D3.7 - Holistic Long-Term Framework Scenarios - Draft

Work Package 3 - Digital Agriculture / Forestry Uptake – Forecast & Foresight

Authors: Eckhard Störmer (Future Impacts)

Jessica Prendergast, Clara Jöster-Morisse,
Cornelia Daheim (Future Impacts)

Date: 24.03.2025

Funded by the European Union

Full Title	**4Growth** - Digital Agriculture and Forestry: Understanding the Market to Forecast and Support Future Growth			
Project number	101134855		Acronym	4Growth
Start date	01.01.2024		Duration	36 months
Granting authority	European Research Executive Agency (REA)			
Project Coordinator	STICHTING WAGENINGEN RESEARCH (WR)			
Date of delivery	Contractual	M15	Actual	M15
Type	R - Document, report		Dissemination level	PU - Public
Lead beneficiary	Future Impacts			
Lead author	Eckhard Störmer		Email	Stoermer@future-impacts.de
Other authors	Jessica Prendergast (Future Impacts), Clara Jöster-Morisse (Future Impacts), Cornelia Daheim (Future Impacts)			
Reviewer(s)	Ellesha Dunn (LE Europe); Daire Boyle (Evenflow)			
Keywords	Foresight; scenarios; digital agriculture; digital forestry; 2040			

Document Revision History				
Version	**Issue date**	**Stage**	**Changes**	**Contributor**
0.1	07.02.2025	Draft	Extended outline	Future Impacts
0.2	04.03.2025	Draft	Internal draft for review	Future Impacts
0.3	11.03.2025	Draft	Review feedback Daire Boyle	Evenflow
0.4	17.02.2025	Draft	Review feedback Ellesha Dunn	LE Europe
0.5	21.02.2025	Final Draft	Final version	Future Impacts
0.6	24.03.2025	Final Draft	Edited final version	WR

Contents

Table of Tables

Table of Figures

Executive Summary

This report introduces **a set of holistic, long-term framework scenarios for the future of digitalisation in European agriculture and forestry up to 2040**. Developed within the **4Growth foresight module,** these scenarios serve as a strategic tool to assess how different framework conditions shape the uptake of digital and data-driven solutions in these sectors. By analysing alternative futures, the scenarios clarify the **fundamental requirements for the adoption of digital technologies** and data infrastructure **under varying conditions**, supporting **anticipatory policymaking** in digital, agricultural, forestry, and bioeconomy policies.

The holistic, long-term framework scenarios consist of **four distinct scenarios: three alternative framework scenarios and one "baseline"** scenario. The three alternative framework scenarios feature **a sustainability-driven Europe** (Reimagining Progress), **a fragmented and unequal Europe** (The Fractured Continent), and **a corporate-dominated Europe** (The Corporate Epoch) (for more details, see Table 1). **The baseline scenario assumes a continuation of the developments of the past 15 years**, showcasing a world characterised by ongoing technological advancements and the continued digitalisation of the sector. It also acknowledges persistent challenges that shape its development.

What do these different framework conditions mean for digitalisation in agriculture and forestry? The scenarios describe a broad range of possible developments:

- From ***Reimagining Progress*****,** where digital technologies serve as enablers of sustainability-driven agriculture and forestry, fostering collaboration among stakeholders and market players to enhance the living conditions of people and the environment.
- To ***The Corporate Epoch***, in which digitalisation primarily focuses on yield and profit maximisation within closed corporate platform ecosystems.
- In contrast, ***The Fractured Continent*** depicts a fragmented landscape where digital applications operate at varying levels of advancement but remain isolated due to a lack of interoperability and unequal access to digital infrastructure and tools.
- Finally, the ***baseline*** assumes a continuous development of digitalisation in agriculture and forestry, marked by the integration of AI, remote sensing, IoT, and automation to optimise resource use, improve decision-making, and ensure long-term sustainability.

The set of scenarios is a powerful tool for anticipating disruptions: **Reimagining Progress can serve as a visionary lighthouse**, while the **other scenarios highlight key challenges that must be addressed**. Table 1 provides an overview of the three alternative framework scenarios.

This report presents an initial version of the scenario work, which will continue to evolve. As the process advances, more profound insights will emerge, **further developing the scenarios and their implications** for digital agriculture and forestry and the policy measures needed to navigate these futures.

