this use case are IoT specialized Small and Medium-sized Enterprises (SMEs), haulers, drivers, inspection personal, farmers.

The added value of the proposed technologies and digitalization comprised by this use case is in the reduction of cumbersome and fatiguing manual work tasks, which can lead to errors. The automation of these processes will reduce labor time for both drivers, haulers, and inspection personnel. To realize this, sufficient connectivity, high data transmission throughput, reduced latency to support live streaming of images and videos need to be provided.

UC 3.4 Data- and AI-driven Next Generation Livestock Transport.

This identified use case is concerning a smart livestock transport and breed trading framework, predominantly composed of ICT and AI, to develop, deploy, and promote sustainable development practices to address sustainability and quality of this specialised business. In the livestock trading business, customers (farmers) and authorities can collaborate in co-creating AI services and products to benefit both the drivers, hauler, trading, breeders, farmers and authority inspectors and offers a solution towards delivering sustainable long-term benefits for the trading of livestock over long distances. A co-creation process supports the opportunity for promoting all stakeholder participation and bottom-up innovation approaches. The livestock transport and breed trading sector as well as inspectors are already increasingly relying on ICT and foresee that sensors and data acquisition that is already available will have potential for relevant AI solutions. These AI solutions are for the moment envisioned and not under development. The prevalent user needs in this context is acquiring more and more data and add more and more sensors to generate the data that possibly can support the desired bottom-up AI innovation approaches.

Current practice is ICT solutions providing low throughput of data with information about route, global position, and compartment temperature. There is a lot of manual work, registration and paperwork done by both driver, operational centre, farmer and inspector to keep the sustainability at a high level for long distance transport of livestock. A turnover to automation including sensors and AI is desired by the stakeholders to make every activity of the value chain more efficient and less labour intensive. It is also about quality assurance in every activity of the value chain, not only quality of the transported animals, but also the quality of various inspections, which are presently done by humans. This use case refers to the user need 3D, which is about recording more data from sensors, health parameters and move towards using artificial intelligence (AI) systems. The user need is a request to record data for future big data and IoT solutions, although they are unknown/unspecified today. Several stakeholders are expecting and requesting future data driven developments for livestock transport to increase the quality of the transport process. The involved stakeholders are researchers, hauler, livestock transport trailer manufacturer, breed trading companies, authorities, EU funding policies.

Ideas and research of smart livestock transport can be accomplished without (mainly manual data collection) or with big fata technologies. However, the analysis of large and complex data sets that allows not only identifying hypothesis-driven but also data-driven patterns requires big data technologies. Since livestock transport consists of mobile units, it is required that data acquisition can be carried out anywhere, and therefore the only solutions are either to store data in the memory of the on-board data acquisition devices or transmit data with use of cellular network connections and possibly satellite and/or Wi-Fi. The costs of transmission and storage of data will have an influence on which platforms to place the data analysis methodology and software.

The main objective of the use case is to acquire large data sets and video streaming encompassing information for detection of animal characteristics, compartment conditions, global position, weather, traffic, farm, animal health (before/after loading, during transport), driving characteristics (from electronic control units (ECUs) on truck and trailer), and much more that has not been thought of yet. Cellular broadband at the level of fiber-optic cable QoS is required for this use case, because of demands of high data transfer rate per emitter, medium latency and low density of emitters are estimated. To make it cost efficient, one node must handle many emitters simultaneously, each requiring high throughput. Fiber-optic cable technologies are not suitable for the intrinsic mobility of the devices. 4G does not guarantee these performances. Research and development are going to play a key role in the AI and statistical modeling developments that meet the above-mentioned use case objectives. The objective of on-line transmission of large datasets is obvious. However, big datasets provide added value to the research and development of solutions which then results in contributing to sustainability, efficiency and high quality of transport and breed trading of livestock. Typically, research funding is directed towards the combination of general research topics, animal welfare and AI. Bottom-up AI innovations focusing on smart livestock transport and trading of breeding animals over long distances are needed.

6. Living Lab N.4 – Türkiye – Smart Olive Tree Farming

6.1. Characteristics of the Olive Production Sector in Türkiye

Olive tree is a plant native to the Anatolian region, and its main products (olive fruit and olive oil) have been considered important food and commercial products since ancient times. In recent years, with the increasing interest in healthy life and nutrition in the world, the importance of the production and consumption of table olives and olive oil is increasing. Turkiye constitutes a vital gene pool with 93 domestic olive varieties.

According to the Food and Agriculture Organization (FAO) data, Türkiye ranks fifth among olive-producing countries in the world in terms of planting area [18]. According to the International Olive Council data, Türkiye ranks second in the world in olive oil production and first in table olive production [19].

Olive has a share of 3% of Türkiye's agriculture. According to the Turkish Farmer Registration System data, 185.796 farmers are engaged in olive farming. Considering the direct and indirect participation in the olive production sector, this sector is thought to provide immediate livelihoods to an estimated two million people. In addition, commercial activities take place to process olives for oil and table use. Considering all the commercial activities around the production and processing of olives, it can be said that they constitute a field of occupation for approximately ten million people.

Olive production in Türkiye is done with traditional methods, and most producers belong to rural communities. Olive farming is generally carried out in the form of small-scale family businesses. The production area is 5-10 ha, and the average yield per tree is 18.3 kg [18] [20].

Modern planting systems, mechanization and digitalization are taking place rapidly in olive farming around the world. On the other hand, Türkiye is not at the same level as developed countries in integrating technology and digitalization into olive farming. The biggest reason for this is the low-income level of olive farming producers and lack of telecommunication coverage in the countryside. Lack of agriculture knowledge of the olive producer, difficulty accessing digital products, and technological infrastructure can be counted as other reasons. Experts' training of rural people, eliminating the deficiencies and mistakes in traditional olive farming, is expected to positively affect the yield and quality and contribute to Türkiye's economy.

In regions with low productivity, the adoption of innovations is lower due to the lack of knowledge of the producers about modern agricultural techniques, low education level, and the problems arising from the lack of coordination and organization. Hence, special training programs for small-scale family businesses must be developed to sustain rural life and the future of olive farming. Along with general agricultural topics, the training should also focus on the use of technology.

On the other hand, it should not be forgotten that olive cultivation in Türkiye is not only an economic activity but also has a history of thousands of years. Therefore, its socio-cultural aspect is vital; it is a way of life for many rural communities.

6.2. Implementation of Research Methodology

The COMMECT partners connected to the LL Türkiye considered the stakeholders involved in the value chain to define the needs of olive producers. Initially, olive farmers were interviewed to determine user needs. First, end-users' level of knowledge and interest in digital farming systems was discussed during the interviews. Secondly, the connectivity problems or experience in using digital agriculture systems was determined. The early warning systems established to solve the issues identified will be tested in the living lab, and the results will be evaluated. Identified issues and possible solutions will be discussed in workshops with other stakeholders in the value chain. The questionnaires that were created using the outputs from the workshops supported the information gathering about the connectivity needs of olive farmers. This information will be used to evaluate the socio-economic impacts in WP3. The consideration of the information obtained from the workshops, surveys, and stakeholders, enables determination of the technical, economic, and social needs. Based on these needs, the LL Türkiye will organize training activities for the users. Educational activities will be conducted with rural communities and refugees. The development of olive farmers participating in the training will be determined by impact assessment analysis.

The research methodology that was followed is summarised in Figure 14.

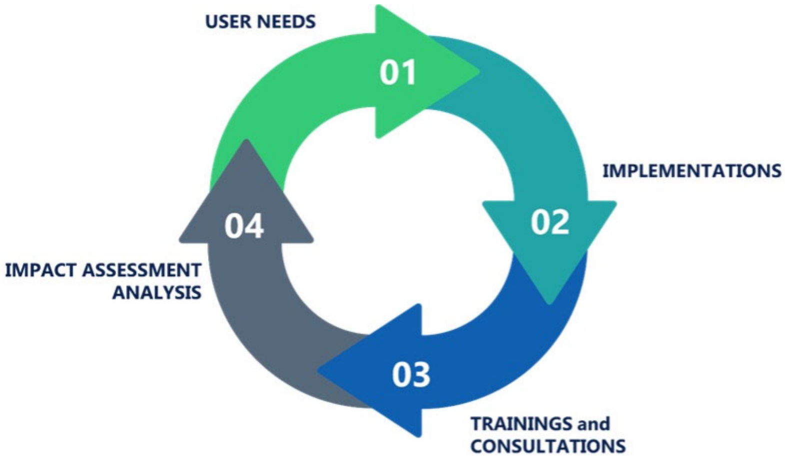

Figure 14. LL Türkiye research methodology.

First, in developing the solution proposals, impact analyses for the methods to be used should be made together with all the table olive and olive oil sector stakeholders and with a holistic evaluation.

Within the COMMECT project, it is desired to obtain information that will help us learn about the most relevant problems of olive farmers in their daily work and how to support them best. This information is collected and evaluated through workshops and surveys with olive farmers.

Secondly, workshops and surveys will be also held with olive processing industrialists and other stakeholders in the value chain after olives have been harvested. Cooperatives and olive production unions will also be evaluated in this group. It will be investigated how these stakeholders can contribute to the solution of the COMMECT project by determining the connections of these stakeholders with the olive farmers and the technical and social problems experienced.

In all workshops and surveys to be held, the stakeholders' contributions in the value chain to the problems or solutions will also be evaluated.

6.3. Value Chain Analysis

The value chain of the olive sector in Türkiye was determined by [21]. This value chain includes olive farmers, the processors, traders, marketing (retail) and lastly the consumers. There are examples of olive farms that also do the processing, trading and marketing. In addition, producer associations are the most important stakeholders that shorten and support the value chain from olive farmers to consumers. Olive farmers come first in the value chain as illustrated in Figure 15. Most olive farming in Türkiye is carried out with cooperatives of which small and scattered family businesses are members.

Figure 15. Value chain of the Turkiye olive sector.

The COMMECT partners connected to the LL Türkiye interviewed with all groups in the value chain to conduct a stakeholder analysis of Turkish olive cultivation.

6.4. Stakeholder Analysis

Approximately 70% of the olives produced in Türkiye are used in olive oil production, and the remaining part is used as table olives. Turkish largest olive oil producer association is TARIS. In the production of table olives, the largest producer association is MARMARABIRLIK. Apart from these two significant producer associations, there are also many small-scale producer associations.

Olive farmers, who undertake the daily work and management of the olive orchard, are mentioned as one group of essential stakeholders. This group is more vulnerable and uninformed about the effects of climate change, disease outbreaks, and economic changes and uncertainties.

A second group is the olive processing industrialists and other stakeholders in the value chain after olives have been harvested. This group also comprises representatives from cooperatives and olive production unions. There are business and olive quality concerns between this group of stakeholders and the olive farmers.

6.5. User Needs

In recent years, the agricultural sector has become increasingly reliant on technological advancements. The Internet of Things (IoT) is a new technology that is expected to boost productivity in farming and agricultural activities, leading to higher yields and lower costs per kilogram of olives. Olive agriculture worldwide is rapidly adopting modern planting systems, mechanization, and digitalization. However, in Türkiye, the integration of technology and agriculture is progressing slowly due to the country's reliance on traditional olive cultivation methods. The digitalization of agriculture in Türkiye is hampered by various factors, including difficulties and problems with digital solution applications.

In total 51% of the olive farmers interviewed were between the ages of 51-65, and 34% were between the ages of 36-50 and the rest between the ages of 21-35. They all knew about Narrowband-IoT (NB-IoT) and enhanced Machine-Type Communications (eMTC) digital farming systems and early warning systems. However, only about 2% of them use these systems due to the lack of technical and financial equipment. The rest of the olive farmers interviewed indicated the willingness to use NB-IoT and eMTC digital farming systems and early warning systems, indicating that their network connectivity needs will increase.

