CHAMELEON

A Holistic Approach to Sustainable, Digital EU Agriculture, Forestry, Livestock and Rural Development based on Reconfigurable Aerial Enablers and Edge Artificial Intelligence-on-Demand Systems

CHAMELEON D4.4 ADSS visualization and user interface v1

Work package	WP4: CHAMELEON Solution for multi-purpose onboarding
Task	Task 4.6: ADSS Visualization and user interface
Authors	**Sotirios Berdes – SQD** **Christos Iliopoulos - SQD** **Alexandros Karvounis-Zoumpos – SQD**
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Table of contents

Index of figures

LIST OF ABBREVIATIONS AND ACRONYMS

Abbreviation	Meaning
ADSS	Agriculture Decision Support System
AI	Artificial Intelligence
API	Application Programming Interface
ASGI	Asynchronous Server Gateway Interface
CAD	Computer-Aided Design
CI	Continuous Integration
CD	Continuous Development
D	Deliverable
DIP	Drone Innovation Platform
DL	Deep Learning
GIS	Geographic Information System
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
M	Month
PD	Participatory Design
SQuaRE	Software Quality Requirements and Evaluation
T	Task
UAVs	Unmanned Aerial Vehicles
UCD	User-Centered Design
UI	User Interface
WP	Work Package

1   EXECUTIVE SUMMARY

The main purpose of the present deliverable is to propose an initial approach regarding the Agricultural Decision Support System, ADSS for short. This is the v1 of this deliverable with v2 planned to be delivered at M29. The aim of the ADSS is to deliver an intuitive and user-friendly system to the end-user, in order to help them make decisions and improve the outcome of their efforts through the visualization of information, monitoring of status and automation of tasks. The ADSS consists of several components such as the Geographic Information System (GIS), the Digital Twin of the area of interest and the different visualizations of the connected services/bundles. The design of the ADSS will follow a user-centred design (UCD) and a participatory design (PD) approach. The ADSS will be validated and evaluated based on the Software Quality Requirements and Evaluation (SQuaRE) standard, including accessibility, interoperability, scalability and functionality completeness (ISO/IEC25010:2011).

2   INTRODUCTION

2.1   BACKGROUND

Agriculture, along with the wide areas that it covers, is a vital sector strongly related among others to food production, economic stability and livelihood. The sector of agriculture faces multifaceted challenges, some of which can be confronted with technology. Thus, the current traditional approaches need to be reinvented to maximise the fruits of the farmer's labour.

Technology is revolutionizing countless sectors, among them agriculture. Hardware technologies are being used in regard to farmer's tools, sensors and other related systems that enhance the everyday life of the farmer. Software is used in many ways in Agriculture as well, ranging from software programs that do simple calculations to complex AI and DL algorithms that aim to predict yield crop, crop growth and development, and other complex solutions.

The aim of the ADSS is to integrate innovative solutions such as those of data analytics, GIS, remote sensing, and UAVs, to provide the farmer with enough information to support them with their decision-making. By integrating these innovative solutions, and the support of the farmer's decision-making, the outcome will be evident in terms of improved crop performances, the maintenance of environmental quality and others.

By providing information in a friendly UI, in a game-like manner, the ease of use for the end-user will increase, making the process one that can be part of the everyday life of the farmer. In this manner, the ADSS and all related technologies of the CHAMELEON project that will be used and showcased through the ADSS will become evidently useful technologies that have real-life applications and value.

2.2   PURPOSE AND SCOPE

The primary objective of this document is to provide the initial version of the ADSS, at this time a conceptual design and implementation schema of how all the related technologies, tools and services will be used in conjunction to serve the end-user. The ADSS aims to leverage the advanced technologies being developed in the CHAMELEON project and the data-driven insights to revolutionize the current decision-making processes of the farmers.

The specific objectives among others include:

Improve Agricultural Efficiency: Through the integration of different technologies, the objective is to eventually improve the agricultural efficiency that the farmer can achieve.

Provide 3D Digital Twin: The 3D digital twin can also be used to contextualize and geolocate precisely the site of interest to facilitate its analysis and processing by AI.

Enhance Decision-Making: Through the combination of different technologies, the end-user will be enabled and supported to make decisions that are based on innovative technologies, providing information as well as results and suggestions.

User-Friendly Interface: The interface of the ADSS is designed to be user-friendly, increasing this way the usability and overall value that the farmer gains from it.

This document entails various aspects in relation to the design, architecture, development and evaluation of the ADSS.

The specific objectives among others include:

1. Overview of the ADSS architecture and functionalities.
2. Insights into GIS, possible technologies and its use on the ADSS.
3. An overview of the user-centred approach and principles used for the development of the ADSS.
4. The Digital Twin implementation of the ADSS.
5. Examination of data visualisation utilized in the ADSS.
6. How we are going to enhance Agricultural Decision making with the ADSS.
7. The integration plan with the CHAMELEON DIP developed in WP5.
8. Finally, the method we will use to validate the ADSS is presented.

2.3 APPROACH

During this task, best practices of innovative methodologies and strategies will be used to ensure the successful development of the ADSS.

The key methodologies that will be used for the development of the ADSS are the User-Centered Design (UCD) approach and the Agile Development Methodology. As will be developed in more detail later on, the UCD focuses on the end-users, their needs and their requirements through all steps of the technology development lifecycle. Furthermore, the Agile Development methodology allows for flexibility and adaptability in the development process and pairs perfectly with the UCD as it uses iterative and incremental software development cycles to get feedback from the end-uses as fast as possible and then reiterate based on the feedback received.

State-of-the-art technologies will be used along with best practices for all the related parts and steps of the development process. Such practices involve among others practices in regard to CI/CD pipelines, software testing, and deployment cycles.

This approach of developing, emphasizing the User-Centered approach and utilizing the Agile Development Methodology will enable us to build and deliver to the end user a powerful user-friendly Agricultural Decision Support System.

2.4 RELATION WITH OTHER DELIVERABLES

This Deliverable which is part of the results of T4.6 of WP4, is connected with other WPs and Tasks and Deliverables as well. Below can be found a few of those most closely connected:

- **WP2 Deliverables D2.1 and D2.3:** WP2 focuses on the Conceptualisation, use cases and system architecture, as is the WP title. The present deliverable is strongly linked with D2.1 and its updated version D2.3. The two deliverables, focus on defining the use cases, during which the developments of the work presented in this deliverable will be demonstrated and validated.

- **WP2 Deliverables D2.2, D2.4 and D2.5:** These two deliverables complete the rest of the WP2 main objectives, focusing on technical requirements and system architecture. Again, D2.2 and its two updated versions D2.4 and D2.5 are strongly connected with the current deliverable. The architecture and technical requirements both stemming from the technologies that will be implemented but also combining them together, serve at least as a base and as information that has to be greatly considered.

- **WP4 Deliverables D4.3 and D4.7:** WP4 entails a series of technological offerings, part of which is the Bundles and services developed as well as the ADSS currently described in this document. The deliverable D4.3, which is to be delivered at the same time as this deliverable at M18, as well as the updated version D4.7, are strictly connected to this deliverable and the functionalities described herein, as the goal for them is to describe the bundles and services that will be developed in Tasks T4.3, T4.4 and T4.5. A part of the ADSS is the visualisations of the outputs of these bundles and services, making the documents that are described of vital importance to the current deliverable and its updated.

- **WP5 Deliverables D5.1 and D5.4:** WP5 focuses on the CHAMELEON innovation platform. The two deliverables, D5.1 and its updated version D5.4, aim to develop in detail the specifics of the developments of tasks T5.1 and T5.2, regarding the DIP technical solution reference architecture and the Data governance plan. The DIP will serve as a platform that connects different tools and services that will be offered by the CHAMELEON project. The connection lies in that the ADSS will be one of the applications that the DIP will help connect with other tools and services of the project, creating a strong link between the tasks and the deliverables.