Reimagining Progress: Europe's New Deal with the Planet (Scenario 1)	**The Fractured Continent: Europe's Splintered Circular Economy Under Pressure** (Scenario 2)	**The Corporate Epoch: Multinationals and the New European Order** (Scenario 3)
Despite significant challenges along the way, Europe in 2040 is a **global leader in sustainability, leveraging technological innovation, multilateral cooperation, and transformed consumption patterns** to **respect planetary boundaries** and **curb climate change**. The EU leverages **digital innovation and mission-driven science** to advance sustainable agri-food and forestry practices, foster biodiversity, and promote plant-based diets, supported by **open knowledge sharing and equitable access to high-tech solutions**.	Europe in 2040 is a **continent of contrasts**: innovative in pockets yet fragmented in governance and society. The **strategic transition to a circular economy shows promise but is hampered** by **resource pressures, technological failures**, and **social inequalities**. **Climate change continues to accelerate**, highlighting the urgent need for unified action - a goal that remains elusive in this **polarised and fragmented world.** Agri-forestry practices prioritise **short-term productivity over sustainability**, while **fragmented digital policies and infrastructure** exacerbate inequalities.	In 2040, the European corporate epoch has already more or less established - defined by the **dominance of multinational corporations** that shape governance, economies, and societies. While **rapid economic growth and technological innovation** flourish, they come at the **cost of rising inequalities, environmental degradation, and increasing tensions** between corporate powers and fragmented governmental resistance. Agriculture and forestry are **heavily industrialised and controlled by a few global agribusinesses**, while **monopolised technology** exacerbates digital divides, limiting equitable access and innovation.
Key features of the EU in 2040: • **Respectful of Planetary Boundaries and Policy Evolution** • **Increasingly Sustainable Economy and Consumption** • **Resource Scarcity and Energy Transformation** • **Strong Global Governance and Diplomacy** • **Climate Change Mitigated, Warming Kept around 2°** Agri-forestry and digitisation specific features in 2040: • **High-Tech Innovation and Knowledge Sharing** • **EU World-Leading in Sustainable Agri-Food & Forestry**	Key features of the EU in 2040: • **Increased Nationalism and Resource Insecurity** • **Fragmented European Governance** • **Uneven Circular Economy Transition** • **Increasing Social Inequalities and Polarisation** • **Accelerating Climate Crisis and Environmental Degradation** Agri-forestry and digitisation specific features in 2040: • **Unsustainable Agri-Forestry Practices** • **Fragmented Digital Policies and Infrastructure and Interoperability Challenges**	Key features of the EU in 2040: • **Highly Individualistic Society and Competitive Economic Growth** • **Corporate Dominance in Governance** • **Exacerbated Resource Scarcity and Price Volatility** • **Social Fragmentation and Polarization** • **Escalating Climate Crisis** Agri-forestry and digitisation specific features in 2040: • **Heavily Industrialised Agriculture and Forestry in the Hand of Some Giants** • **Monopolised Technologies**

Table 1. Overview of the three alternative scenarios (Source: Future Impacts)

1. Introduction

The 4Growth project aims to **determine where, how, and to what extent digital and data technologies in agriculture and forestry are being adopted** by 2040. To achieve its goal, the project combines observatories of the current state with two distinct methods for examining future trajectories.

- **Market Monitoring and Forecast Tool** (MMFT): This economic model estimates and forecasts the uptake of digital technologies in the agriculture and forestry market[1] from the year 2020 to 2040, estimating seven different parameters – market potential, addressable market, market penetration, shipments, installed base, revenues, and prices.
- **Foresight Module:** This module explores alternative future pathways in the framework conditions of agriculture and forestry and identifies main disruptions that could accelerate or hinder digitalisation in these sectors.

This report presents one of the core outputs of the foresight module in a draft version: a set of **holistic, long-term framework foresight scenarios** illustrating different conditions under which the uptake of digital technologies in agriculture and forestry could evolve by 2040. Hereby, the scenarios clarify the **fundamental requirements for the adoption of digital technologies** and data infrastructure **under varying conditions.** These scenarios serve as a **tool for policymakers and stakeholders to anticipate challenges, adapt strategies**, and **enhance resilience** in a rapidly changing environment.