According to the weather information questionnaire, it was determined that the most important sources of information were television and radio, followed by XG network-connected smartphones (Figure 16). Older farmers need to learn how to use their XG connected smartphones as they also view weather reports. Among olive farmers, the rate of using XG network-connected smartphone applications was 69%, the rate of using television and radio was 94%, and the rate of using computers was 8% (Figure 16).

Figure 16. The source of weather information.

The following results, in Figure 17, were obtained by ranking the methods olive farmers will use in decision-making processes for applications such as plant protection, irrigation, and fertilization in the future according to their importance. The six-point Likert Scale was used to measure the producers' views regarding the use of which devices to use in the future (Figure 17).

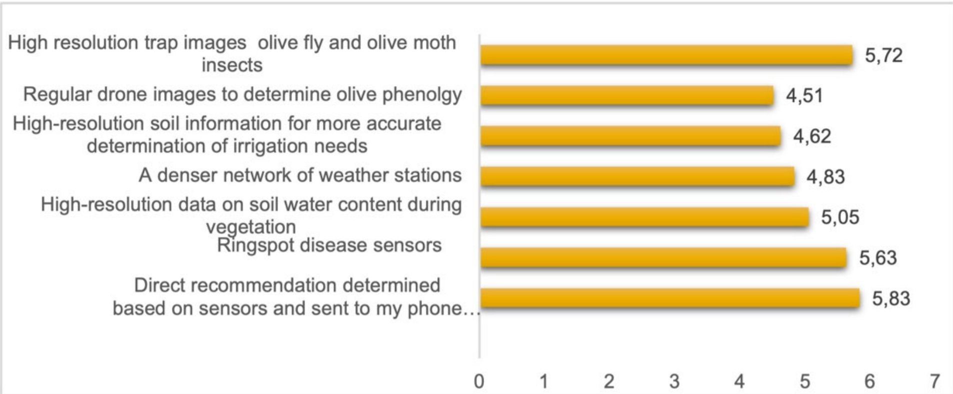

Figure 17. The overall ranking of devices for use with decision-making in olive cultivation.

This Living Lab aims to support the necessary green and digital transition. COMMECT will explore how soil and other conditions can be closely monitored in olive cultivation using XG and edge solutions that enable disease risk management and optimal spraying decisions. The main user needs identified by the Turkish LL are listed below.

4A-B Control for pest and disease

Olive fruit fly [22] is the primary pest of olive orchards, both in Türkiye and in the Mediterranean region where olive production takes place. It causes a significant amount of yield and quality losses. The larvae give rise to direct damage. Larvae from the egg eat the fruit flesh by opening galleries around the seed. Its damage in the olive sector has significant importance since it causes the fruits to decay and the acidity in the olive oil to rise. For effective control, it is very important that pesticides are applied when necessary and on time. This is possible by monitoring the olive fly adults in nature. Overuse pesticide application harms human health and the natural environment. It also increases production costs.

Spraying should be done before the olive fly becomes harmful by using digital traps to identify the first flies, such that, when the number and species of pests exceeds a certain threshold, spraying recommendations get activated. Information technologies containing artificial intelligence should be developed to enable plant health diagnoses and pesticide warnings to be communicated directly to the olive farmers. There is then a need for faster and reliable network connectivity for transmitting data from the many digital traps, mobile devices and user-friendly interfaces. There is a need of more efficient control of pests, while reducing the environmental impact. Increase in yield and quality is also expected from using digital pest traps.

In recent years, there has been an increase in olive diseases due to climate change. Inadequate spraying and spraying not done at the right time cause yield and quality losses. In addition, overuse fungicide application harms human health and the environment and also increases production costs. Early warning systems can accurately determine spraying times by using climate data to control diseases and pests in olive groves.

The most important disease seen in olive trees in Turkey is *Spilocaea oleaginea* (Castagne) S. Hughes (ring spot). This disease causes leaves to fall, making trees unproductive. By using data from weather stations to estimate when the climatic and olive plant conditions are suitable for diseases to occur, a warning could be sent to the olive farmer or orchard manager. A faster and reliable internet connection, suitable weather stations, mobile devices and user-friendly interfaces are all needed to develop an ICT system that recommend the timing and correct strategy for control of diseases in olive orchards.

Network connectivity should be available in rural areas and farms. There is a need of more biological efficient control of olive tree diseases, while reducing the environmental impact. Increase in yield and quality is also expected from using weather stations and ICT. The income levels of the farmers engaged with olive farming are low. For this reason, the digital solutions and support services offered should have affordable prices.

4C Providing education to rural communities and refugees.

Many refugees from the Middle East have migrated to Türkiye in recent years. Refugees from Syria, Iraq, and Afghanistan in Türkiye need social adaptation and labour opportunity engagement. Most of them work as agricultural workers in olive orchards. Their farm practice knowledge needs to improve, and they must learn about olive farming through training (disease pest, pruning, fertilization, etc.). Also, future olive farmers living in rural areas need training in olive farming. Within the scope of the COMMECT project, and acting as a use case, groups formed by refugees and olive farmers in rural areas will be trained by experts at periodic intervals and informed about olive agriculture and digitalization. There are low-income levels of rural communities and refugees. In addition, the labour force in agriculture do not have sufficient knowledge about farming. There are difficulties with socio-economic integration. Even if the information is available, more literacy is needed to allow farmers and workers to use the available technologies and methods. The low literacy rate is one of the main challenges to disseminating olive farming practices in Türkiye. Farm management and economy are also negatively affected by faults and imperfections by workers. Rural communities and refugees should be given specialized training on olive cultivation, which could for instance cover topics such as olive disease and pest control, olive pruning, olive harvest, irrigation, fertilization, and tillage. Socio-economic integration of rural communities and refugees is important. However, in the transition to an information-based society, developing agricultural information-processing technologies infrastructure for accessing information and information literacy is essential and highly needed.

6.6. Use Cases

Two use cases were derived from the user needs, that specifically deal with ICT solutions and wireless network connectivity.

UC 4.1 Microclimate Monitoring for Early Disease and Pest Detection

Rural farmers and refugee workers need to be aware of the environmental and soil conditions to better plan their olive orchard activities and make the right timely decisions to produce higher-yielding quality olives. Monitoring of pathogen-environment interactions based on weather/micro-climatic data is, therefore, essential for the control of diseases in olive orchards. Micro-climatic conditions should be followed, especially in controlling ring spot (*Spilocaea oleaginea* (Castagne) S. Hughes) disease, which can cause severe damage to olives. With the help of data from weather station sensors and models for pathogen-environment interactions will provide disease forecast and early warnings for the disease establishment when certain conditions are met. The use case is tied to the user needs *4A Control for diseases* and *4B Control for pests* and *4C Providing education to rural communities and refugees*.

The use case is about generating warnings by an automated ICT system. For control, climate data, developmental stages of the pathogen causing the disease can be monitored regularly. *Spilocaea oleaginea* fungus can be spread by insects and the wind, and locally through rainwater. If chemical control is required, the most appropriate time for the spraying is determined, and necessary announcements are made. Data collected from the sensors installed in the olive orchards will feed early warning systems that notify olive farmers about the most effective control time for diseases and pests timing. With the use of early warning systems, sustainability of olive cultivation will increase, as well as the yield and quality of harvested olives.

1) The use of weather station sensors is essential for olive producers and the technical personnel (including refugees), and producer representatives who assist the producers in olive farming. In particular, weather data will be collected and evaluated by ICT solutions to detect diseases at an early stage and thus guide the application of fungicides. Microclimate factors significantly affect the development of olive ring spot disease, which is the most critical disease in olives. Timely spraying of fungicide at optimal weather conditions will provide adequate control. In addition, losses of olives due to the disease will be reduced, and the income from olive farming is expected to increase. The use of microclimate data from weather stations in combination with disease models is an aid for spraying strategies which user interface and Apps on PC and mobile devices will facilitate the work of technical staff. In Türkiye, the early warning system is actively used in the control of some diseases (*Plasmopara viticola* and *Lobesia botrana* in vineyards, *Venturia inaequalis* in apple orchards, *Erwinia amylovora* in pear orchards) [23].
2) Data from weather station devices will provide information for modelling the establishment of the olive fly. Olive fly population development is dependent on microclimate events. The olive fly spends the winter in the soil as pupae and emerges in the spring when the temperature rises above 10 ^{o}C. In addition, the maximum temperature required for the development of the olive fly is 30 ^{o}C [19] [24]. The information to be provided by weather station devices will determine the relationship of the pest population with microclimate events.

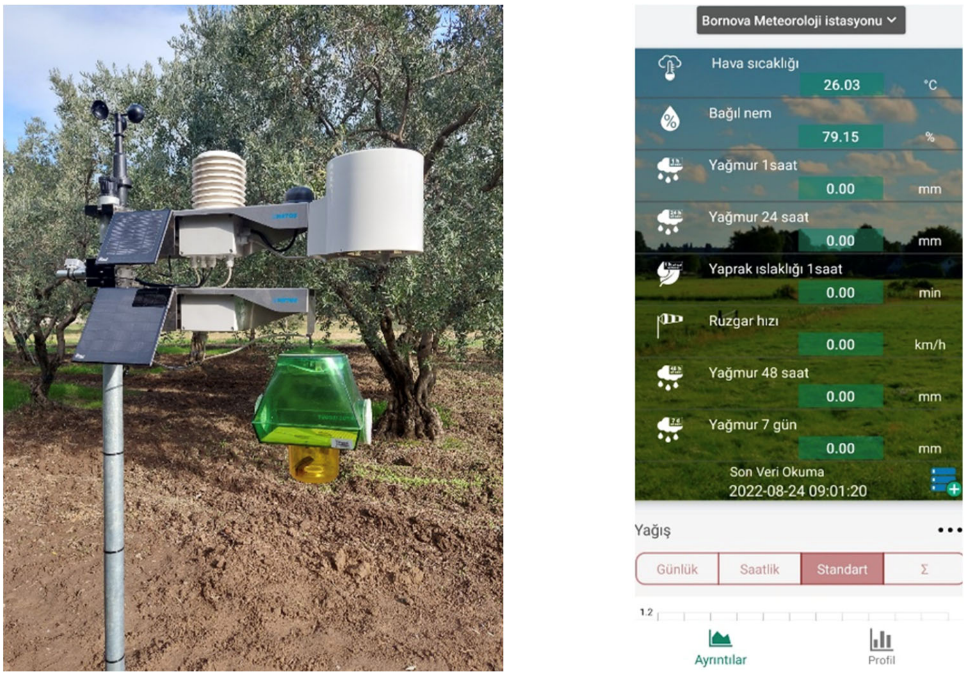

Figure 18. A soil-plant-atmosphere sensor station, including soil sensors and weather data acquisition sensors.

The use case requires for IoT, cellular XG, and wireless networks extending coverage in the rural areas of Turkish olive orchards. This will enable the transfer of data from soil-plant-atmosphere sensor stations comprising information about soil water content, soil and air temperature, precipitation, and other relevant parameters (Figure 18). The digitalisation has benefits such as efficiency in agricultural production, less pesticide use, protection of human health and the environment, labour savings, education, prevention of excessive use of pesticides, reduction of pesticide and labour costs, protection of a biological balance and diversity, prevention of pesticide resistance, and finally improvement of product quality.