- **WP5 Deliverables D5.3 and D5.6:** The D5.3 along with its updated version D5.6 are titled Integration with CHAMELEON drone ecosystem v1 and V2 respectively. The information contained in these two deliverables is of vital importance and connection to this deliverable as it helps connect the bigger picture and the integration of the different technologies as a whole.

3 DESIGN AND DEVELOPMENT OF ADSS

The Agriculture Decision Support System (ADSS) is designed to provide a robust and flexible platform for enhancing agricultural decision-making.

The Agriculture Decision Support System (ADSS) User-Interface (UI) core components are the Geographic Information System (GIS) and the 3D Digital Twin. The role of these components is to create an informative agricultural landscape representation. The Geographic Information System (GIS) leverages geospatial data to produce insightful maps, while the 3D Digital Twin provides a three-dimensional perspective. These components improve the visualization of the ADSS and enable users to access a wealth of data. By integrating the ADSS UI with the ADSS API we can present to the end-users' comprehensive insights in a user-friendly and interactive format.

Agriculture Decision Support System (ADSS) architecture API (Application Programming Interface) connects the ADSS UI with the database which stores information, including historical data, user information, and other agricultural information, and the Bundle services connector which is used to interact with different services such as crop and vegetation monitoring, extreme weather event and drought, health and pests, wildfire detection, monitoring livestock and soil. The API ensures seamless communication, enabling end-users to access and manipulate data effortlessly.

The Agriculture Decision Support System (ADSS) architecture leverages technology and data to empower end-users with comprehensive insights, enabling them to make informed decisions for more productive, efficient, and sustainable agriculture.

Regarding the ADSS platform development, we will choose a JavaScript Framework such as ReactJS for its UI because of its versatility and robust ecosystem, allowing us to create a dynamic and user-friendly interface. ReactJS [1] also provides high performance due to the virtual DOM and server-side rendering, which makes complex apps run extremely fast. For the API we will choose α Python Framework such as FastAPI [2] due to its high-performance capabilities. FastAPI maximizes performance by utilizing the full potential of critical libraries and tools such as Pydantic [3] and the ASGI [4] ecosystem. The modularity and simplicity of FastAPI allow for seamless integration with load balancers, facilitating scalability and ensuring efficient resource utilization.

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[1] ReactJS Legacy. A JavasScript library for building user interfaces. Retrieved on November 2023. https://legacy.reactjs.org/

[2] FastAPI. FastAPI framework, high performance, easy to learn, fast to code, ready for production. Retrieved on November 2023. https://fastapi.tiangolo.com/

[3] Pydantic. Pydantic is the most widely used data validation library for Python. Retrieved on November 2023. https://docs.pydantic.dev/latest/

[4] ASGI. ASGI Documentation. Retrieved on November 2023. https://asgi.readthedocs.io/en/latest/

In below Figure 1, the high-level architecture of the ADSS is presented, with the end-user having direct access to the ADSS UI, which is connected to the ADSS API, which in turn is connected to a database or more and a bundle connector.
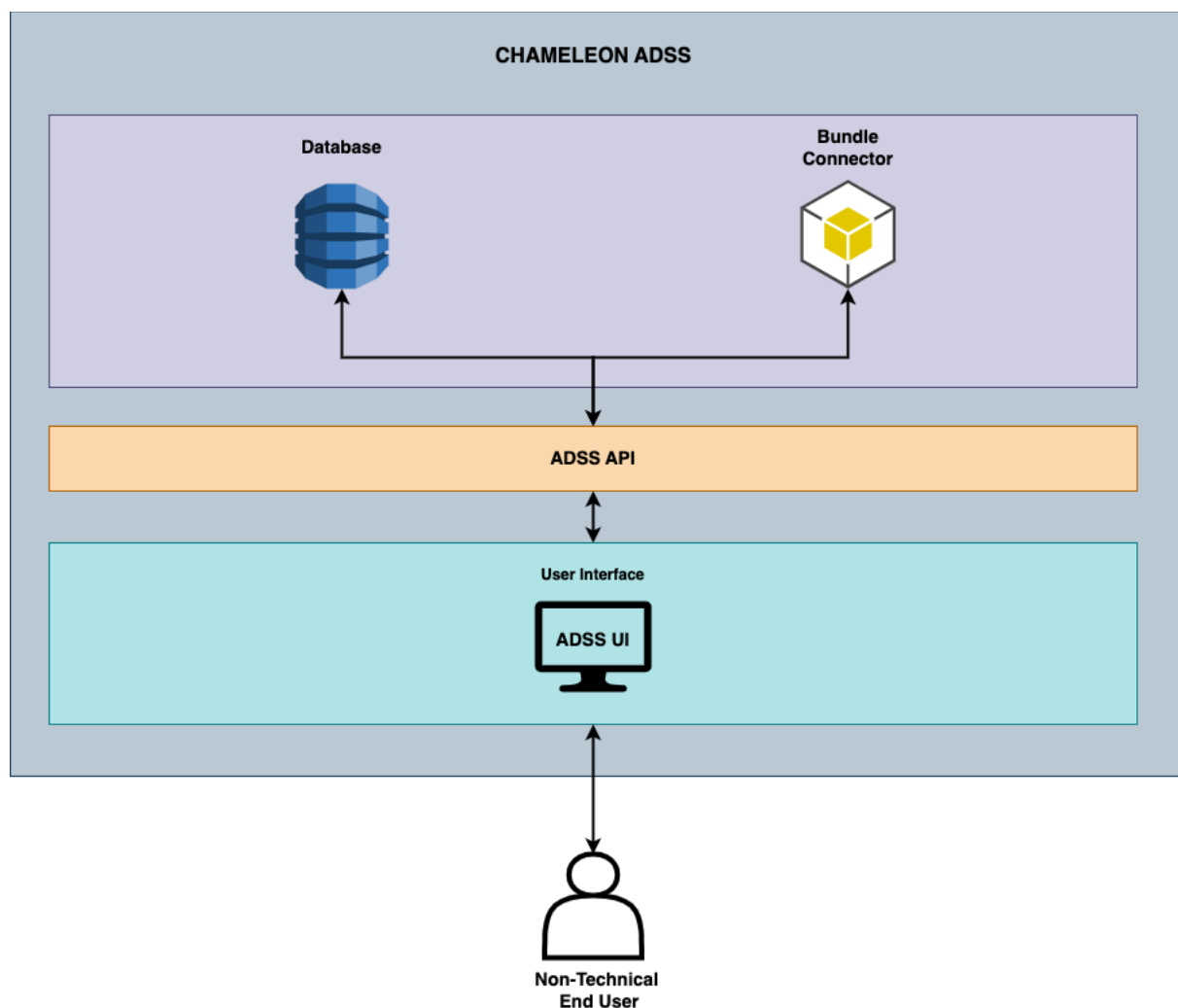
Figure 1: ADSS high-level architecture diagram

3.1 GIS OVERVIEW

A Geographic Information System (GIS) is a computer system that analyzes and displays geographically referenced information. It uses data that is attached to a unique location. [5] The applications of these systems are evident in many sectors. For the CHAMELEON project, the application will be related to the agricultural sector, as is the project.