What foresight scenarios are:

Scenario planning is a **key methodology in strategic foresight** and is widely used in research and public sector decision-making and policymaking. Institutions such as the European Commission, European Parliament, the Organisation for Economic Cooperation and Development (OECD), and the United Nations (UN) have increasingly applied foresight scenarios to explore long-term policy challenges and opportunities (Daheim, 2023; van Woensel, 2024; Galvin, 2025; Monteiro and Dal Borgo, 2023; Tõnurist and Hanson, 2020; OECD, 2024; UNDP, 2022).

In contrast to forecasting, which projects a **single most probable** future, **scenarios** describe **multiple plausible futures** based on explicit, internally consistent assumptions (Bishop, 2017). Hence, foresight scenarios help manage uncertainty by identifying potential disruptions, systemic interactions, and alternative pathways rather than predicting a singular outcome (Wilkinson et al., 2013).

Aim of the framework scenarios as part of the Foresight Module in the 4Growth project:

The 4Growth framework scenarios explore potential **contextual conditions** shaping digitalisation in European agriculture and forestry sectors up to 2040. While the scenarios

[1] Examples are farm management information systems / forest inventory management systems, precision farming, automated machinery and robotics, monitoring and tracking technologies, etc.

focus on Europe, they take also global shifts in the **geopolitical, economic, environmental, social and technological landscape** into account.

Key Objectives of the Framework Scenarios:

- **Explore disruptions beyond business-as-usual assumptions**: Recent disruptions have shown that reality often defies "business as usual", making it essential to consider alternative pathways.
- **Anticipate sector-specific challenges**: Agriculture and forestry serve humanity's basic needs; their primary production is essential. Digitalisation depends on infrastructure, governance, market conditions, the willingness and capacity of farmers / foresters and consumers to take up technologies, and trust. The **actor's ability and ambition to advance the uptake of digital solutions** are uncertain.
- **Inform policy and strategy development**: The scenarios provide structured insights to support policymaking and sectors' strategic decision-making.

Alternative framework scenarios and baseline:

The holistic, long-term framework scenarios consist of four distinct scenarios: **three alternative framework scenarios and one "baseline" scenario**. The three alternative scenarios illustrate different possible framework conditions for 2040, whereas the baseline scenario represents the most likely future pathway assuming a continuation of current trajectories. While the **alternative framework scenarios use a qualitative foresight approach** and are the report's primary focus, the **baseline scenario draws from a quantitative approach**, as it incorporates results from the 4Growth Market Model and Forecast Tool (MMFT) by LE Europe. All scenarios are holistic (i.e., encompassing multiple dimensions of change), long-term (i.e., extending to 2040), and framework-oriented (i.e., focusing on broader structural conditions).

How to read the report:

This report is structured as follows:

- **Section 2 outlines the foresight methodology** used to develop the scenarios.
- **Section 3 presents the baseline and the three alternative scenarios**, each with a concise summary and a narrative depicting its world in 2040. The implications for digitalisation in agriculture and forestry are also analysed. **At the end of section 3, the three alternative scenarios** are compared, and their implications for digitalisation in agriculture and forestry are discussed.
- Finally, **section 4 details the next steps in the Foresight Module**, focusing on deeper scenario refinement and policy recommendations.

This report presents an initial draft of the scenario work. The framework scenarios will continue to evolve, integrating further insights to develop additional detail on their implications for digital agriculture and forestry.

2. Scenario Methodology

The alternative framework scenarios were developed using a **transparent "building block" scenario methodology**, specifically a **key factor-based approach** (Gausemeier et al., 1998; Kosow and Gaßner 2008; Marthaler et al., 2020; Peterson et al., 2003; Weppner et al., 2025). This approach comprises **four distinct steps**. First, it **identifies** a number of **key factors** - highly influential yet uncertain determinants of the future shaping digitalisation in agriculture and forestry up to 2040. It then **projects several of their potential developments** and **combines these projections to construct consistent scenarios**. Finally, the scenario's **implications for digital agriculture and forestry** are analysed. This methodology is particularly valuable for the 4Growth project, as it **allows scenarios to be continuously developed further based on new insights from other work packages** and **enables systematic updates as new developments emerge**.