UC 4.2 Monitoring of Pest Insect Traps

Following the olive fly population in nature is essential in terms of pest control. For this purpose, some manual food traps and pheromone traps are used in traditional agriculture [22] (Figure 19). These traps are placed in some areas and checked periodically, to determine the time of olive fly presence in the orchard, and decisions can be made according to the population density. However, it is difficult to control the olive fly in olive cultivation, which is generally carried out in mountainous regions in Türkiye. Frequent manual inspection of the traps is required for population density control. The olive fly has a very high reproductive ability and can do much damage quickly. Therefore, it is important to follow the olive fly population carefully and frequently to apply insecticides on time. Since the olive fly has the potential to cause significant damage in a short time, even a few days of delay in its control can cause considerable damage. The UC4.2 provides a solution that covers the user need *4B Control of pests (olive fly)*.

The digital traps are designed and developed for monitoring olive fruit flies. This use case will focus on advanced connected electronic pest traps capturing the olive fly. Connected electronic traps are yellow sticky traps that contain pheromones that attract adults. The system is based on a unique electronic design and these traps are equipped with an integrated digital camera that acquire pictures two or three times a day and wireless transmission of images, that can be displayed via a smart phone App or web application. With electronic traps instead of manually controlled traps, olive fly control in long distance olive groves will be monitored remotely without the need for frequent manual inspection. This will ensure that the olive fly population is constantly monitored and sprayed at the right time. Digital traps are insect traps with integrated electronics (camera system, modem, power source with solar panel) and sticky plate Figure 20). Due to their low weight, these traps can be hung anywhere in the orchard.

Figure 19. Two types of traps for manual inspection of Olive fly.

Various digital traps have been designed and evaluated in recent years. In order for the images obtained by these devices to be used in early warning systems, they must be able to instantly receive and transmit the data set without any connection problems. The artificial intelligence infrastructure in these traps allows the identification of the target insect.

Two digital trap types will be used in olive fly population monitoring in the LL Türkiye use case. Data from digital traps should be compared with traps for manual inspection. The goal is to monitor the population in hard-to-reach areas by providing remote controls on the digital environment with electronic olive fly traps that are installed in some pilot regions.

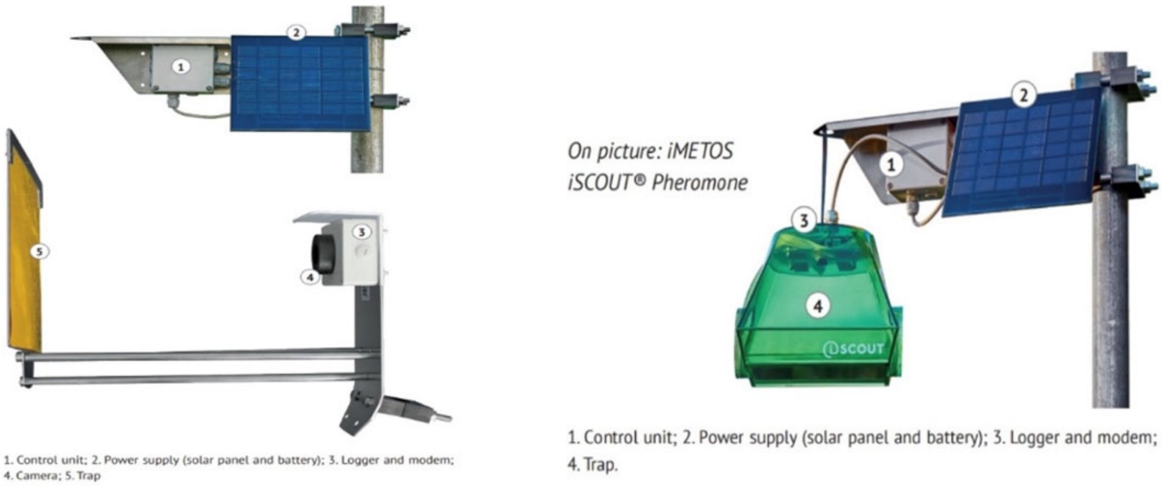

Figure 20. Two types of digital traps for monitoring Olive fly population.

By spreading digital traps in rural areas, the Olive fly population will be controlled from agricultural advisory centres, from where recommendation of pest control can be received by olive orchards owners and managers, and centres that can warn the rural area community about the spraying campaigns against olive fly. The spatial distribution of the digital traps should be established according to the size of the olive orchards and the target pest. There are three central olive regions in Türkiye that can be used for the use case application of wireless network solutions. The first is Izmir (Olive Research Institute application area), the second region is Hatay (Olive Research Institute), and the third region is Antalya (Olivepark Garden). Due to the great earthquake in Hatay, digital traps in that region are under reconstruction. In addition, recorded climate data from soil-plant-atmosphere sensor stations should be evaluated and associated with the registered olive fly population.

There is a worldwide need to study the effects of digital traps for olive fly or other pest population monitoring in designated regions. If these traps are effective in terms of detection of pests and stable transmission of data, they will be made available to technical staff and producers and will be expanded first in these regions and then in all olive production regions. As mentioned above, even a few days of delay in the control of olive flies can cause considerable damage. With the help of digital traps, the pest population will be controlled in time, even at long distances, and the quality and yield losses that may occur in olive production will be prevented by making the necessary intervention. In addition, important steps will be taken in olive farming and the use of technology. With the increase in yield and improvement in quality, there will be an increase in the income of the rural people engaged in olive farming.

Manual feed-induced traps and pheromone-induced traps can be used in traditional agriculture with periodic site visits. Digital traps do not need a regular on-site visit but broadband connectivity. The challenges in olive farming are the energy availability and cellular network coverage gaps in the olive orchards. Olive gardens are available and preferred by the farmers in the hilly regions where other agriculture types are not possible or difficult. The use case is about enhancing broadband connectivity by XG-based or specific IoT wireless networks, with the addition of demands to energy efficiency. The location of the digital traps and the transmitting units are selected based on energy requirements and availability and the possible wireless network for broadband connectivity. An almost complete coverage of a given olive orchard is a user need, meaning that data transmission from an arbitrary position in an olive orchard is essential, and extension of coverage should be possible locally.

7. Living Lab N.5 – Serbia – Sustainable Agriculture and Preservation of Natural Environment

7.1. Characteristics of Sustainable Agriculture and Nature Preservation Incentives in Serbia

Agriculture in Serbia is an important sector that employs around 21% of the country workforce accounting around 10% of Serbia's GDP [25]. Land suitable for arable production represents around 70% of total agriculture land and is mostly located in the Vojvodina province (45% of all used arable land), in the northern part of Serbia. The main crops produced are wheat, maize, sunflower, and sugar beet, and under the fruit crops the focus is on apples, grapes, raspberries, and blueberries.

The Gospođinci village, located in the Vojvodina province, is a community where agriculture is the primary source of employment and the community's livelihood depends on the success of their crops and livestock production. There are two nature parks in the area, Mrtva Tisa and Jegrička, with agriculture fields which make a complex ecosystem, where agriculture has a significant impact on the environment. Mrtva Tisa is a nature park with rich flora and fauna, including the white lily, listed as a natural rarity in Serbia. Pearl Island, bordering the Mrtva Tisa nature park, is an agricultural area, cultivated by farmers from the surrounding villages.

The area lacks infrastructure communication, electric and transport (dirt roads throughout the fields, no electricity, patchy 4G connectivity). These aspects present challenges for rapid deployment of digital solutions supporting introduction of more productive, and yet sustainable agricultural practices and limits the ability of the community to monitor the status of the environment. With the increased impact of the climate change on the agricultural operation (and the lack of competence in reacting/adapting to is), the need for large-scale irrigation has become evident. The increased fuel costs are slowing down the rate of introduction of irrigation systems, while the noise and emissions are impacting the environment of the nearby nature parks.

7.2. Implementation of Research Methodology

A stakeholder analysis focused on identifying and prioritizing the key stakeholders affected by sustainable agriculture and nature preservation initiatives was conducted. It included recognizing the roles, interests, and potential influence of various stakeholders, including local farmers and their associations, local government entities, and private companies involved in agriculture and renewable energy sectors.

The initial needs of the community were identified through a series of one-to-one discussions with farmers, representatives of a farmers' association, public administration and local businesses, all residents of the local living lab rural community. Qualitative data collection techniques such as semi-structured interviews and focus group discussions were employed. Open-ended questions allowed the farmers to share their experiences, opinions, and concerns regarding sustainable agriculture, nature preservation and associated challenges. The collected data was organized and categorized into specific topics such as irrigation optimization, pesticide usage optimization, sustainable energy sources, network connectivity, and environmental protection.

The needs and the main problems that farmers are faced with, were defined during the workshop organized in mid-December of 2022 with members of the ZZSA farmer association. The workshop with 50 community members, most of them farmers, was designed as an interactive one to encourage active participation of all participants, facilitating knowledge sharing. The collected information is used as the basis for defining LL5 use cases.

Based on these activities, user needs and challenges expressed by the farmers were identified. These needs were then prioritized based on their significance, impact on sustainable agriculture and nature preservation, and alignment with the project objectives. To ensure the validity and refinement of the identified needs, feedback was sought from relevant experts and stakeholders specializing in sustainable agriculture, renewable energy, and environmental conservation. The findings from the workshop, data analysis, and validation processes were used to identify user needs and accordingly requirements and use cases.

To address the identified requirements, the Living Lab Serbia will establish a shared energy, communication and computing infrastructure that can support both the needs of agricultural operations and activities aimed at maintaining and improving environmental conditions in the nature parks. To that end, a system comprised of portable/mobile solar generators equipped with communication, computing and sensing technology will be used.

The renewable energy sources will replace fossil-fuel generators for powering water pumps and irrigation systems. At the same time, these energy sources will enable establishment of community based LPWAN and/or private 5G networks providing connectivity in rural areas. Such a setup will enable the deployment of battery-powered sensors for continuous monitoring of environmental (air temperature, humidity and quality, precipitation, noise level measurement, etc.), soil (temperature, moisture, conductivity) and crop-related parameters (growth status, vitality, etc.) The measurements acquired by these sensors will be used to provide insights into environmental conditions of the protected nature area and the surrounding region as well as to support agricultural operations helping farmers and the local community in sustaining clean environment and improving agricultural production.

The edge computing capabilities will enable the creation of autonomous systems capable of controlling and automating agricultural operations, while reducing traffic load, and, consequently, reducing the need for high-throughput network connections to Internet and cloud-based functionality.

The described living lab activities will be executed over a prolonged period (two seasons) to provide opportunity to evaluate the envisioned systems in the field in varying conditions to and to comprehensively validate their compliance with the identified requirements.

7.3. Value Chain Analysis

Agriculture and food production is the most crucial export sector for Serbia, employing over 100.000 people [25], accounting for over 10 percent of the country's GDP and around 20 percent of all exports. The food processing industry accounts for approximately one-third of Serbia's entire processing industry. Currently, over 15,000 food businesses are operational. Approximately 99,4 percent of these are family households.

The most important trading partner for Serbia is the EU. Exports to EU countries account for 55 percent of Serbia's total agricultural exports, whereas imports from the EU represent 50 percent of Serbia's total agricultural imports [26]. The Serbian products with the best production and export potential remain grains, oilseeds, sugar, fruits, vegetables, non-alcoholic beverages, water, and confectionery products.