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[5] USGS. What is a geographic information system (GIS). Retrieved on November 2023. https://www.usgs.gov/faqs/what-geographic-information-system-gis
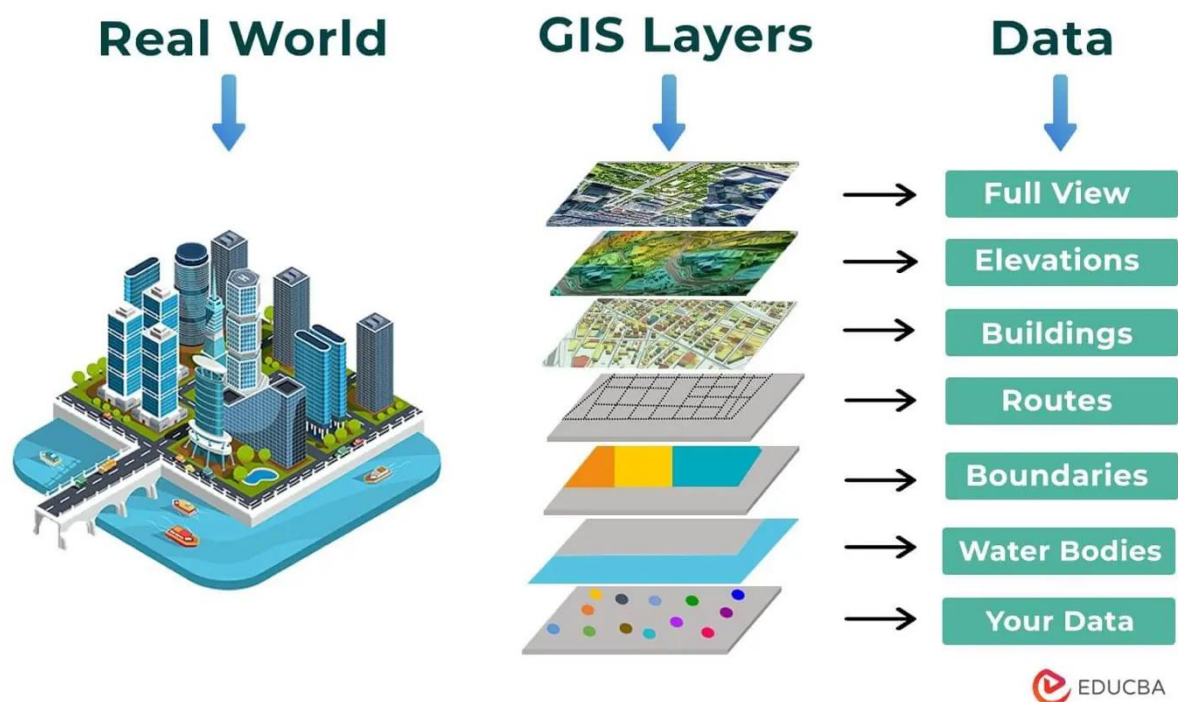
Figure 2: GIS example (Priya Pedamkar[6])

3.1.1 GEOGRAPHIC INFORMATION SYSTEM (GIS) – USE CASE

For the needs of the CHAMELEON project, there are many bundles and services that are being developed in the areas of agriculture and rural areas, livestock monitoring and forestry. Below is described a specific use case of a forestry service.

Imagine there's been a wildfire, a Geographic Information System (GIS) can help us assess the areas affected by extracting information from satellite images such as Landstad-8 or Sentinel-2. Using these images through a GIS we can calculate the Normalized Burn Ratio for both pre-fire and post-fire conditions and assess the burn severity based on some calculations according to the UN-SPIDER[7]. The results will be a map in the Geographic Information System (GIS) with different severity levels and the quantified severity of the burned area as those that can be seen in the below Figure 3.

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[6] Priya Pedamkar. Applications of GIS. Retrieved on November 2023. https://www.educba.com/applications-of-gis/

[7] United Nations. Normalized Burn Ratio (NBR). Retrieved on November 2023. https://un-spider.org/advisory-support/recommended-practices/recommended-practice-burn-severity/in-detail/normalized-burn-ratio

Figure 3: Burn Severity (United Nations[8])

This is only an example of how a Geographic Information System (GIS) can help us quantify the severity of the burn, providing valuable information for recovery and management efforts. A GIS has many other uses in earth sciences, biology, resource management, other fields and Agriculture as we will analyse in the next section.

3.1.2 GEOGRAPHIC INFORMATION SYSTEM (GIS) IN AGRICULTURE DECISION SUPPORT SYSTEM (ADSS)

The Geographic Information System (GIS) is a core component integrated into the ADSS to improve agriculture decision support. The GIS represents a geospatial solution with a user-friendly interface built on the React framework for usage in web applications. The Geographic Information System (GIS) primary objective is to offer reliable agriculture functionality by leveraging technology and geospatial data. The Geographic Information System (GIS) collects, and analyzes geospatial data relevant to agriculture.

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[8] United Nations. Normalized Burn Ratio (NBR). Retrieved on November 2023. https://un-spider.org/advisory-support/recommended-practices/recommended-practice-burn-severity/in-detail/normalized-burn-ratio
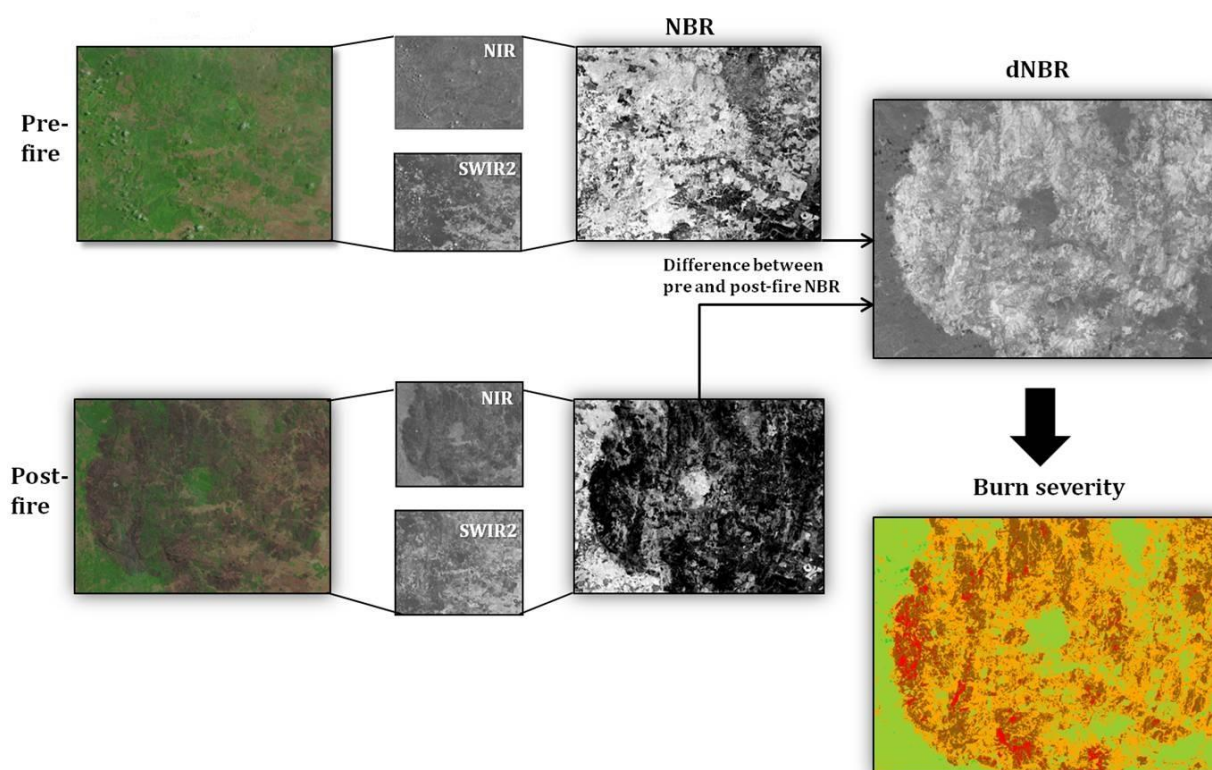
Data Collection, Processing, Visualization, and Decision Support

GIS collects data for a variety of purposes, such as crop and vegetation monitoring, extreme weather events and drought, health and pests, wildfires, and monitoring livestock and soil. After being gathered, this data is processed to create useful insights for assisting end-users in making appropriate decisions and achieving better results. This phase involves geospatial analysis techniques to identify patterns, trends, and anomalies critical to agricultural operations. Subsequently, GIS leverages this processed data to create informative geospatial layers and visualizations, providing end-users the ability to understand the spatial distribution of key agricultural parameters. The conclusion of GIS capabilities is the provision of suggestions and decision assistance tools via an easy-to-use WebGIS.