While Figure 1 illustrates all methodological steps, the following sections provide in-depth details on each step:

Step 1: Identification of key factors.

The key factors – i.e., the most influential factors shaping the future of digitalisation in agriculture and forestry - were identified drawing on insights from both **horizon scanning** (Störmer et al., 2024) and **a systematic literature review of existing scenario studies**:

- **Horizon Scanning:** A 360-degree literature analysis using the **STEEP framework** (Fisher et al., 2020) to map contextual factors, moving from **global perspectives to sector-specific aspects**. This process leveraged the **4Growth horizon scanning grid** and previously analysed trends (Störmer et al., 2024) as a structured taxonomy and content input.
- **Systematic Literature Review:** A criteria-led approach was used to **identify and review key foresight scenario publications** relevant to the future of digitalisation in agriculture and forestry. This included integrating insights from major scenario studies, such as the IPCC's climate change scenarios (see Annex 3 for detailed methodology and study selection).

Following these steps, an **initial long list of potential key factors** was compiled and **systematically clustered**. To ensure comprehensive coverage, **a gap analysis** was conducted to identify and incorporate any overlooked aspects. Each factor was then assessed for its **level of uncertainty and potential impact**[2] (Bressan et al., 2019). This process resulted in a **shortlist of ten key factors** - highly uncertain yet impactful factors for the future of digitalisation in agriculture and forestry - along with one additional factor with (relatively) low uncertainty (i.e., a so-called "given" factor see Annex 1).

Step 2: Development of future projections.

For each of the ten key factors, **multiple projections** – plausible future developments up to 2040 – were developed. Like the key factors themselves, these projections were informed by

[2] "Impact" refers to the direct impacts about the European agriculture and forestry sector in 2040 and its tendency to take up digital solutions. "Uncertainty" refers to how certain you are / one can be about how this factor develops in the future, i.e. until 2040.

horizon scanning and insights from existing scenario studies. Additionally, their development considered:

- **Path dependencies**, i.e., the long-term influence of past decisions and inertia, such as existing infrastructures, education systems, and societal mindsets.
- **Niche developments**, i.e., emerging innovations, shifting markets, and technological breakthroughs.
- **Images of the future**, i.e., normative visions shaping expectations and goals[3].

For each key factor, **up to three alternative projections** were developed, each representing an alternative trajectory. These key factors and their projections were then **organised within a morphological box** (see Annex 1, Figure 3). This structured overview serves as the foundation for the next step: combining projections to develop consistent scenarios.

Step 3: Drafting consistent alternative framework scenarios.

Logically **connecting the future projections,** formed the starting point for developing consistent and plausible scenarios, as illustrated through the connections in the morphological box (see Annex 1, Figure 3). Brief bullet-point sketches were then created to **outline the key characteristics of each scenario**. The **expanded or "full" scenarios** contain **detailed narratives**, describing the world in 2040 and the pathways leading to it. To ensure their robustness and validity, the scenarios were **validated, evaluated and developed further** in several workshops, including a review session in the 4Growth Work Package 3 workshop[4] (January 2025). Specifically, the scenarios were checked for conflicts to **ensure logical consistency and assessed for plausibility**; the step included a cross-referencing testing with previous scenario studies (see, the literature review from Step 1).

Out of this process, **three consistent alternative framework scenarios** emerged.

Step 4: Analysing implications for digital agriculture and forestry.

In a final step, the **implications of each of the three scenarios** for agriculture and forestry sectors and the need and ability to take up digital solutions were **assessed through structured analysis and an expert workshop**:

- The structured expert analysis drew on **insights from horizon scanning**, the **review of relevant foresight literature**, and expertise from **previous research** activities (e.g., Muench et al., 2022; van Woensel et al., 2016; Wintermann et al., 2022). The findings were in some respects enriched with insights from generated by **generative AI tools** (e.g., ChatGPT), which were critically reviewed by the research team[5].

[3] The different perspectives refer to Futures Triangle concept from Inayatullah (2023).
[4] The workshop brought together expertise in market modelling from LE Europe, agriculture and forestry from WUR, innovative technologies and 4Growth project overview from Evenflow and foresight from Future Impacts.
[5] Detail on how AI was used is lined out in more detail in the following respective sections on methodology for those steps where AI was used.