The agriculture value chain for arable crops encompasses all the steps and actors involved in bringing agricultural products to the market, adding value at each stage of the process. It includes different stages from inputs supply (seeds, fertilizers, pesticides, machineries, technology), followed by crop cultivation, harvesting, post-harvest activities, processing, storage, transportation, distribution, and marketing. Products are sold directly or processed to meet quality and safety standards. The agricultural value chain emphasizes the importance of efficiently connecting these stages to optimize production, minimize waste, reduce costs, and ensure that consumers have access to safe and quality agricultural products. The Ministry of

Agriculture, Forestry, and Water Management (MAFWM) is responsible for the government's international and domestic agricultural trade strategy, food processing, rural development, forestry, and water management. In Vojvodina province the intensive production of cereals and industrial plants is dominated type of agriculture production.

Food Safety Law in Serbia, adopted in 2019, which is in line with the EU General Food Safety Regulation, (EC 178/2002) introduces a comprehensive and integrated approach to food safety, covering all stages of the food chain including production of animal feed, primary food production, storage, transport, and retailing. Each stage involves various stakeholders creating a comprehensive food safety system, that collectively shape the industry's outcomes.

The Living Lab deployment will contribute to the agriculture value chain by enabling sustainable practices, optimizing resource usage, adopting renewable energy sources, promoting environmental preserving, and fostering knowledge exchange. Altogether, the latter enhance the efficiency, quality and environmental responsibility of the entire agricultural process, benefiting all stakeholders from farmers to consumers and safeguarding the local ecosystem.

7.4. Stakeholder Analysis

The key stakeholders involved in the agricultural value chain and those who could be influenced by the implementation of sustainable agriculture and nature preservation initiatives in LL5 are as follows:

1. Farmers and farmer associations: By improving their agricultural practices, increasing yields and profitability, and minimizing negative environmental footprint, these stakeholders are at the heart of the agriculture value chain. Their decisions and practices directly impact the quality and quantity of the agricultural products.

2. Companies (i.e., such as digital service providers, hardware providers, solar tracker producers,) with the interest in expanding the market and using pilot sites for testing and upgrading of products and services. Companies directly collaborate with farmers, promoting sustainable practices, knowledge exchange, and community collaboration.

3. Local government entities: Government entities play a significant role in shaping agricultural policies, regulations, and trade strategies. Local government can benefit by promoting sustainable development in the region and attracting the investment to help them to improve agriculture practice, preserving the natural habitats and ecosystems in the nearby nature parks, but also increasing the visibility of the region as tourist destination.

4. Environmental organizations: Organizations focused on environmental conservation and sustainability advocate for responsible agricultural practices. They influence public opinion, government policies, and industry standards related to environmental impact and sustainability.

5. Local community in the Gospodjinci village and surrounding area: Interested to have access to environmental related parameters as well as nature preservation.

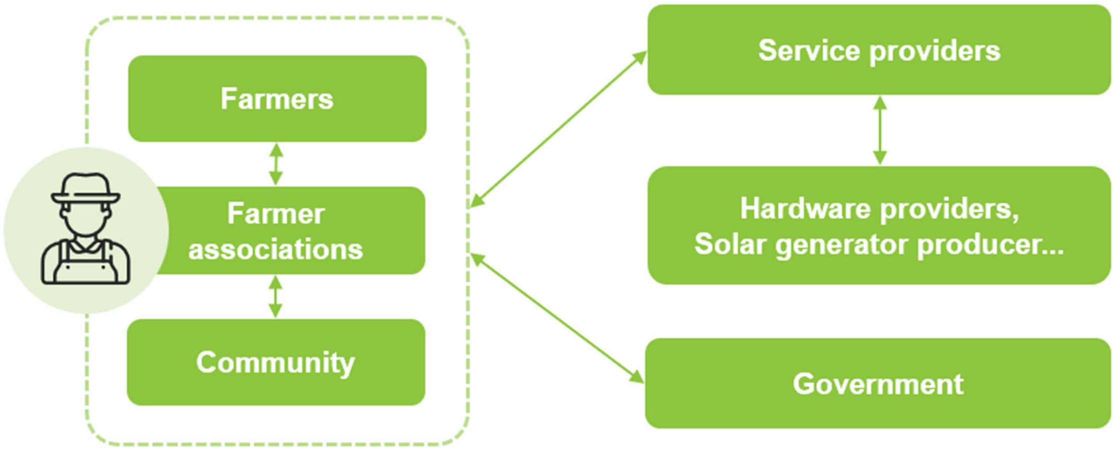

Figure 21. Stakeholders of Sustainable Agriculture and Preservation of Natural Environment.

7.5. User Needs

The main challenges in agriculture production are the possibility to execute relevant activities on time. The current practice relies more on the experience of farmers than on measurements taken in the field, resulting in sub-optimal practices, increasing production costs, and negatively impacting the environment. Farmers mainly use fossil fuel-based generators for powering irrigation systems thus generating high levels of $CO2$ emission and noise. Usually, applying pesticides more that it is necessary leads not only to decreased crop quality but also to negative environmental footprint.

Additionally, farmers activities have a huge influence on the nature park that is surrounded by the agriculture area. The nature park preservation is a critical aspect of environmental protection and the overall well-being of natural ecosystems. In protecting and preserving the nature parks rangers play a vital role. However, there is currently lack of real time insight into hazard activities causing of nature park ecosystem.

The list of identified user needs is presented below.

5A Better network connectivity

Poor mobile network and low-power wide area coverage in agriculture areas is required to enable connectivity for environmental, soil, weather, crops, etc. sensors which are one of the key elements of modern digital farming systems. Of particular importance is the availability of LPWAN networks to enable deployment of battery-powered devices (sensors) for in-field monitoring

5B Access to a sustainable source of energy

Irrigation systems are deployed at around 180.000 ha in the region but are actively used on, 30-40.000 ha only. The lack of power supply infrastructure is one of the reasons why only a small percentage of the existing irrigation systems is in use. Currently, fossil-fuel generators are used as power supply resulting in a large negative impact on the environment while adding significantly to the costs of the production. Replacing them with a solution that uses renewable energy will contribute to the nature park preservation, reduction of environmental footprint as well as to decreasing the production costs. Farmers need a cost-effective solution that could, potentially, be shared by the whole community to optimize the costs. Implementation of the shared use will require automatic planning taking into account the vegetation status of crops at individual fields in combination with the status of the soil at these fields.

5C Ensure the insight into environmental parameters.

The nature parks surrounded by the agriculture land is under high influence of the agricultural activities (i.e. pesticide spraying, fertilization, overirrigation etc) having a huge environmental footprint. The local community is aware of the influence of agriculture at the nature park and are interested in having more insight into the environmental parameters. Additionally, rangers working in the national park regularly visit and monitor the park, but they lack real-time insights into environmental conditions and potential sources of pollution. A solution providing information about parameters such as air quality, water quality and noise level is required from both the community, rangers and the local government perspectives.

5D Digitalisation of agriculture activities

Crop production is highly influenced by the environmental conditions that drive the needs for specific activities. Without real time insights in the environmental parameters, farmers are able to undertake their activities only based on the experience that usually leads to over or under irrigation, over spraying, choosing suboptimal time for different activities etc. in particular with the changing climate which invalidates the dates and practices used in previous years. Farmers require insight into parameters that influence on decision making in everyday practice. Additionally, they need a solution that automatically analysed gathered data providing simple advice to activities to be undertaken. Further, farmers are often faced with thieves, stealing equipment like irrigation pumps and weather stations, or damaging and stealing crops. To combat with such issues, video monitoring systems could represent a good approach if the analysis of the captured video is done automatically and locally, i.e., not requiring transmission of video streams to cloud for processing.

5E Rural community collaboration space

Farmers throughout the whole community are faced with similar problems. They need a place where they can exchange agricultural data, good practise examples and information. This should facilitate engagement between multiple stakeholders, including local farmers, associations, service providers, and local government entities. It should provide a space for open communication, collaboration, and coordination among these diverse groups.

5F Ensuring the safety of crops and equipment

Farmers are faced with a problem of securing their equipment i.e. installed devices, pumps, irrigation systems. Additionally, they have a problem with stealing of crops (especially vegetables) that are produced at distant fields. On the other side, rangers and local community witnesses different hazard activities in the nature park, especially unauthorized vehicle access in specific zones. Both, farmers and local community need a solution enabling to secure crops, equipment and nature park ecosystem.

7.6. Use Cases

UC 5.1 Creation of a shared rural infrastructure

UC 5.1 aims to address the need for networking options to enable connectivity for different sensors and devices and to provide stable power supply and network connectivity for agricultural devices using sustainable energy sources. The use case is addressing the user needs *5A Better network connectivity* and *5B Access to a sustainable source of energy.*

Powering up electric irrigation pumps, providing network connectivity, processing data on the edge, etc. requires electric energy. To be able to provide power supply, mobile solar generators, designed as foldable tractor trailers capable of generating up to 30kW of electricity, will be used.

This generator will serve multiple purposes within the agricultural ecosystem and the LL Serbia. It will power up:

- A LoRaWAN gateway and 4G/5G router to provide stable connectivity to the deployed sensors (weather stations, video cameras used for crop monitoring, soil sensors, etc.)
- Irrigation pumps replacing fuel-run pumps,
- One or more video cameras to monitor the status of the crops,
- An edge ML device responsible for processing video and audio streams, and sensor data.

The mobile generator must provide sufficient power to operate at least the irrigation system and a LoRaWAN gateway and optionally two video cameras and edgeML gateway as well. Additionally, the generator has to be equipped with batteries of sufficient capacity to power-up the connected devices for at least 12 hours. Also, the mobility of the power generator on rural roads without any significant issues or damage throughout the entire growing season is required.

Establishment of LPWAN network infrastructure with high availability and reliability is necessary to enable data collecting and transferring. The majority of agriculture fields must be covered with LPWAN network. The acquired data from in field deployed devices must be forwarded to the specific platform, enabling centralized storage, analysis, and access to the data.

The user value of UC 5.1 lies in providing reliable power supply and extended network coverage in the rural area. By establishing a community LPWAN network, farmers and stakeholders will have access to real-time data from the fields, facilitating informed decision-making and optimized agricultural practices. As the network becomes operational and integrates with the sensor devices, UC 5.1 will advance, providing a stable and scalable solution for data collection and transmission within the LL Servia community.

The use case is fundamental to all user needs described in the previous section. The benefits of UC 5.1 include increased efficiency in data gathering, enhanced collaboration among farmers and stakeholders and reduced environmental footprint. The shared network infrastructure fosters knowledge exchange, allowing farmers to learn from each other's experiences, share best practices, and collectively work towards sustainable agricultural practices. This collaboration promotes community building, resilience, and economic growth within the arable farming area.

UC 5.2 Securing crops and equipment

This use case is focused on implementing edge machine learning (ML) computing algorithms for detection of events and processes in the field. It is driven by the user’s need to secure their assets against theft while maintaining the ability to monitor crops growth, field activities and protect nature park from hazard activities. The use case is addressing the user need *5F Ensuring the safety of crops and equipment* and *5D Digitalisation of agriculture activities*. The UC is focused on continuous capturing of video and audio recordings and accordingly analysis at edgeML device for which different ML algorithms will be designed, deployed, and validated using the shared infrastructure provided by UC 5.1:

- Detection of people and vehicles: Key objective is to identify the presence and movement of individuals and vehicles in the monitored area. ML model will be developed to distinguish between normal activities and suspicious behaviour, triggering alerts if and when necessary.

- Crop progress monitoring (growth status, height and size) will assist farmers in making informed decision to support agricultural operations.
- Audio/noise recognition: Detecting and recognizing audio patterns and noise is essential for identifying various activities in the near surroundings. ML algorithm will be trained to classify and distinct audio patterns, ensuring timely response to any unexpected situations.

By executing this UC, the users will benefit having a solution that enhance security and enable rapid responses to potential threats and optimizes agricultural practices by providing insights into crop development and field activities.