JS Libraries

We are using some specialized JS libraries to develop a user-friendly interface and geospatial visualizations for the Geographic Information System (GIS). These libraries enable us to produce maps and visualizations that provide agricultural professionals with access to geospatial data. OpenStreetMap, Google Maps, Mapbox GL JS, Leaflet, etc are a few of the libraries that can be used to this end. They will enable us to develop a simple and intuitive user interface that will let end-users take full advantage of geospatial data to enhance agricultural decision-making.

Through the GIS integration into the Agriculture Decision Support System (ADSS), end-users will be equipped with the tools and insights needed to make informed decisions, maximize their land's potential in terms of yield increase, reduce environmental effects, and enhance agricultural productivity.
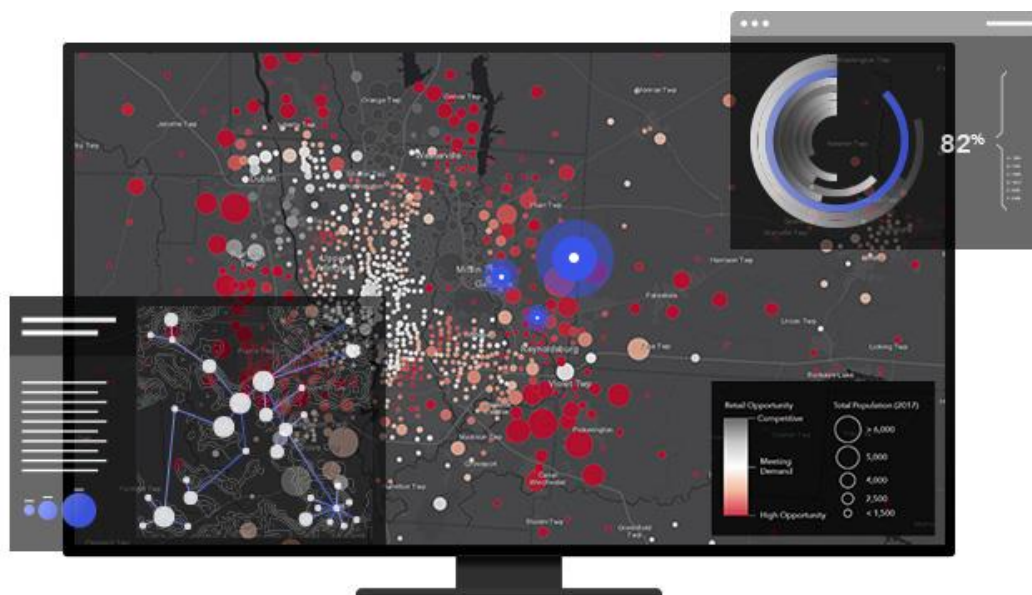

Figure 4: ArcGIS analyze data online (esri.com[9])

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[9] Esri. ArcGIS Online overview. Retrieved on November 2023. https://www.esri.com/en-us/arcgis/products/arcgis-online/overview#analyze-data.

3.2 USER-CENTERED DESIGN

User-centered design (UCD) is an iterative design process in which designers and other stakeholders focus on the users and their needs in each phase of the design process.[10]

3.2.1 USER-CENTERED DESIGN PRINCIPLES

1. **Focusing on the people:** The basic principle of user-centered design is this. It entails being understanding of the end users' requirements, preferences, and constraints.
2. **Solving the right problem:** Defining and understanding the problem correctly is essential before jumping to solutions. Designing for the real needs of users requires extensive study and analysis.
3. **Recognizing everything as a unified system:** Because everything in the system is interconnected, changing one part of the system can have an impact on others.
4. **Not rushing to a solution:** A variety of complicated aspects, including societies, cultures, political pressures, and economic concerns, are involved in user-centered design.

3.2.2 USER-CENTERED DESIGN STAGES

1. **Research:** This stage of the research focuses on understanding the users' needs, preferences, and behaviors.
2. **Requirements:** This stage of the requirements focuses on defining the requirements for the problems and pain points we intend to solve for the users based on the research findings.
3. **Design:** This stage of the design focuses on the creation of solutions such as wireframes, mockups, and prototypes addressing users' needs and pain points based on the requirements.
4. **Evaluate:** This stage of evaluation focuses on testing the designed solutions with end-users to identify usability issues and improvements.
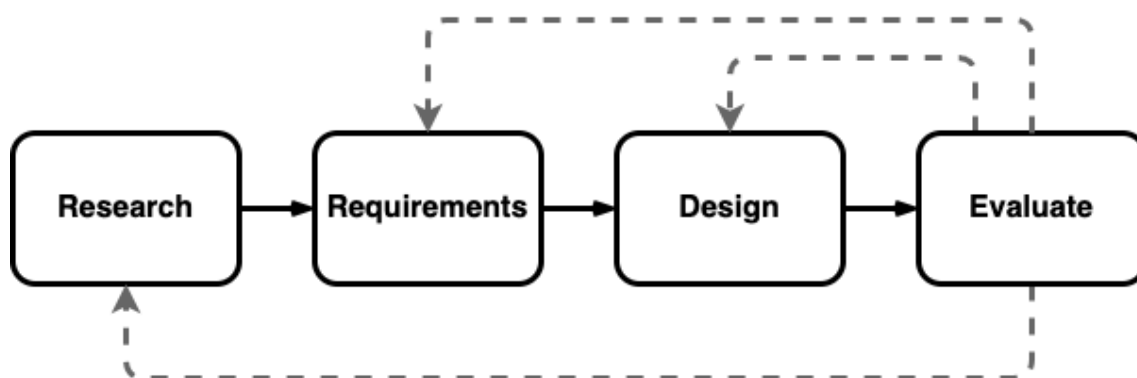

Figure 5: The 4 stages of the user-centered design

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[10] Interaction Design Foundation. User-Centered Design. Retrieved on November 2023. https://www.interaction-design.org/literature/topics/user-centered-design.

3.2.3 AGRICULTURE DECISION SUPPORT SYSTEM (ADSS) IMPLEMENTATION THROUGH UCD

User-centered design is important in the implementation of the Agriculture Decision Support System (ADSS) because it enhances the usability, accessibility, and overall effectiveness of the system. It ensures that the Agriculture Decision Support System (ADSS) aligns with the needs and preferences of its users, resulting in improved decision-making, increased adoption, and overall success in the agriculture sector. User-centered design (UCD) reduces the learning curve, fosters user satisfaction, and ultimately improves the efficiency and effectiveness of agricultural operations as will be detailed in a later chapter.

3.3 DIGITAL TWIN INTEGRATION

3.3.1 WHAT IS A 3D DIGITAL TWIN

A 3D digital twin model is a digital representation of an intended or real physical asset, process, or environment that resembles its real-world counterpart in terms of appearance and behavior for simulation and monitoring purposes. The use of 3D modeling to produce digital representations of real-world objects, such as machinery or buildings as well as entire regions, is an example of a 3D digital twin. It gives the user the ability to represent something in the virtual world by recording a real, physical object. Additionally, diagnostics and monitoring can be performed on a 3D-rendered digital twin of the area of interest to support end users in making decisions. Geographic 3D digital twins are becoming more and more common in agricultural, forestry, farming, and urban planning applications. They are typically presented as interactive platforms that record and show 3D spatial data to models of surrounding environments.