- This was followed by an **expert workshop with members of the 4Growth consortium**[6] (February 2025).

The scenario implications were specifically assessed in relation to:

- **The agriculture and forestry model** (i.e., market structure, dominant business models, sources of income, prevalent practices, etc.)
- **Digital technology adoption, data governance**, and **access to digital infrastructure**[7]**.**

The outcomes of these analyses resulted in **sector-specific implications for the three consistent alternative framework scenarios**.

[6] The workshop brought together the full range of expertise in digital agriculture and forestry, science communication, market analysis, forecasting and foresight of the 13 4Growth consortium partners (Wageningen University and Research, Evenflow, Agricultural University of Athens, reframe.food, LE Europe, Future Impacts, vizzuality, ILVO, INTIA, CTIFL, VTT, AgriFood Lithuania. Aristotle University of Thessaloniki).

[7] For the technology implications, the authors were taking up first insights from Task 2.1 State of the Art analysis (SOTA), D2.3 report. In the upcoming iterations refining and enriching the implications, SOTA insights will be deeper analysed.

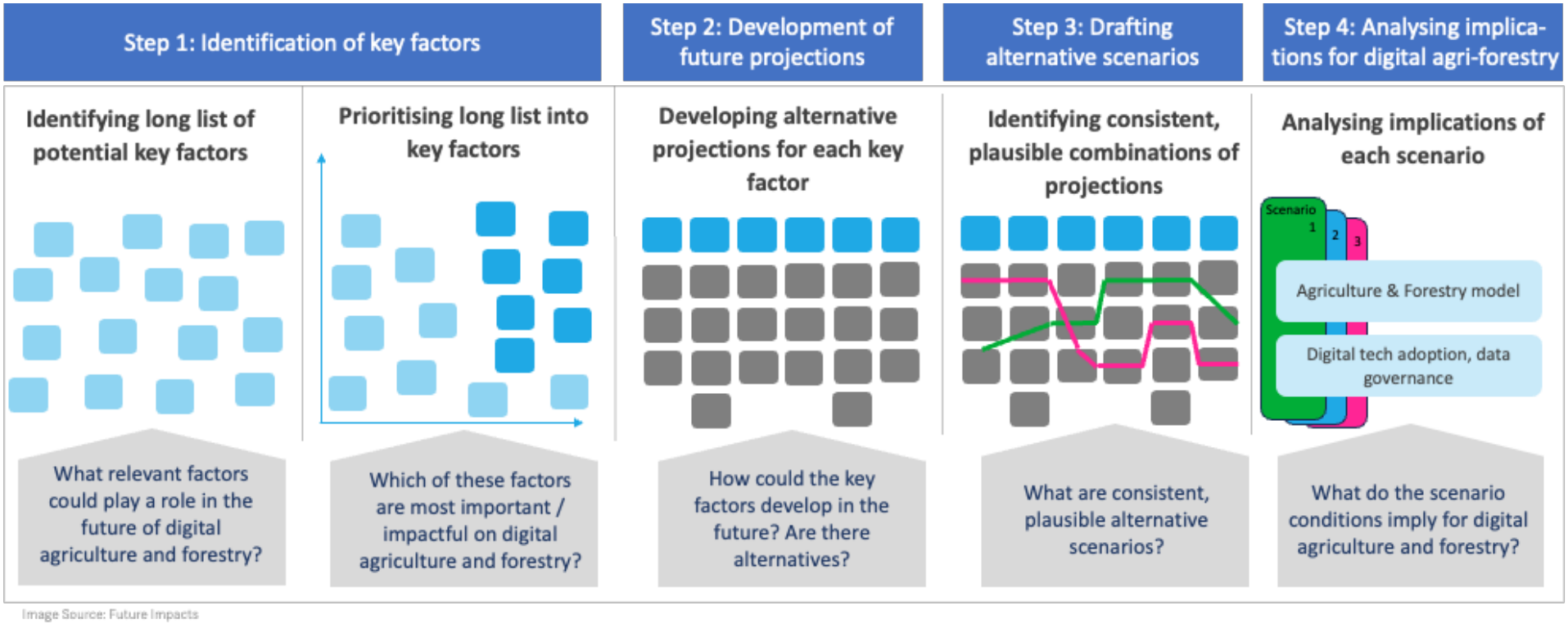

Figure 1: Key steps to develop the alternative scenarios (the baseline scenario follows a separate approach) (Source: Future Impacts).