UC 5.3 Shared environmental monitoring platform

This UC 5.3 is focused on monitoring of air quality, water quality and noise level in the nature park, contributing to preservation of the park and prevention of activities harming the environment (like the use of fossil fuel boats).

While the concept of environmental monitoring is well-established, the specific implementation within the Mrtva Tisa nature park will require the deployment of set of devices for monitoring air quality (air temperature, CO_2, NO_2, SO_2, O_3, PM), water quality (temperature, pH, dissolved oxygen, EC/salinity, oxidation-reduction potential) and noise level. For a smooth execution of this UC, the infrastructure addressed by the UC 5.1 will be used, enabling continuous data collecting and transferring. The collected data will be available via a shared environment monitoring platform. All collected data should be accessible to all users, supporting nature park preservation and prevention of activities that harm the environment. By monitoring air quality, water quality and noise levels, potential threats/incidents will be identified on time thus ensuring proper corrective measures which consequently lead to the preservation of the park's natural environment.

The use case is specifically tied to the *5C Ensure the insight into environmental parameters* and its benefits are reflected in minimization of potential harm to the environment and disturbances to wildlife leading to the long-term preservation of the park, ensuring its ecological balance and biodiversity. By monitoring air quality and noise levels, potential harm to the environment and disturbances to wildlife can be minimized. This contributes to the long-term preservation of the park, ensuring its ecological balance and biodiversity. Additionally, the availability of real-time data and on-time response capabilities enhance the overall experience for the nature park visitors, rangers and farmers in surrounding area.

UC 5.4 Shared digital agriculture platform

The current agriculture practice is still traditional, based on experience that usually leads to over spraying or over irrigation of crops thus having a negative impact on the environment, especially on soil degradation and biodiversity loss.

To be able to improve their everyday practices, farmers need to have insight into environment and soil conditions and accordingly plan their activities and make on-time decisions in order to produce sufficient quantity of quality food. This use case will gather different data (air temperature, air humidity, amount of precipitation, wind speed/direction, solar radiation, soil moisture, soil temperature) from devices installed under UC 5.1. This use case is tied to the user needs *5C Ensure the insight into environmental parameters* and *5D Digitalisation of agriculture activities.*

All gathered data from in-field installed devices should be stored in the agroNET platform (DNET's proprietary solution) and used as input in different embedded expert modules and edge computing devices to analyse real-time data and offer recommendations for optimizing the number of irrigation cycles and pesticide spraying. This data analytics process plays a vital role in making informed decisions on when activities should be carried out (i.e. when and how to irrigate crops, when to spray with pesticides). Access to the platform and data relevant to all farmers (such as weather conditions, forecasts, and disease predictions) will be provided to all farmers, allowing them to benefit from digital agriculture technologies and data-driven insights. Data related to specific fields remains accessible only to the respective field owners. Data collected across the fields belonging to the community will be aggregated, contextualized, and prepared for use by the relevant domain data spaces, serving as an additional source of income for the community.

Access to digital agriculture platform helps to bridge the digital divide in rural areas and enhance access to information and knowledge thus having a big impact on farming, including increased yields, optimized costs, improved resource management (water and soil), decreased use of pesticides with overall less environmental footprint.

UC 5.5 Shared community platform

This UC, specifically tied to the need *5E Rural community collaboration space,* focuses on development of the shared platform that fosters collaboration and knowledge sharing, creating a supportive community network. The platform acts as a farmer’s “co-pilot” that will serve as a central place for exchange of data, sharing best practices, and offering advice among the farming community. The co-pilot should be expandable to support different user requirements, with simple user-friendly interface.

The socio-economic benefits are reflected in knowledge exchange, allowing farmers to learn from each other's experiences, share best practices, and collectively work towards sustainable agricultural practices. This use case involves several stakeholders: local farmers and their associations, service providers, local government.

8. Living Labs Synergies

After performing the different workshops and interviews in all five LLs, the partners of the COMMECT project have identified common points within the different user needs and use cases.

The LLs in Luxembourg, Denmark, Türkiye and Serbia, have identified the common need of the users to have certain automated monitoring systems (e.g., irrigation, fertilizer application, pesticide application, livestock conditions, as well as for equipment) that respond to the readings of different sensors (weather stations, leaf wetness, etc.) or to image-based decision-making tools. To make use of these systems, the IoT devices capturing the relevant information will need wireless networks to transmit the measured data in a timely manner, which will require seamless connectivity in different types of rural areas. The use cases with examples of monitoring are *UC1.1 In-Field Microclimate and Crop Monitoring in Vineyards*, *UC3.1 Monitoring of Livestock Transport along Rural Routes*, *UC4.1 Microclimate Monitoring for Early Disease and Pest Detection*, and *UC5.3 Shared environmental monitoring platform*.

For other use cases, broadband connectivity is required to transmit larger amounts of data such as images, data for building digital twin in viticulture, remote operation in forestry, live video streaming of animals being loaded/unloaded to livestock trailers etc. Examples of this are *UC 1.2 Digital Twin for Digitalized Management of Vineyards, UC2.1 Remote operational support from expert for forest machine operator, UC 3.3 Monitoring of Livestock off- or on-loading processes*, and *UC4.2 Monitoring of Pest Insect Traps*.

The identified synergies within the LLs, suggest that it may be possible to test the range of connectivity solutions proposed by the technical partners across the different LLs. Further information on which technologies could be used to solve the different use cases will be included in *D1.2 – COMMECT Requirements and KPIs.* Generally, the different LLs have available a set of solutions to meet their needs that cannot be used due to the lack of connectivity, which seems to be the main common point hampering digitalization. It also appears that a common focus was on cost efficiency of connectivity solutions as generalised on basis of all identified user needs and use cases.

9. Conclusions

In this deliverable the COMMECT project defined different use cases within the 5 Living Labs, that are expected to shape the present and/or expected future services that digital access could enable for rural communities. This analysis resulted in identifying the stakeholders and the roles of those in each use case, the user needs, the technical and business issues, the required targets of use case scenarios and solutions (if suggested) and the measures that must be taken.

In this deliverable, the use cases per each Living Lab were presented. These use cases were separated in different topics, ranging from digital monitoring of crops, local weather, and forestry machines, real-time situational awareness of forestry personal and livestock in transit, seamless data transmission (stationary as well for on the move), remote control of forestry machinery, solar power generated local network, to AI and machine vision solutions in livestock transport and digital twin of biological systems (cf. vineyard case).

The user needs for each use case topic were identified from the perspective of the stakeholders as well as end-users. There were user needs that were found to apply to multiple use case topics and others that characterized some of them. More specifically, there were 29 specific user needs derived and presented in total.

Finally, the use case topics relations to future services that digital access could enable for rural communities were evaluated, considering that it should be unified and able to serve the next steps in D1.2 towards describing a set of requirements and technical Key Performance Indicators (KPIs) for each of the chosen use cases and services to be supported by COMMECT.

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Appendix 1 – LL. 1 – Luxembourg

Overview of Collected Data and Definition of user needs.

Table 1. Overview of viticulture related user stories, current problems and challenges, new solutions and user needs as well as effects on user-centered business.

User need ID	Topic	Problem/ opportunities scope	How it's done today?	New innovative solutions	User needs	Stakeholders/ Supply chain	Expected effect from new solutions	Others affected by solutions
	Short name describing the topic: this is somehow a "short name" for the user need	*Short description of the problem*	*Short explanation of how it is it done today, or whether there is a solution at all*	*Short description of the solution, proposed by the stakeholders*	*What do they need to improve this situation? How would the user like it to be? (Connectivity related, supporting the new solution)*	*Who is bringing up the problem? For whom is it a problem?*	*For stakeholders and actors*	*For environmental, societal, social economics, legislation etc.*
1A	Downy mildew control	Lack of density of the network of weather station for small-scale prediction of the course of infection of downy mildew	Rough prediction of infection progression based on 6 weather stations	Improve prediction of small-scale infection progression with additional weather stations and leaf wetness sensors	Improvement of the decision-making reliability for plant protection measures against downy mildew	Winegrowers, Farm Managers, Researchers	Realization of effective and resource-saving plant protection	Less impact for environment through site and time specific application, economic impact: Saving of treatment
1B	Management of drought stress	Drought leads to growth impairments and death in young vines from the 1st to the 5th year of standing	Irrigation is done manually based on the personal experience of the farm managers.	Estimation of irrigation needs based on digital water balance models using soil and climate data	Decision Support by digital water balance and irrigation model	Winegrowers, Farm Managers, Researchers	Improving the establishment reliability of young vines enables more effective variety changes and adaptation to changing economic conditions	Economic and environmental impact: Reduced loss of young plants
1C	Site-specific-fertilization	Spatial soil heterogeneity causes heterogeneity of nutrient supply and vitality of vines in one plot	Manual adjustment of fertilizer intensity by varying the amount of fertilizer applied based on the experience of the farm manager.	Determination of fertilizer requirements through digital provision of high-resolution soil information	Decision support through a model for site-specific fertilizer requirement determination	Winegrowers, Farm Managers, Researchers	Realization of effective and resource-saving fertilization and plant nutrition	Environmental impact
1D	Single plant inventory	Winegrowers as well as researchers generally do not know the exact position of single plants	Plants have column and row identifiers	Stems can be detected automatically to create high precision inventories	Users need to be able to add and retrieve information about any single wine plant	Winegrowers, researchers	enables both more detailed monitoring as well as more effective management	Economic impact through optimised planning
1E	Leaf Level Symptom Mapping	The exact location of an affected leaf is unknown	Diseases are generally recorded on a per plant basis	Features that are detected based on imagery can be	The ability to link image-based features directly to	Winegrowers, researchers	helps winegrowers to monitor their plants as well as	Economic impact through optimised planning

				directly mapped with high precision	a given plant in the vineyard		researchers to get a more direct link between expert-based ratings and image-based features	
1F	Local pattern analysis	Heterogeneity within a field and resulting differences like heat stress, water need, plant protection	One application for the entire field/vineyard or no application (irrigation)	Giving bird-eye perspective images to the winegrower and interpret them together or use the data for research and analysis of the driving factors	New patterns appear with climate change, and they need to be understood to tackle the problem. Information needs to be sent to the end-user	Discussions with winegrowers during events like the yearly field visits and experience from previous research projects	Better/site specific and smart management	Environmental impact is reduced, saving for water and pesticides
1G	Regional spatial information on vegetation vitality	Regional heterogeneity is there but not analysed. Patterns (former known) are changing with climate change	Currently, there is not much irrigation done, but it might be needed in near future and the scarce resources must be distributed in an optimised way	Regional analysis of earth observation (satellite) data	Providing information to the stakeholder which are administrative authorities	Experience from previous research projects and discussions with climate experts	Better understanding of regions patterns and provision of a basis for optimised planning	Environmental and societal impact by optimised and fair distribution of resources

Appendix 2 – LL. 2 – Norway

Overview of Collected Data and Definition of user needs.

Table 2. Overview of forestry related user stories, current problems and challenges, new solutions and user needs as well as effects on user-centered business. Kongsvinger, Norway.