Figure 6: A 3D Digital Twin of an Environment. (matterport.com[11])

3.3.2 HOW IS A 3D DIGITAL TWIN MADE

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[11] Matterport. What is a 3D digital twin technology?. Retrieved on November 2023. https://matterport.com/learn/digital-twin

3D Digital twin models can be produced by scanning real-world objects or by importing conceptual models (such as models from CAD, or GIS) in 3D visualization applications. LiDAR (Light Detection and Ranging) is a remote sensing technique that uses light from a laser to measure out Elevation like buildings, ground, and forest and can be used to generate Point Cloud data that represent a 3D Digital Twin. LiDAR uses ultraviolet, visible, or near-infrared sources to sense objects and it calculates how long it takes a pulse — Light Energy emitted by Lidar — to return to the sensor to measure the distance[12]. It enables precise and accurate inspection of both constructed and natural features. Many different fields, such as surveying, geology, mining, urban planning, architecture, transportation, agriculture, and forestry use LiDAR technology.
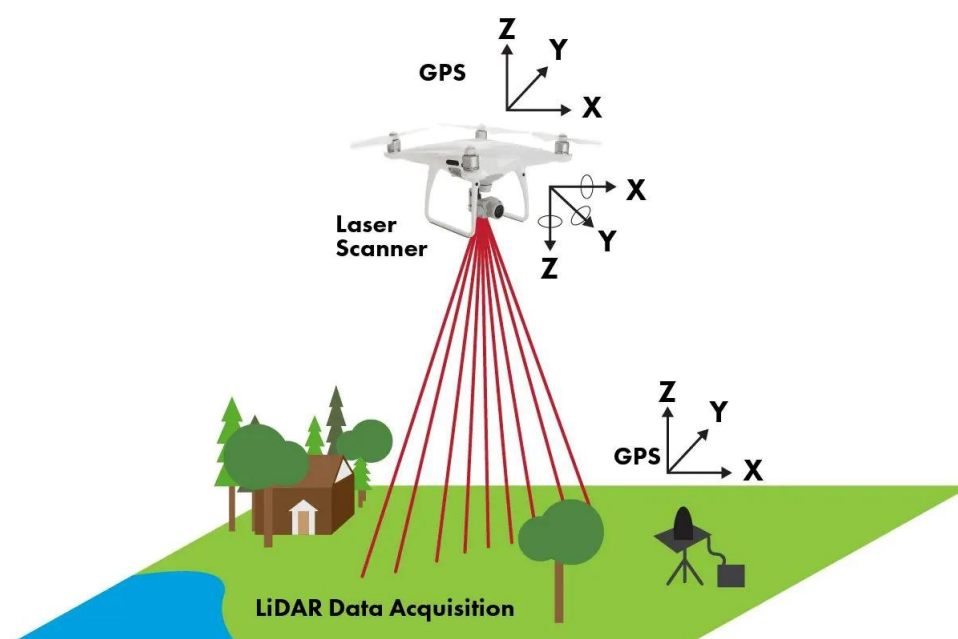
Figure 7: A drone using LiDAR technology. (flyguys.com[13])

3.3.3 POINT CLOUD DATA

A Point Cloud is a collection of discrete data points in space. The points can represent a 3D object/shape or environment, and X, Y, and Z are the sets of coordinates associated with each point position in the 3D space. Photogrammetry software or 3D scanners that measure a large number of points on the exterior surfaces of nearby objects typically generate point clouds.

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[12] Abdishakur (Book Author). What is LiDAR point cloud data?. Retrieved on November 2023. https://medium.com/spatial-data-science/what-is-lidar-point-cloud-data-a547ed29edf5#:~:text=A%20typical%20LiDAR%20data%20product,of%20features%20and%20GPS%20time

[13]Flyguys. When do I Need LiDAR?. Retrieved on November 2023. https://flyguys.com/when-do-i-need-lidar/

Point Clouds are the output of 3D scanning procedures and are used in a variety of applications including animation rendering and the creation of 3D CAD models for manufactured parts. [14]

<div align="center">

Figure 8: A 3D visualization of a Point Cloud. (Baez et. al., 2020[15])

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3.3.4 DIGITAL TWINS OF FORESTS

Digital Twins of forests play a vital role in understanding and monitoring the effects of drought and disease on trees. Forestry-related digital twin solutions provide easy access to 3D maps of forests or agric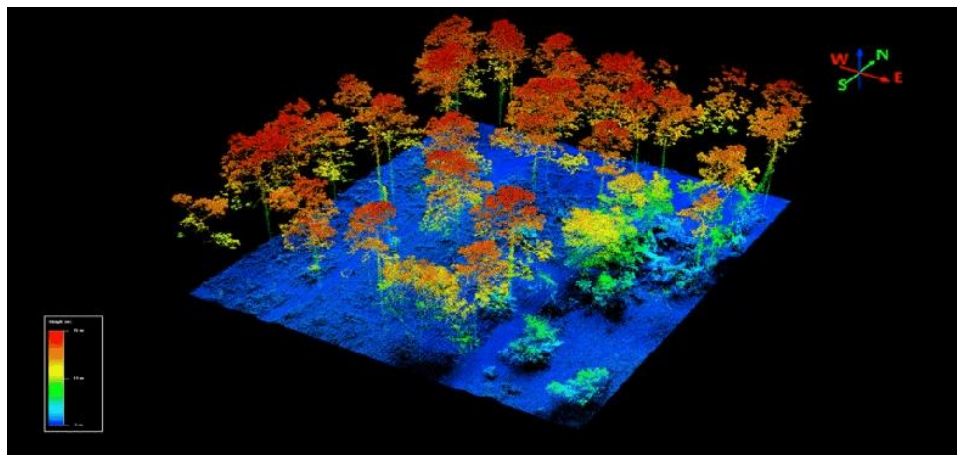ulture. This also presents enormous opportunities, from small features to macro tree inventory measurement capabilities. Additionally, experts can predict stress on large landscapes, generate ready-to-use weed control maps, and track changes to assets. Building and dynamically updating a digital twin of a landscape in real-time and optimizing woodland ownership from that digital twin becomes easier with digital twin technology solutions such as buffer analysis, landscape planning, inventory and forest harvesting planning, and timber inventory monitoring. [16]

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[14] Wikipedia. Point Cloud Data. Retrieved on November 2023. https://en.wikipedia.org/wiki/Point_cloud

[15] Baez et. al., 2020. Comparing High-Resolution Satellite and GatorEye UAV Lidar Data for Trail Mapping in Mixed Pine and Oak Forests in Central Florida Using a Participatory Approach. Retrieved on November 2023. https://www.researchgate.net/figure/An-example-portion-of-the-LiDAR-point-cloud-used-for-this-project-which-was-acquired-at_fig2_348036382

[16] Zhihan Lv et. al., 2022 Editorial: Digital twins of plant and forest. Retrieved on November 2023. https://www.frontiersin.org/articles/10.3389/fpls.2022.1049240

Figure 9: A 3D Digital Twin of a forest area as represented by a LiDAR Point Cloud. (blog.lidarnews.com[17])

3.3.5 DIGITAL TWINS IN SUSTAINABLE AGRICULTURE AND FORESTRY

Digital twins have great potential for success in sustainable agriculture, which is of great significance to advancing smart agricultural solutions that can help farmers and agricultural engineers. The application of digital twin technology in agriculture can help in scenarios such as crop monitoring, irrigation management, and soil analysis. [18]

3.3.6 DIGITAL TWINS IN LIVESTOCK FARMING

Artificial intelligence (AI), machine learning (ML) and big data are consistently called upon to analyze and comprehend many facets of modern daily life. AI and its sub-domain ML are widely used in animal husbandry to monitor both the animals and the environment around the clock, which leads to a better understanding of animal behavior and distress, disease control and prevention, and effective business decisions for the farmer. [19]

3.3.7 JS LIBRARIES

To build the WebGIS part of the ADSS, we are using ReactJS along with some specialized Point Cloud data and 3D rendering libraries to develop a user-friendly interface for geospatial visualizations. These libraries enable us to reproduce the 3D Digital Twins of land, forest, and urban areas' visualizations that provide agricultural professionals with access to geospatial data so that the use of this application will empower and enable the end users to drive their

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[17] The Lidar News Blog. 3D Mapping of Forests at Large Scale with Lidar. Retrieved on November 2023 from https://blog.lidarnews.com/3d-mapping-forests-large-scale-lidar/

[18] Turkish Journal of Agriculture and Forestry. Artificial intelligence and digital twins in sustainable agriculture and forestry: a survey. Retrieved on November 2023 from https://journals.tubitak.gov.tr/cgi/viewcontent.cgi?article=3033&context=agriculture

[19] Suresh Neethirajan. Digital Twins in Livestock Farming. Retrieved on November 2023 from https://www.mdpi.com/2076-2615/11/4/1008

decisions based on real-life live data. Potree[20], Three.js[21], and Cesium [22]are some of these libraries. These will enable us to build a simple and intuitive user interface that will let users take full advantage of 3D geospatial data to enhance agricultural decision-making.