On the baseline approach.

Unlike the **qualitative foresight scenarios**, the **baseline scenario (Scenario 0)** is derived from a **quantitative forecast model**. Using the **4Growth Market Monitoring and Forecast Tool (MMFT)**, this approach projects the uptake for digital technologies in agriculture and forestry market form the year 2020 to 2040 based on seven different parameters – market potential, addressable market, market penetration, shipments, installed base, revenues, and prices (LE Europe, Annex 4).

Whereas **foresight** explores multiple plausible futures shaped by **uncertainties**, **forecasting** estimates the **most likely trajectory** using historical data[8] (Bishop, 2017; Bressan et al., 2019). While their methodologies differ, these approaches are **complementary**:

- The **MMFT baseline scenario** serves as a **reference case**, estimating digitalisation trends under current trajectories, based on existing quantitative data.
- The **alternative framework scenarios** explore potential disruptions, structural changes, and uncertainties that could lead to **divergent futures,** based on qualitative research.

In the upcoming project steps, the MMFT will also attempt to provide **quantitative market estimates** for some of the **core assumptions** in the alternative framework scenarios (see Hirsch et al., 2013; Hobday et al., 2020).

While this chapter has outlined the methodology behind the development of consistent alternative framework scenarios and the context in which the baseline was developed by LE Europe, the next chapter will present all four 4Growth scenarios to date.

[8] However, the volatility in the current poli-crises world makes disruptive changes more likely than a continuation of the status quo.

3. Overview of the 4Growth Scenarios

3.1 Introduction to the 4Growth Scenarios

In order to promote a better anticipatory understanding of potential future pathways – the different possible future framework conditions in which digital technologies could be adopted and integrated in EU agriculture and forestry in the EU in the future – this section presents a **baseline and three alternative scenarios**. The baseline scenario projects current developments (and is based on the results of the MMFT model), while the three alternative scenarios explore "what-if" questions, helping to prepare for uncertainties such as:

- The role of sustainability policies (climate and biodiversity policies), along with support from business and society.
- Geopolitical tensions and their impact on trade and supply chain reliability.
- The role of multinational corporations in controlling platform ecosystems and extent of government regulation.
- The balance between nationalist sentiments and openness to EU and multilateral cooperation.
- The speed and direction of digital innovation and their potential to support sustainability beyond productivity growth targets.

3.2 The 4Growth Scenarios (First Draft)

3.2.1 Baseline[9] (Scenario 0)

LE Europe, in collaboration with Future Impacts, has developed a baseline scenario on technology adoption trajectories in agriculture and forestry across Europe and globally. Here, we introduce the summary of development assumptions. More details can be found in Annex 4.

This scenario outlines key drivers and trends shaping the digital transformation of agriculture and forestry, considering economic, technological, environmental, and societal factors. The baseline assumes a continuation of current trends with moderate technological advancement, regulatory developments, and evolving market dynamics.

The EU and the world in 2040

By 2040, the global population is forecast to grow to 9.2 billion by 2040, a 13% increase from 2025. However, the amount of utilised agricultural area is expected to shrink in Europe, so will not match this growth rate. Therefore, farmers globally face growing pressure to increase productivity with limited land resources. Moreover, there is an increasing demand for sustainable forestry, with wood-based construction methods gaining traction and biodiversity initiatives requiring sections of managed forests to be set aside for conservation. As a result,

[9] This section 3.2.1 is gratefully provided by the 4Growth partners from LE Europe, Rasmus Flytkjaer, Ellesha Dunn and colleagues based on their findings from Task 3.1.

both sectors individually need to produce more efficiently against a backdrop of shrinking areas of productive land.

Economic and geopolitical factors continue to shape global trade and supply chains, with digitalisation playing a key role in mitigating risks and enhancing resilience. Europe's agriculture and forestry sectors remain interconnected with international markets, relying on essential inputs while exporting high-value agricultural and wood-based products. Meanwhile, climate action policies and shifting consumer preferences for sustainably sourced products drive further investment in green and digital innovations.