User need ID	**Topic**	**Problem/ opportunities scope**	**How it's done today?**	**New innovative solutions**	**User needs**	**Stakeholders/ Supply chain**	**Expected effect from new solutions**	**Others affected by solutions**
	Short name describing the topic: this is somehow a "short name" for the user need	*Short description of the problem*	*Short explanation of how it is it done today, or whether there is a solution at all*	*Short description of the solution, proposed by the stakeholders*	*What do they need to improve this situation? How would the user like it to be? (Connectivity related, supporting the new solution)*	*Who is bringing up the problem? For whom is it a problem?*	*For stakeholders and actors*	*For environmental, societal, social economics, legislation etc.*
2A	Connectivity solutions for forestry operations	Lack of 4G/5G etc. network	Use 4G mobile network technology where available	Follow supply chain activities in real time from logging to sawing Remote steering of machine (flat terrain)	Improved coverage and communication	All value chain stakeholders	Optimization of logistics, including measurement of length, volume etc.)	
2B	Digitalization - forest profile	Lack of information on the life/health of the tree online	Only when the tree is logged, length, etc. is measured (in bulk). No profile of the single tree when planted, e.g. position and "health conditions". Visual sight of trees also used	Smart (VR) glasses support the operator in decision on which tree to cut) Scanning of forest, from plane or UAVs to assess health conditions	Information on individual trees from planting to logging	Forest owner Operator/ Machine owner Sawmill	Increased net profit from differentiation of price per log. Directed logging, due to inside data per tree, length, health etc.	
2C	Digitalization -precision forestry	From meter to centimeter	Since GPS precision is 20 meters, trees close to other property boundaries are not cut (to be on the safe side)	Precision via GPS/Mobile/5G to centimetres	Improved coverage and or satellite data	Forest owner Measurement agency Operator/Machine owner	Increase volume to log at given area, and hence increase profit.	
2D	Data silos	Lack of distribution of forest data across value chain)	Little of no distribution of forest data between value chain activities). Order for logging is received via email home at operator Old and new data formats	Standardization Forest data after registered logging order to operator is online and available for all following value chain stakeholders	Standardization and data flow through the value chain.	All value chain stakeholders FeltGIS	More speedy process for invoice and billing (Challenge on ownership, access, and secrecy of data)	

2E	Operator safety	More safe working conditions for operator (Health, Safety and Environment)	Operator of machines work alone in the forest without coverage, often only 4G mobile. Pressure on efficiency and large number of errors. Low recruitment of operators Risk area around machines (10-20m)	Improved coverage Alarm button in machine or monitoring of position or in activity (machine) Monitoring of operator (on machine) through video camera (5G) from central	Improved coverage and/or on-site safety measures	Operator Machine owner Forest owner AMK, Emergency Norw. Defence	Decrease of accidents More popular jobs (VR operator sitting home or in office landscape	
2F	Digitalisation of forestry PEFC and CO_2 certification	Measurement of value chain activities (SBP and PEFC certification)	Calling contact person to estimate Co2, lack of precision	Each stakeholder upload Co2 data using a dedicated service	Standardization and ease of use	All value chain stakeholders	Reduced time spent and more accurate Co2 accounting Relevant for each sale Traffic lights concept	
2G	Documentation - protected area	Lack of documentation of forestry close to protected areas (with diverse species/ biodiversity)	Manual reports are produced. Diversity of communication solutions applied.	Video documentation with live stream. Video based education for new operators Solution for uploading of videos to document	Maps with improved resolution	Operators/Machine owners	Easy documentation of logging work Decrease in accidents with logging inside restricted areas	

Appendix 3 – LL. 3 – Denmark

Overview of Collected Data and Definition of user needs.

Table 3. Overview of livestock transport related user stories, current problems and challenges, new solutions and user needs as well as effects on user-centered business.

User need ID	Topic	Problem/ opportunities scope	How it's done today?	New innovative solutions	User needs	Stakeholders/ Supply chain	Expected effect from new solutions	Others affected by solutions
	Short name describing the topic: this is somehow a "short name" for the user need	*Short description of the problem*	*Short explanation of how it is it done today, or whether there is a solution at all*	*Short description of the solution, proposed by the stakeholders*	*What do they need to improve this situation? How would the user like it to be? (Connectivity related, supporting the new solution)*	*Who is bringing up the problem? For whom is it a problem?*	*For stakeholders and actors*	*For environmental, societal, social economics, legislation etc.*
3A	Guidance systems that can provide safe and reliable livestock transportation	Driver's self-organization has its limits. As traffic becomes heavier or there are unforeseen incidents (such as a crash, a breakdown, or other random events), the traffic system can become unstable. In just a few minutes, traffic conditions can transition from running smoothly to severe delays. As the number of vehicles increases, internet connection via cellular networks intensifies, and the number of allocated channels (bandwidth), occupied by vehicles moving on the road increases. Guidance systems and traffic jam alerts are not sufficient. Not	There is no solution to prioritize livestock transport at traffic congestions or route planning in Google, Garmin, TomTom etc. recalculating routes for livestock transport.	Traffic Information Systems (TIS) integrating information from millions of vehicles, public traffic services to alert for optimized route with a frequency of each minute. Road authorities/police should be able to register online whether an animal transport is jammed by traffic, in order to support either by escorting or calling the driver to assist. Special designed software and management tool that gather all relevant information to avoid black zones (disease spread), traffic congestions, optimal route to nearest reloading stables, destination, etc.	Seamless data access to millions of vehicles that are helpful in catering the road traffic issues for current and future TIS systems. More frequent map availability provides the most accurate routes, i.e., connectivity such that maps on driver's terminal can be updated immediately if the route plan changes according to TIS. Short term need is to ensure connectivity to road cameras in Europe, e.g., livetraffic.eu. Data rate relative to update of map display is needed continuously. Expecting increasing connection (device) density (users per km2)	Driver, haulier, and distributor, better animal welfare (less total transport time) and avoidance of reloading of animals.	Livestock transport having high priority by authorities to let them pass any traffic congestion first. Less workload for distributor, as deviations from route and delays makes a lot of noise in logistics and journey log, if the 24-hour transport limit is exceeded. The authorities need a lot of information to accept the deviation and to obtain dispensation.	Reduce fuel consumption. Enhanced mobility in general. Providers of Vehicular Ad-Hoc Networks (VANET)

		designed to prioritize animal transport. Limit to transport time of 24 hours, and also a problem if the vehicle is not returned in time for quarantine before next transport assignment.			Smart traffic corridors, more advanced TIS, e.g., livetraffic.eu, or on-board TomTom mobility services require high frequency of requesting and sending data (~1 Hz).			
3B	Safe livestock transport to non-EU countries	Livestock transport from EU to countries outside EU (third countries) will not be possible in the future due to electronic tracking issues In order to get export refunds on livestock, exporters are required to follow Regulation No. 1/2005, guaranteeing the protection of animals during transport and to minimize suffering and cruelty, until the first place of unloading in the non-EU country or at final destination.	Currently export to non-EU countries are legal without tracking, but it is expected that new regulation will not allow livestock transport outside EU without tracking demands like it is for transport inside EU	None, tracking and datalogging is regulated for transport inside EU only.	Ensuring connectivity in countries outside EU, for instance Serbia, Ukraine, Albania and Macedonia. Route planning in relation to connectivity	Driver, haulier, distributor, and clients/customers (i.e., farmers)	Enable current tracking systems to be operational in third countries in order to follow new amendments to Regulation No. 1/2005.	Improved documentation of animal welfare during transport to non-EU countries
3C	Frequent journey logs reporting	The 15 min interval between transmitted journey log data (manufacture setting, roaming cost related) can be problematic in areas where data transmission through the cellular network is poor. It happens occasionally that missing update to journey logs stays on for 45 minutes at the logistic centre. It requires more work at the logistic centre to contact the driver by	The occasionally long intervals between displayed location and journey log are accepted, but when the situation occur, it requires additional follow up work by the logistic centre personal and distributor to make sure that the livestock transport is progressing as planned, e.g., by phone calls to the driver. It is not always due to connectivity issues,	More advanced logic to optimize the volume and quality of collected data. Compression techniques to make it feasible to compress journey log data in real time before the data is sent to the cloud. Roaming costs correlated to the degree of compression of data packages, to prompt IoT providers to reduce data amount Software updates to existing datalogging	Faster correction of errors/malfunction occurring for transport equipment, i.e., compartment climate and drinking systems, trailers, truck, and sudden illness symptoms of livestock on board, etc. Lower costs of connectivity/roaming for telematics solutions. Better mobile internet coverage in order to avoid too long time between updates	Driver and distributor.	Improved quality control of livestock during transport, customer related guarantee. Allow for big data approach in relation to quality assurance of each livestock transport. Increased transition from hard copy journey log to digitalisation of journey log.	

		phone to follow up on the temperature, planned route, etc. to ensure the quality of the actual livestock transport.	but it can also be malfunctions of on-board equipment, which is an important information for the logistic centre to take immediate actions on. The driver follows designated protocols for controlling temperature, drinking availability, and other matters related to quality standards set by EC regulation 1/2005 and the Danish Transport Standard.	systems on livestock transporting trailers and trucks.	transmitted to the logistic centre			
3D	Data-driven solutions for livestock transport	Increase in CO_2, ammonia, sound (coughing) and other factors during livestock stay in transport trailers have impact on animal health and quality. It is expected that the data amount will increase in the future when sensors and possibility of automatic compartment climate control and AI increases. The journey log has a parameter concerning assessment of the pig's fitness for transport according to guidelines for visual and common inspection of the whole herd. Individual pigs are not assessed and documented in journey log, which is of interest	Recording to storage on trailer computer and showing basic control parameters on dashboards. Journey log is formulated according to legislation, and is not specific on individual pigs' quality parameters – these are only of interest for the distributor and their customers.	Real time and online monitoring of e.g., ammonia, CO_2, sound (coughing) such that the logistic centre can interfere with driver. Machine vision to record the essential parameters for scoring individual pigs' fitness for transport, for documentation purposes, that can be uploaded from the vehicle on request. Real-time aspect of the technology is very valuable, providing immediate insight into how quickly fans and misters can lower the temperatures on the vehicles – post processing of data from several trailers to improve trailer and trailer deck designs. navigation and fleet management systems,"	Big data transmitting on-line. Cloud or edge computing-based machine vision systems to score for health parameters, i.e. scoring individual pigs for fitness for transport. Need to be able to upload videos from cameras having it FOV at the integrated entrance.	Driver and distributor. Improved quality control of livestock during transport, which is relevant for distributor and their customers for assurance of high quality of livestock transport.	There are many unknowns in terms of future livestock transport based on big data. However, what we are being told, is that big data can improve many issues, and thus it is a matter of preparing for those new solutions for improvement Livestock transport is already data driven, and more data acquisition and documentation are expected in the future for the matter of seamlessly assessing the quality of livestock transport.	

		for the distributor and their customer.		Recording more data from sensors, health parameters and artificial intelligence (AI) systems, and just record more data for future big data and IoT solutions, although they are unknown/unspecified today. Expecting data driven developments for livestock transport				
3E	Automated counting of pigs during loading/reloading/unloading and authority inspection	The legal journey log shall comprise a 100% correct number of pigs on-board. The manual count is laborious, difficult, and fatiguing.	Manual count of pigs by driver, and during the random inspections by authorities (typically veterinarians)	Machine vision for counting pigs at the compartment integrated entrance when loading and unloading pigs from trailer. Image processing software on trailer computer, and very ruggedized cameras and illumination source as it is a harsh environment, wet, cold, hot, manure, ammonia, disinfection agents etc.	It should be possible to upload video recordings from the trailer data storage on request. Image processed data providing the number of pigs on-board should be additional data to the existing data package, not necessary the complete video streaming (i.e., cloud solution for image processing).	Inspector (veterinarian), driver and distributor. Possibility for rationalisation at authority inspections and control of the journey log.	Much higher assurance of correct journey log	
3F	End-user can experience networks under real-world conditions before implementation of IoT, logistic, and remote-control solutions, etc.	The pig farmers need to provide internet for the official veterinarians controlling the transports, else the fee is more costly. Heavy loads of documents to upload to servers, and on on-line entry of data during inspection. Missing the analysis of sufficient connectivity on selected small spots, before selling and implementing IoT solutions, for instance	Trial and error, and if coverage is not sufficient, network providers are contacted to solve the problem.	Real-world network performance, coverage, and signal measurement and analytics service that provide an accurate and site-specific characterization of the end-user's mobile network experience corresponding to communication performance requirements and service types set by the end-user.	Performance, coverage, and signal measurement and analytics service derived from site-specific geographic coordinates, i.e., the user defined data usage hotspots. Need to improve engineering and marketing efforts when depending products/services on mobile internet connection.	Manufactures and providers of IoT solutions, logistic tools, remote control systems, etc. in rural areas in Europe.	End-user can experience networks under real-world conditions before implementation of IoT logistic, and remote-control solutions, etc.	Improved public reliability and thrust to automated solutions.