3.4   DATA VISUALIZATION

In a modern data-driven world, it's imperative that we are able to view and understand data. This is where data visualization plays its part. With the goal of making data more accessible and understandable than ever, data visualization is the way to analyze and share information.

Data visualization is the graphical representation of information and data. By using visual elements like charts, graphs, and maps, data visualization tools provide an accessible way to see and understand trends, outliers, and patterns in data. Additionally, it provides an excellent way for employees or business owners to present data to non-technical audiences without confusion. The importance of data visualization is simple: it helps people see, interact with, and better understand data. Whether simple or complex, the right visualization can bring everyone on the same page, regardless of their level of expertise. [23]

Data visualization techniques and tools are essential for creating and managing 3D Digital Twins. By using point cloud data (LiDAR), and JS technologies we can render 3D Digital Twins models in web applications. They have a significant impact on agriculture, forestry, urban planning, and farming as they can be used to optimize productivity, affect decision making, and simulate different scenarios. Here is some information regarding data visualization techniques and tools.

There are numerous software solutions available to help humans visualise large amounts of data or the results of complex algorithms. Tableau, Microsoft Power Bi, and Google Data Studio are examples of software solutions. All of these solutions provide benefits to end users and are typically simple to implement. They are capable of creating interactive dashboards, reports, and visualisation views. At the same time, they allow you to connect a variety of other tools and data sources directly to their tools.

In terms of data visualization regarding the ADSS there are many ways in which we can provide the end-user with the tools to understand the output provided by the bundles in order to help them with the decision support.

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[20] Potree. Free open-source WebGL based point cloud renderer for large point clouds. Retrieved on November 2023. https://potree.github.io/

[21] Three.js. A cross-browser JavaScript library and application programming interface (API) used to create and display animated 3D computer graphics in a web browser. Retrieved on November 2023. https://threejs.org/

[22] Cesium. A JavaScript library for creating 3D globes and 2D maps in a web browser without a plugin. Retrieved on November 2023. https://cesium.com/

[23] Tableau. What is Data Visualization. Retrieved on November 2023. https://www.tableau.com/learn/articles/data-visualization

3.4.1 WHAT IS GEOSPATIAL DATA VISUALIZATIONS

Geospatial visualizations focus on the relationship between data and its physical location, by using maps as their primary tool. They showcase the physical connection between data points and can be used to identify problems, track changes, understand trends, and perform forecasting related to specific places and times. Geospatial visualizations are susceptible to various problems such as scaling and auto-correlation. They have been historically used to map illness, resources, and navigation, and are now prevalent in applications like Google Maps.

3.4.2 OVERLAYS AS DATA VISUALIZATIONS

Overlays on WebGIS applications are a type of geospatial data visualization that allows the rendering of layers on a map using latitude and longitude to provide insights. They serve as a container for additional data, allowing for the creation of context through the use of shapes like polygons and colour to visually inform the end-user. To visualize geospatial data, various map types, such as point maps, choropleth maps, and heat maps, can be used, each with its own set of advantages and disadvantages. Many of the bundles that are currently under development will provide layers as output of their AI and ML models that visualised in the ADSS. These information layers will be used to easily visualise the results of the services, for the area of interest of the end-user.

3.4.3 TEXT AS DATA VISUALIZATIONS

In summary, text as data visualization in geospatial applications can be achieved through various methods, such as labels, annotation, graphic text, dynamic text, and automatic typographic maps. These techniques allow for the incorporation of human language and text data into map visualizations, providing additional context and information to the user. The most suitable forms of data visualisations will be used as part of the solution provided by the ADSS.

3.5 ENHANCING AGRICULTURAL DECISION-MAKING

Agriculture Decision Support System (ADSS) in combination with the Geographic Information System, the 3D Digital Twin, and the Bundle Services provides a complete transformative approach to enhancing agricultural decision-making. It empowers the end-users with the tools, data and the visualizations they need to make informed decisions, improve their operations, and achieve profitable and environmentally friendly agricultural practices.
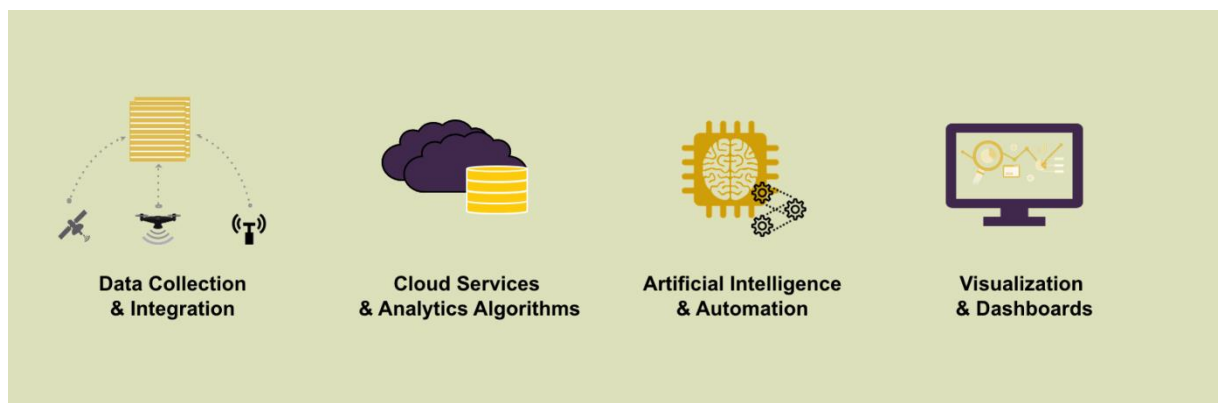
Figure 10: Decision Support Tool

The Agriculture Decision Support System (ADSS) can provide end-users with a view of their agricultural landscape. This allows end-users to visualize geospatial and 3D data alongside with the Bundle services, creating a holistic understanding of their agricultural operations. As a result, end-users can make informed decisions based on a wealth of relevant information, including crop health, soil conditions, livestock status, weather forecasts, and more. For example, ADSS will help with these insights the end-users respond quickly to changing conditions and unforeseen events so that they can make the necessary decisions to protect crops, livestock, and other needs from extreme weather events, pest infestations, wildfires, and more. Furthermore, the ADSS can optimize resource management as well as provide insights for crops and vegetation regarding the health and growth of the crops, adapting to the end-users' needs. Soil insights can guide nutrient application, livestock tracking can ensure animal health, and drought informs water resource allocation. These insights lead to better decisions, more efficient resource management, and more.

3.6   INTEGRATION WITH CHAMELEON DIP

The integration of the Agriculture Decision Support System (ADSS) with the Drone Innovation Platform (DIP) enhances the functionality and user experience by providing authentication, user information, and user's bundles information to our Agriculture Decision Support System (ADSS).