Digital agriculture and forestry in 2040

Digitalisation in agriculture and forestry continues to accelerate, with artificial intelligence (AI), remote sensing, the Internet of Things (IoT), and automation becoming integral to decision-making and resource optimisation. Precision farming technologies, AI-driven analytics, and Global Navigation Satellite Systems (GNNS)-enabled systems allow farmers to maximise yields while adapting to economic pressures. However, demographic shifts, particularly an ageing farming population, slow down widespread adoption. Targeted training programmes and incentives are required to bridge the generational gap and ensure that smaller farms can access and implement digital solutions effectively.

Similarly, forestry relies on digital twin technologies, satellite imaging, and real-time analytics for forest monitoring., carbon sequestration, and optimised harvesting. Although investment and regulatory adaptation vary across regions, digitalisation has become essential for improving productivity and sustainability. Challenges such as regulatory barriers, data privacy concerns, and infrastructure limitations persist, but continued private and public sector investment drives innovation.

Key drivers of the baseline scenario

Here, we introduce a summary of some of the development assumptions that provide the foundation of this scenario (more details can be found in Annex 4):

Economic development: The global economy follows a moderate growth trajectory, with Europe experiencing steady but uneven economic development.

Globalisation: Trade and international cooperation remain key drivers of digital technology adoption. The agriculture and forestry sectors are increasingly interconnected, with multinational companies investing in digital solutions to optimise supply chains.

Supply chain dependencies (imports/exports): Europe continues to rely on imports for certain key agricultural inputs, but investments in automation and precision agriculture help mitigate some risks. Forestry supply chains increasingly integrate digital monitoring systems to track deforestation and sustainable sourcing.

Climate action: Climate change impacts worsen. Governments and industries increase their commitments to climate targets, pushing for sustainable and digitalised farming and forestry practices.

Technology developments (R&D): Research and development in digital agriculture and forestry continue to accelerate, driven by public and private sector investments.

Market concentration: Consolidation reduces the number of small farms while large-scale farms adopt digital efficiency solutions.

Food security: Digital technologies enhance food security by improving yield predictions, reducing food waste, and optimising supply chains.

Consumption/nutrition habits/building and constructing materials: Consumer demand for sustainably sourced products increasingly influences agricultural and forestry practices.

Energy sector using bioenergy: The transition to bioenergy gains momentum, with digital technologies optimising biomass supply chains.

3.2.2 Reimagining Progress: Europe's New Deal with the Planet (Scenario 1)

By 2040, Europe leads in sustainability, overcoming challenges through technology, cooperation, and transformed consumption. The EU drives sustainable agri-food, forestry, biodiversity, and plant-based diets with digital innovation, mission-driven science, and open knowledge sharing.

The scenario in a nutshell:

- In response to environmental crises, **policymakers, industries, and society unite to prioritise sustainability**. Stricter policies drive Europe toward net-zero carbon, biodiversity restoration, and reduced degradation.
- Europe, followed by other regions, adopts a **sustainable economy focused on resource efficiency, circular models, and conscious consumption**, like low-meat diets, balancing local production with global trade.
- A **stronger multilateral framework** emerges, **led by the EU** in diplomacy, green tech, and sustainable value chains. The world commits to a **Global Green Deal** with adaptable goals.
- Rising resource scarcity drives higher prices and sustainable extraction, while **energy transitions and carbon sinks become key**. Upskilling supports workers in shrinking sectors.
- Despite past emissions, **mitigation keeps warming near 2°C**, setting a sustainable global course.

The EU and the world in 2040:

By 2040, in response to escalating environmental crises, **policymakers, industries, and society unite to prioritise sustainability**. Rising resource costs drive sustainable extraction, while **ambitious climate policies** push Europe toward net-zero carbon emissions, biodiversity restoration, and reduced environmental degradation.

Despite initial resistance, a stronger multilateral political framework emerges, with **the EU leading global governance through diplomacy, green technology, and sustainable value chains**. Transforming energy systems and implementing carbon sinks become essential in combating climate change. The **world commits to a Global Green Deal** with customised goals and strategies.