		around farms where Wi-Fi is not a solution, or wind turbine control, etc. There are issues with small areas (for example 50x50 m) where the mobile internet connection is poor. These small 'white' spots are not visible on any coverage maps by network providers. The grid cell coverage maps are not applicable for the industry depending their products/services on mobile internet connection.		Modelling of connectivity based on a geographic coordinate, i.e., high resolution maps.				
3G	Automatic license plate recognition for allowing the transport vehicles access to the farm	It is the pig farmers responsibility to reject transport vehicles entering their farms if the livestock transport company does not fulfil the documentation, certification and correct cleaning and disinfection status. This is done manually, even though the documentation is digital on tjekvogn.dk. There is a risk of human error, which in the end and with frequent incidences has economic impacts for farmers and distributors. No broadband connection at a majority of farms in	Manual inspection of trailer and truck cleaning and disinfection status, transport certificates etc. during receipt of transport vehicle. The farmer need information about the status of the trailer, are the documents and certificates obtained, documentation issues, before receipt of livestock transport vehicle on the farm	The number plate recognition consists of two cameras. Two cameras are needed, one for front plate scan (truck) and one for back plate scan (trailer). Or could be an app on smartphones. Connected to boom gate. If documentation is not in order from www.tjekvogn.dk, then the truck and trailer is not allowed to enter the farm. The digitalization of entering and exit of livestock transports from farms has additional effect on the required documentation of the	Some automatic number plate recognition systems are cloud based, and thus image streaming to server is necessary. Require about 3 Mbps for each camera. Need coverage where the cameras are located.	Farmers and livestock distributors	Higher efficiency and quality assurance linked to the pig transport value chain.	

		Europe, which challenge the streaming of images from cloud-based number plate recognition.		trading of pigs at farm level.				

Appendix 4 – LL. 4 – Türkiye

Overview of Collected Data and Definition of user needs.

Table 4. Overview of olive production sector related user stories, current problems and challenges, new solutions and user needs as well as effects on user-centered business.

User need ID	Topic	Problem/ opportunities scope	How it's done today?	New innovative solutions	User needs	Stakeholders/ Supply chain	Expected effect from new solutions	Others affected by solutions
	Short name describing the topic: this is somehow a "short name" for the user need	*Short description of the problem*	*Short explanation of how it is it done today, or whether there is a solution at all*	*Short description of the solution, proposed by the stakeholders*	*What do they need to improve this situation? How would the user like it to be? (Connectivity related, supporting the new solution)*	*Who is bringing up the problem? For whom is it a problem?*	*For stakeholders and actors*	*For environment, societal, social economics, legislation etc.*
4A	Control for disease	Yield losses due to insufficient spraying at the right time. Environmental damage due to overuse of drugs. Economic damage as a result of overuse of drugs.	Either more spraying is done than necessary or no spraying is done at all. In both cases, economic and environmental damage occurs.	When environmental conditions suitable for diseases occur by using climate stations, a warning is sent to the end-user or user representatives.	A faster and reliable internet connection, climate stations, mobile devices and user-friendly interfaces.	Farmers and traders	Effective fight against the disease. Reducing environmental impact. Yield and quality increase.	Warehousemen, intermediaries and exporters
4B	Control for pests (olive fly)	Yield and quality losses due to insufficient spraying at the right time. Environmental damage due to overuse of drugs. Economic damage as a result of overuse of drugs.	Either more spraying is done than necessary or no spraying is done at all. In both cases, economic and environmental damage occurs.	Spraying is done when harmful using digital traps. The malware is introduced to the artificial intelligence and the diagnosis is transmitted directly to the end-user.	A faster and reliable internet connection, digital traps, mobile devices and user-friendly interfaces.	Farmers and traders	Effective control of pests. Reducing environmental impact. Yield and quality increase.	Warehousemen, intermediaries and exporters
4C	Providing education to rural communities and refugees	Low-income levels of rural communities and refugees. Working as an agricultural worker and	Rural communities and refugees working as unskilled workers are unable to work in specialized and high-income jobs.	Rural communities and refugees should be given specialized training on olive cultivation.	Olive disease and pest control training. Olive pruning training. Olive harvest training.	Farmers, Rural communities and refugees	Socio-economic integration of rural communities and refugees Earning higher income	Farmers, warehousemen, intermediaries and exporters

		not having enough knowledge about the subject. Difficulties in socio-economic integration.	Farmers are also harmed due to faulty practices.		Irrigation, fertilization and tillage training in olives		High yield and quality in olives	

Appendix 5 – LL. 5 – Serbia

Overview of Collected Data and Definition of user needs.

Table 5. Overview of sustainable agriculture and nature preservation related user stories, current problems and challenges, new solutions and user needs as well as effects on user-centered business.

User need ID	Topic	How it's done today?	New innovative solutions	User needs	Stakeholders/ Supply chain	Expected effect from new solutions	Others affected by solutions
	Short name describing the topic: this is somehow a "short name" for the user need	*Short explanation of how it is it done today, or whether there is a solution at all*	*Short description of the solution, proposed by the stakeholders*	*What do they need to improve this situation? How would the user like it to be? (Connectivity related, supporting the new solution)*	*Who is bringing up the problem? For whom is it a problem?*	*For stakeholders and actors*	*For environment, societal, social economics, legislation etc.*
5A	Network connectivity	Poor mobile network coverage is available in farming area which is not sufficient for transferring data from IoT devices. There is no possibility of data gathering currently, no devices and sensors are installed.	Deployment of a LoRaWAN network server specifically for the LL5 community. This server acts as a central hub for collecting data from all the deployed LoRaWAN gateways in the fields.	Better network connectivity at the community level	Farmers, private companies (HW and service providers)	Community-based LPWAN connectivity	Economic, societal
5B	Renewable energy usage	The necessary electrical energy for the irrigation systems (and other needs) is obtained by diesel generators.	Mobile solar generator designed as a foldable tractor trailer with the ability to generate 5kW to 30 kW of electricity.	Access to a sustainable source of energy.	Farmers, private companies, government.	Decreasing CO_2 emission while using renewable energy solution for agriculture needs	Economic, environment, societal
5C	Environmental protection	Nature park is monitored without having real time insight into environmental	Installation of sensors in national park Mrtva Tisa for monitoring not only basic environment conditions, but	Environment protection through more effectively monitoring of nature parks.	All use case stakeholders.	Biodiversity protection, preserving nature parks from hazardous activities.	Environment, societal

		conditions, noise level and air quality.	also noise level and air quality.				
5D	Digitalisation of agriculture activities	Presently, the practices of irrigation and pesticide usage rely more on experience rather than concrete facts, which often results in issues such as overirrigation, under-irrigation, or excessive pesticide application.	Decision support solution based on soil conditions, crop requirements, microclimate measurements, crop development stage and real time measurements form IoT sensors with use of expert modules for pest and disease prediction and irrigation optimization.	Decision support system for irrigation optimisation and pesticide usage optimisation.	Farmers	Optimized water usage and pesticide usage	Economic, environmental.
5E	Collaboration space	Farmers usually share knowledge and experience in person	Development of the shared platform that fosters collaboration and knowledge sharing, creating a supportive community network	Central community collaboration space	Local farmers and their associations, service providers, local government.	Platform should facilitate engagement between multiple stakeholders, including local farmers, associations, service providers, and local government entities. It should provide a space for open communication, collaboration, and coordination among these diverse groups.	Societal
5F	Ensuring the safety of crops and equipment	Rangers and local community witnesses different hazard activities in the nature park, especially unauthorized	A solution enabling to secure crops, equipment and nature park ecosystem	Farmers are faced with a problem of securing their equipment i.e. installed devices, pumps, irrigation systems. Additionally, they have a problem with stealing	Both, farmers and local community	Protection of nature parks, equipment and crops	Economic, societal

		vehicle access in specific zones.		of crops (especially vegetables) that are produced at distant fields.			

Appendix 6 – Guidelines for compilation of user needs

This is a practical guideline for conducting participatory workshops or meetings by the COMMECT Living Labs to gather information on end-user elicitation of topics, including actors and functionalities, problems, challenges, solutions and concluding user needs. It is about establishing a knowledge base on current challenges/needs of rural, remote communities. The overall objective of info gathering workshop/meetings is to get as much input to identify and define topics, preferable told from A to Z. It is also about identifying the current as well as future challenges and needs in relation to both practical issues throughout the explores topics that is centred around the Living Lab (LL) and the LL users identified, e.g. digitalisation, tele/data communication and the most promising business ideas (e.g. product, services) for elicitation of the user needs in the region or internationally. Not the least, it is about identifying challenges with getting through with a decision for a complex digital solution, which is dependent on motivating and mobilizing many different stakeholders. Thus, it is also important to identify issues related to socio-economic factors, climate, policies, authorities, legislation, and governance (political institutions).

Please read this document thoroughly for preparing, planning and conduction of workshop or meetings in relation to LL topics provided by one to multiple stakeholders, directly involved in the supply chain, and those who may influence decisions important for the specific topics and definition of user needs. The purpose of the guideline is to keep the process unified as much as possible for supporting the further information processing during the subsequent COMMECT tasks. Once the workshop or meetings results are reviewed, key actors and stakeholders that were not present at the workshop or first meeting, should be selected for telephone interviews or a second round of workshop/meeting to gather more in-depth information.

The procedure can either be workshops with multiple stakeholders and actors, or meetings with a group of stakeholders and/or actors, or multiple meetings with individual stakeholders and sub stakeholders. The procedure depends very much on the business relations of the stakeholder explored topics and supply chains, such the freely speaking is possible during the conversations between stakeholders and actors. It might be difficult to identify all stakeholders up front, where additional stakeholders are identified through exploration of the vertical ecosystem when it is framed. A set of workshops or meetings would therefore be expected.

After a short introduction of the COMMECT project objectives, the actual workshop/meeting starts. The workshop/meeting consists of 6 sessions described below. Depending on organizer experience and available equipment each phase can be implemented completely offline or with the use of supplementary software (e.g. mentimeter.com) so each partner can decide themselves on the most convenient way of workshop organization. Probably, session 3-5 will be carried out simultaneously, however, the leaders of the process should take care to raise most of the questions within sessions.

Results of session 2-5 should be listed in the table in Annex 1 and user needs should be described in separate sections when reporting (highest priority), supported by a mock-up drawing/diagram illustrating the explored topic and user needs (Annex 2) (lower priority in first round of workshops/meetings). Report the user needs directly in D1.1 (via Teams or Sharepoint)

Workshop/meeting phases

Session 1	Intro to COMMECT and workshop
Session objective	Presentation of workshop/meeting agenda.
Session format	For intro to COMMECT the following presentation can be used or modified: COMMECT
Process	Project objective presentation by COMMECT partner.