3.6.1 AUTHENTICATION

The Drone Innovation Platform (DIP) ensures a secure and reliable authentication process. Users can access the Agricultural Decision Support System (ADSS) using the Drone Innovation Platform (DIP) authentication mechanism, ensuring a unified and simplified user authentication mechanism.

3.6.2 USER INFORMATION

Users who are authenticated through the Drone Innovation Platform (DIP) are allowed to the Agricultural Decision Support System (ADSS) to have access to the user information and relevant details. This ensures that the user will be able to leverage this information without having to switch between different systems. By leveraging this information, the Agricultural Decision Support System (ADSS) can tailor its functionalities based on individual user needs, providing a personalized and user-centric experience.

3.6.3 BUNDLES INFORMATION

Drone Innovation Platform (DIP) enables users to customize their bundles. In the context of the Agricultural Decision Support System (ADSS) integration, users can choose their bundles and retrieve information such as crop and vegetation monitoring, extreme weather events and drought, health and pests, wildfires, and monitoring livestock and soil. This approach ensures that users have access to the functionalities that are most relevant in agriculture decision-making.
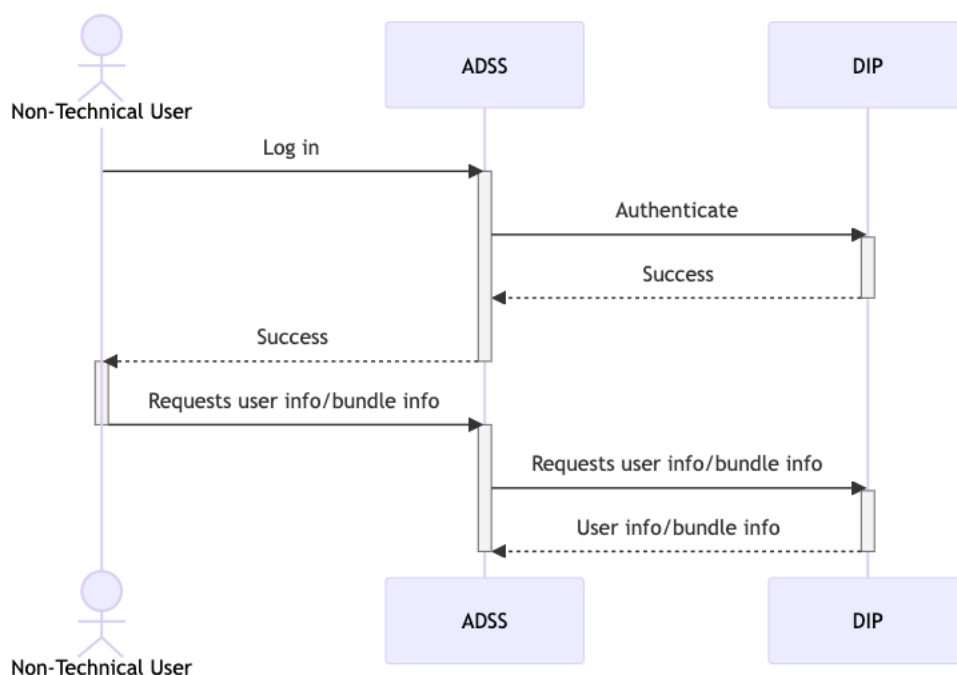
Figure 11: Sequence diagram of ADSS integration with DIP

In the diagram above, a Non-Technical User initiates a process by logging in the Agricultural Decision Support System (ADSS). The Agricultural Decision Support System (ADSS) then authenticates the user by interacting with the Drone Innovation Platform (DIP), successfully verifying the user's credentials. Once the credential of the Non-Technical User are verified, the Agricultural Decision Support System (ADSS) communicates the success back to the user. Then, the authenticated non-technical user requests specific information, such as user details or

bundle information. This action triggers a new set of interactions between the Non-Technical User and the Agricultural Decision Support System (ADSS) which forwards the request to the Drone Innovation Platform (DIP) and responds by providing the requested user information or bundle details. In this diagram, the role of the Agricultural Decision Support System (ADSS) is to act as an intermediary between the non-technical user and the Drone Innovation Platform (DIP).

3.7   NEXT STEPS

In terms of our next steps, as a software development team, during the ADSS development cycle, we use Scrum, one of the agile methodologies, with 2-week sprints and CI/CD practices. We use Continuous Integration and Continuous Delivery (CI/CD) to ensure that our development process is efficient, effective, and automated. This means integrating code changes into a git repository shared by the development team, as well as automated testing. This allows us to ensure that the software application is of high quality and that it is delivered to end users quickly, which meets some of the evaluation criteria chosen from the Software Quality Requirements and Evaluation (SQuaRE) standard, such as accessibility.

The implementation of the WebGIS' components, which comprise the front-end application in ReactJS and the back-end API in FastAPI technology, will proceed simultaneously to make sure we are aligned with the requirements, and we identify security goals early in the development of the application. As soon as all needed information regarding the DIP and each bundle's output data have matured, which are already far into the development cycle, we will create a proof-of-concept application. Using the provided requirements on each bundle we will begin working on a WebGIS that will be able to showcase the various layers such as vegetation monitoring, tree coloring, forests' paths and roads, soil humidity, etc. The logic behind this is that the ADSS will showcase a map and that will be the base upon which various layers, meaning output from the bundles, will be available for showcasing based on what the end user wants to see.
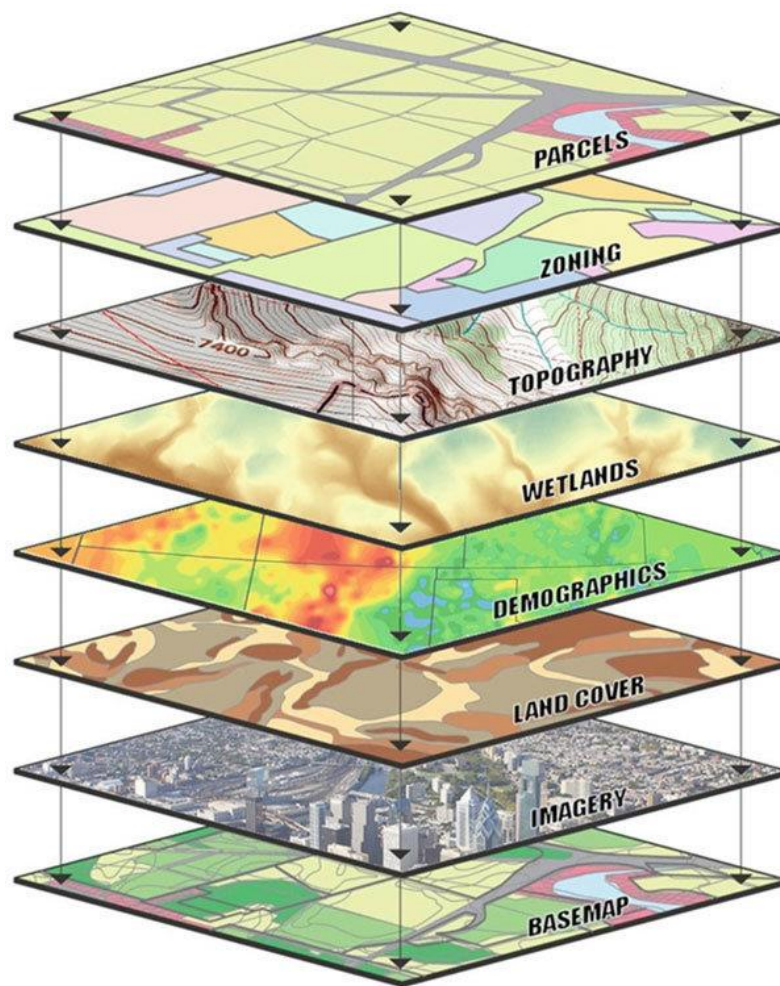
Figure 12: Example of different layers of data that can be combined through a GIS. (Kolios et. al., 2017[24])

[24] Kolios et. al., 2017. WebGIS Applications for Weather, Marine, and Atmospheric Environments. Retrieved on November 2023. https://www.researchgate.net/figure/Different-layers-of-data-can-be-combined-through-a-GIS-to-represent-realistic-and_fig3_318236667

4   VALIDATION AND EVALUATION

To validate the development of the ADSS, evaluation criteria will be used, chosen from the SQuaRE standard, such as accessibility, interoperability, and functionality completeness. This will make sure that the software satisfies the security and quality requirements and operates as intended by utilizing the SQuaRE standard. This process will ensure that the ADSS will be user-friendly and of the highest quality.

4.1   SQUARE CRITERIA & ISO/IEC 25010 COMPLIANCE

The primary reason that projects exceed their budget and schedule, end up with reduced scope, and deliver poor-quality applications that are of no use once delivered or become subjects of constant change is due to missing and/or unclear requirements. Poorly expressed or poorly analyzed quality requirements, such as security, are one source of such issues. Defects created by missing requirements in applications can cost way more money, time, and effort to fix during implementation or, in the worst-case scenario, after the application has been delivered than if they were discovered during the initial requirements phase. Furthermore, it is difficult and costly to improve aspects such as an application's security after it has been fully operational.

4.1.1 SOFTWARE QUALITY REQUIREMENTS ENGINEERING (SQUARE)

The Software Quality Requirements Engineering criteria, or SQuaRE criteria, developed by the Carnegie Mellon Software Engineering Institute provide a step-by-step way to identify and express software quality requirements in a software development project. The SQuaRE methodology can be adapted for use in a variety of software domains and combined with other methodologies, such as the SQUARE method for security requirements. The primary goal of the SQuaRE criteria is to ensure that software quality requirements are clearly expressed and documented even before the development lifecycle of a software application, which can help reduce the risk of vulnerabilities and improve the overall product quality.

4.1.2 ISO AND IEC

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with fields of technical activity.[25]

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[25] ISO. Systems and software engineering — Systems and software Quality Requirements and Evaluation (SQuaRE) — System and software quality models. Retrieved on November 2023. https://www.iso.org/obp/ui/ - iso:std:iso-iec:25010:ed-1:v1:en

Software applications are being used for a vast range of personal and professional tasks. High-quality software and systems are necessary to achieve goals and objectives for human safety, economic success, or personal fulfilment. High-quality software products are necessary to deliver value and avert any negative results for the stakeholders.

There are numerous parties involved in the development and delivery of software applications, such as those who create, purchase, utilize, or support companies that employ them. Ensuring value for stakeholders requires thorough specification and assessment of the caliber of software applications. This can be accomplished by outlining the required and ideal quality attributes connected to the system's stakeholders' aims and objectives. This covers the influence the system has on its stakeholders as well as the quality attributes of the data and software system. When possible, it is crucial that the quality attributes be defined, assessed, and measured using established or well-recognized metrics and assessment techniques. This International Standard's quality models can be utilized to find pertinent quality attributes, which can then be utilized to define requirements, their satisfaction standards, and the related metrics. [25]

ISO/IEC 25010 is a part of the SQuaRE series of International Standards. The product quality model defined in ISO/IEC 25010 comprises the eight quality characteristics shown in the following figure:

Figure 13: The product quality model defined in ISO/IEC 25010 as part of the SQuaRE criteria. (iso25000.com[26])

4.1.3 SQUARE & ISO/IEC 25010 COMPLIANCE IN THE ADSS
The Agriculture Decision Support System (ADSS) can improve agricultural decision-making. The ADSS architecture API connects the ADSS UI with the database, which stores information, including historical data, user information, and other agricultural information. The Security Quality Requirements Engineering (SQuaRE) method can be applied to guarantee that the ADSS conforms with ISO/IEC 25010 standards by using the best practices when implementing the

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[26] ISO 25000. ISO/IEC 25010. Retrieved on November 2023. https://iso25000.com/index.php/en/iso-25000-standards/iso-25010

usability standards. By measuring and assessing the product's quality, the ADSS may ensure that it satisfies the specifications and displays the desired qualities. The ISO/IEC 25010 quality models can also be used by the ADSS to find pertinent quality attributes that can then be utilized to create requirements. During its implementation, the ADSS should comply with the best practices regarding security and user data privacy by following a string of guidelines provided by experts in the field. Data encryption should be implemented, and secure coding can safeguard both security and data privacy. We can prioritize data privacy by minimizing the data kept for each user through data access limitations and by applying data encryption strategies when storing the data. Also, defining sensitive user data and classifying them can offer the right access control to the right users. Regarding code quality standards, the ADSS implementation can follow some of the best practices as documented by experts like clean code practices, testing, regular code reviews as well as planning for the development of the application to avoid unnecessary defects. Below in Figure 14 can be seen an overview of the SQuaRE methods and its main points.
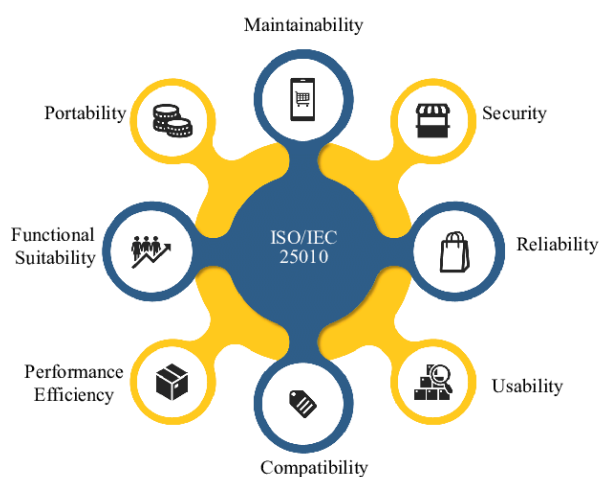

Figure 14: ISO/IEC 25010 Software Quality Model. (Yenduri et al., 2022[27])

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[27] Yenduri, Gokul & Gadekallu, Thippa. (2022). A Systematic Literature Review of Soft Computing Techniques for Software Maintainability Prediction: State-of-the-Art, Challenges and Future Directions. 10.48550/arXiv.2209.10131.

5   CONCLUSIONS AND IMPLICATIONS

In conclusion, the current deliverable has presented in detail the conceptual initial version of the ADSS that will be developed as part of the CHAMELEON project. The different functionalities, features and nuances have been presented in the previous chapters. The ADSS will support farmers in making data-informed decisions by providing a GIS interface, along with visualizations of data and the outputs of different bundles and services and a 3D digital twin of the area of interest. The ADSS will be designed using a User-Centered Design and will be validated based on the SQuaRe criteria. Finally, it will be connected through the DIP with the rest of the CHAMELEON technologies and services, providing a holistic approach to the end-user.

The continued improvement and iteration of the ADSS based on feedback received from the end-users, along with a close following of the latest technological developments will ensure that the developed system will meet the end-users' need and will be adaptable to the evolving agricultural needs and technological innovations. Considerations regarding the scalability and the integration of ADSS with the rest of the CHAMELEON technologies have to be planned carefully to make it seamless and provide the best experience to the end user.

Finally, it is evident that the current Agriculture landscape is everchanging, as are the climate and environmental conditions that the farmer faces on a daily basis. The use of the latest technological solutions transforms from minor importance and optional to very important and necessary. To this end, the ADSS is presented, as part of the CHAMELEON project, as a solution. The ADSS stands as a powerful tool that can be demonstrably used to assist the farmers in making informed decisions, pertaining to crop planning, resource allocation, and risk mitigation, leading to an improved agricultural outcome.

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The Members of the CHAMELEON Consortium:

Contact:

Project Coordinator: **Pantelis Velanas** Acceligence Ltd.	**pvelanas@accelligence.tech**

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