Session 2	Stakeholder analysis in relation to exploration of topics
Session objective	Identifying all the users, actors and stakeholders who may influence or be impacted by the explored topic(s) supply chain(s).
Session format	Round the table during introduction of workshop/meeting participants. Draw the topic diagram as illustrated with an example in appendix 2.
Session questions/expected output	Define the elements and multi-stakeholder roles for each explored topic. What are their main roles, responsibilities, and task goals in relation to the topic(s) and its supply chain(s)? What is the contextual information about the explored topic and supply chain?
Process	After initial stakeholder introduction the participants are asked to submit their main roles, responsibilities, and task goals in relation to each topic. At this session, the facilitator samples all information that are relevant for defining specific topic and supply chain of the topic. Non-present stakeholders of relevance for the topic, as well as for specific supply chain are listed and contacted for an interview or for a second round of workshop/stakeholder meeting.

Session 3	Problems/challenges, topic exploration
Session objective	Identifying problems and challenge throughout the topic supply chain
Session format	Documentation in a table with the same structure as in appendix 1
Session questions/expected output	Who are the most important stakeholders affected by the problems and challenges? Where are they found in the supply chain? What are the most important problems/challenges which digitalization can help solving for the selected topic supply chain? How are these problems/challenges solved today?

	Any interoperability issues (technical, societal, communication, standardisation, digital etc.) between stakeholders/actors in the explored topic, in the topic supply chain? Who are the most important stakeholders influencing issues, and how they are solved?
Process	Exploring topics to provide examples of future use as an aid to understanding and clarifying user needs. Remember to keep track of task/function mapping that specifies the system functions where problems/challenges are focused on

Session 4	User needs that helps/can help solving problems/challenges for the explored topic(s)
Session objective	To interpret the outcome as user needs, i.e. to discuss user needs in this session
Session format	Documentation of user needs in a table with the same structure as in appendix 1. Add any necessary columns to the table.
Session questions/expected output	What software, hardware, and communications systems do you utilize? How many labour hours can be spent by each actor that are involved in the deployment and use of a novel solution or need? What type of effects will digitalization of the problems/challenges give? Is there a maximum allowed time per information transit? Have you or your company considered mobile devices to obtain needed information, remote control, orders, task etc.? What is the one biggest problem associated with providing real-time information on mobile devices? If your company provides (real-time) information for third-party development of smart devices/mobile internet applications, what is the one biggest problem associated with managing such a system? Note the types of transit information you provide to customers and how often you provide it and are real time modes requested? How is information provided to customers, employees, business partners etc. throughout the value chain currently? How do you/your company ensure that information is accessible to and reached the client? Are any standards use to provide information via internet and/or smart devices? What, when, or where situation is your need for telecommunication reliability highest?

	What are the capital, and annual operations and maintenance costs of information transit for you as stakeholder/actor in the value chain? Which departments/staff are involved in the deployment and use of mobile technology to provide online (real-time) information? Any additional “lessons learned” that would benefit companies that are considering providing online (real time) information via mobile devices? Do you have any suggestions on activities/projects/efforts that should be included in the COMMECT continued work with improving connectivity in rural areas? What particular system/device/policy/etc. would enhance yours/your company task(s) in the value chain? What are the security and privacy threats if you/your company is sharing information? What is the user, usability, and organisational requirements?
Process	Exploration of LL related topics to provide examples of future use as an aid to understanding and clarifying user needs. Remember to keep track of task/function mapping that specifies the system functions where problems/challenges are focused on

Session 5	The decision context in which the explored topics is embedded (politicians, associations), stakeholders affected by solutions (climate effects)
Session objective	To identify decision process/systems and describe enablers and hinders for realizing a solution.
Session format	Documentation in a table with the same structure as in appendix 1. Add any necessary columns to the table.
Session questions/expected output	What type of decisions are necessary to realize solutions? What are the criteria settings of new digital solutions? Who influence decisions, in what ways? What are enablers and hinders for decisions to be made?
Process	Involves searching published sources such as research reports, reports, articles, web sites, etc. that throw light upon the definition of explored topics, problems, and possible solutions.

Session 6	Post workshop/meeting research
Session objective	Follow up on explored topic(s) and supply chain(s), user needs, and any input that follow up on the above sessions.
Session format	Post workshop/meeting literature search and interviews with other stakeholders/actors that were not present at workshop/meeting.
Session questions/expected output	What literature are available to support the definition of explored topic(s), supply chain and user needs? What literature are available to support the problems, ideas, solutions etc. discussed at the workshop/meeting? Are there other stakeholders that you know of that we should speak to regarding user needs and experience with future topic related technologies involving data transmission and requirements? If so, please provide contact information.
Process	Involves searching published sources such as research reports, reports, articles, web sites, etc. that throw light upon the definition of explored topic(s), problems, and possible solutions.

Stakeholders, users, and actors mapping

If possible, classify users/stakeholders/actors into groups or spheres of action (public administration, public research, domain governance (e.g., associations, public directorates), extension services, production, marketing, environmental conservation, suppliers, etc.). Different types of interaction between stakeholders should be distinguished (regulation, technical advice, representation, sales, control, cooperation, etc.).

In order to standardise the output of workshops/meetings, the organisers are encouraged to make drawings of topic diagrams (Appendix 2). The Appendix 2 comprises an example of a topic diagram that describes stakeholders, actors and main functionalities. The topic diagram can be modified in MS PowerPoint (file emailed together with guideline).

Checklist workshop/meeting requirements

1) Organization

- One workshop/meeting leader
- Someone who makes minutes (for each break-out group of participants)
- Someone who can process results in the table similar to Appendix 1 during the workshops (for each break-out group of participants) or meetings.
- Optionally, 1-3 extra persons who can assist during the group discussions.

2) Selecting participants Guidelines

To ensure comparability between topic elicitation and to avoid bias within each topic, it is key to have a good selection procedure of participants in the workshop or at the meetings, e.g.:

- Make sure in your explored topic study theme, that participating users/stakeholders/actors comes from different types of agriculture/forestry/viticulture and regional places if national variation is significant.
- Make sure that stakeholders are present to cover the whole supply chain to the greatest extent as possible.

- Participants from industry should come from as much different user story directly involved companies and sub suppliers as possible.

3) Workshop summary

The summary report must consist of the following sections as a minimum:

1. Agenda, names and affiliation of participants, organizing team, place, time and type of information gathering (workshop, meeting, interview)
2. Draw up a user story ecosystem diagram (Appendix 2), and explain in text the user stories, actors and user story steps/tasks, optionally with explanation of information/data flows and other user story specific contents in relation to communication technologies, IOT, etc. Writing down the narrative should help in clarifying how solutions are/will be implemented.
3. Elaborate and discuss the findings in Table 1 (Appendix 1) in separate sections, with special focus on answering the following:
    1. **Problem description:** what the topic is addressing.
    2. **Gap analysis:** which problem(s) the topic has the ambition to cover.
    3. **Impacted stakeholders:** all the actors involved and/or can benefit by the implementation of the topic supply chain and user needs.
    4. **What is to be provided as a new feature:** what is new in terms of service or new technology with regard to the state of the art and similar activities currently available/reported?
4. Reference list of any additional background papers or reports. Background papers and reports should be provided in order to introduce the topic, supply chain and subjects, which were either setting the scene for the discussions in the sessions or additional information based on the discussions.
5. Include sections and Table 1 from the above item 3 in the final report for D1.1 on Teams (D1.1 report), and place additional documents in the Teams folder (Additional).

Annex 1

Table 6. Guideline table for gathering overview of current problems and challenges, new solutions and user needs as well as effects for each explored topics.

User Need ID.	**Explored topic**	**Problem/ opportunity scope**	**How it is done currently**	**New innovative solutions**	**Stakeholders/ supply chain**	**User needs**	**Expected effect from new solutions *(stakeholders and actors)***	**Others affected by solutions (environment, societal, social economics, legislation etc.)**	… (add more columns if relevant)
	Short name describing the topic: this is somehow a "short name" for the user need	*Short description of the problem*	*Short explanation of how it is it done today, or whether there is a solution at all*	*Short description of the solution, proposed by the stakeholders*	*What do they need to improve this situation? How would the user like it to be? (Connectivity related, supporting the new solution)*	*Who is bringing up the problem? For whom is it a problem?*	*For stakeholders and actors*	*For environment, societal, social economics, legislation etc.*	
1A	Example: Data Silos	Lack of distribution of forest data across value chain. Old and new data formats. Little or no distribution of forest data between value chain activities.	Order for logging is received via email home at operator.	Standardization. Forest data after registered logging order to operator is online and available for all following value chain stakeholders.	All value as well as supply chain stakeholders. FeltGIS.	Standardize data across the supply chain. Better flow of data between stakeholders.	More speedy process for invoice and billing (Challenge on ownership, access, and secrecy of data)		

Annex 2

User story modelling (forestry example "Data Silos" (from Table 1) in its simplest version). The purpose is to translate a user scenario into concrete user storytelling and main functionalities.

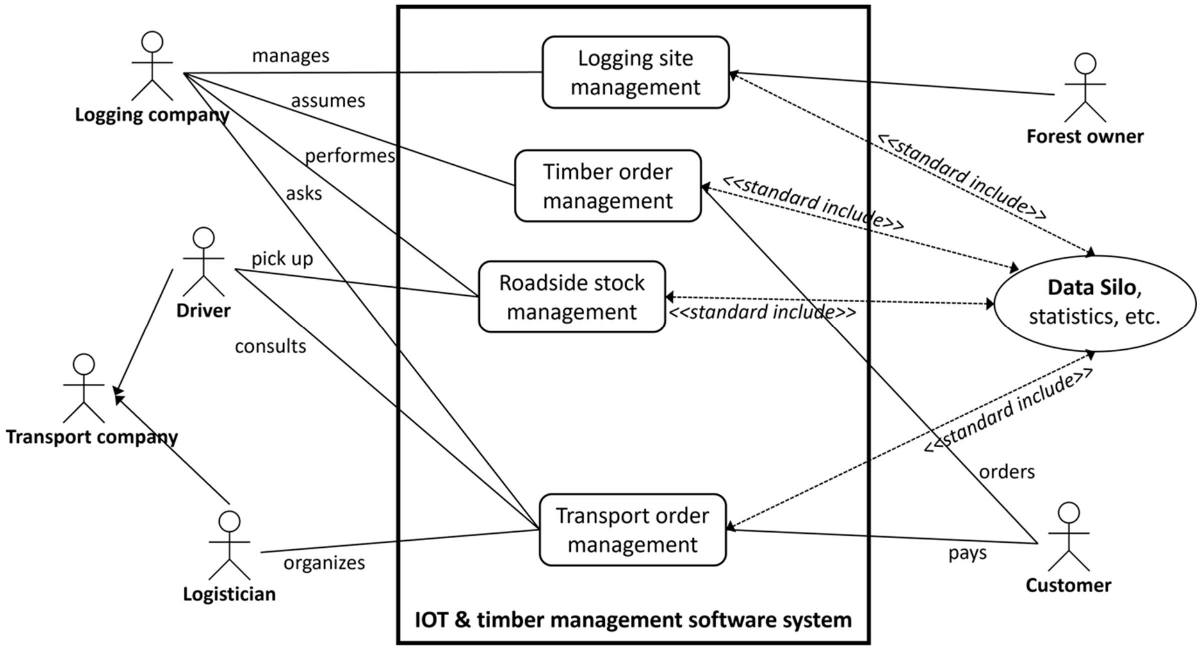

Figure 22. User story modelling diagram.