Europe, followed by other regions, transitions to a **sustainable economy centred on resource efficiency, circular models, and conscious consumption**, including reduced meat intake. **Local, high-quality production** flourishes alongside **sustainable global trade**. Workforce reskilling is crucial as traditional industries shrink. Though past emissions continue to affect the climate, **mitigation efforts keep warming near 2°C**, setting the world on a more sustainable trajectory.

Digital agriculture and forestry in 2040:

In the years leading to 2040, digital technologies and infrastructure drive Europe's sustainable transformation, **integrating domestic and global innovations**. Innovation, policy, consumer demand, and business initiatives promote **eco-friendly agricultural and forestry practices**

and carbon farming and forestry. Global primary production shifts regions where it is most sustainable. Meat consumption drops significantly, with plant-based diets becoming the norm.

Mission-driven science, financed by the EU, member states, private investors and citizens**, advance sustainable agri-food, forestry, and climate solutions**. As biodiversity is a crucial issue, **productive farm and forest land is limited to enable 30% of land reserved for ecosystems and 10% strictly excluded from human intervention**. Open knowledge sharing, fair data allocation, and education fuel the widespread adoption of high-tech and social innovations.

In a digitally advanced yet sustainability-driven world, AI, automation, and data-driven governance play a crucial role in supporting ecological restoration, enhancing resource efficiency, and strengthening climate resilience. The balance between open data, ethical AI, and economic incentives ensures a **regenerative, fair, and resilient agricultural and forestry sector in 2040**. AI-driven precision farming and forestry applications use real-time monitoring of soil, water, crops, livestock, and tree health. Drones, satellite imaging, and field and animal sensors provide detailed data. Digital twins allow real-time data analysis for automated decision-making to optimise inputs (like fertilisers, pesticides, water), planting, sawing, livestock breeding and harvesting while enabling biodiversity and social conditions. **Machine learning systems improve knowledge** about good farm and forestry practices adapted to local soil, weather, and climate conditions. It shows ways to use practices such as crop rotation and micro-climate interventions like strip farming to improve soil quality and biodiversity.

AI-optimised logistics reduce food waste based on detailed consumer insights generated at high privacy levels from farm to fork; similarly, circular wood-based bioeconomy is enabled by material tracking and recycling systems. **Alternative proteins** are partly produced in bio-reactors for artificial meat, algae production, or vertical farms. Farmers first applied **digital monitoring and Industry 4.0-like production processes** in these controlled environment farming conditions and later in the fields and forests. Most machines are fully electric; many heavy machineries have been replaced by **lightweight robotic swarms** to minimise soil compaction and access remote areas for planting and restoration. Agricultural and forestry equipment consistently monitors fields and forests. Robots operate in natural conditions and are designed for nature-robot interaction[10]. They efficiently interact with plants and livestock, adapting to specific micro-contexts. Their tasks include sawing, planting, watering, fertilising, weeding, pest control, and harvesting.

Carbon sequestration and carbon farming are becoming additional business areas for farmers and foresters. Monitoring and decision support enable optimised land use through digital measurement, reporting, and verification systems **ensuring the integrity of carbon credit, reward farmers and foresters for carbon farming** and regenerative practices.

A "data commons" approach enables data sharing while balancing open access with privacy and equity. **Decentralised and federated systems** work with distributed data networks that act on open access following a culture of "open but protected" data principle and interoperability. **As a global leader, the EU ensures data sovereignty and ethical AI governance**, preventing Big Tech from monopolising agricultural and forestry data. Farmers, foresters, and cooperatives are empowered, while sustainable innovation thrives through shared knowledge. Knowledge-sharing platforms and digital education equip farmers and foresters to adopt innovations, fostering resilience. Open-access data strengthens collaboration, enhancing sustainability in agriculture and forestry.

[10] See e.g. Reynolds-Cuéllar and Salazar-Gómez, 2023.

3.2.3 The Fractured Continent: Europe's Splintered Circular Economy Under Pressure (Scenario 2)

In 2040, Europe thrives on innovation but struggles with fragmented governance and societal divides. Agri-forestry favours short-term gains over sustainability, while disjointed digital policies deepen inequalities.

The scenario in a nutshell:

- **Nationalist policies and competition with resource-rich nations** restrict resources, fuel trade wars, and weaken global cooperation. **Resource security overshadows multilateralism**.
- **Economic divides deepen in Europe** as financial barriers limit access to education and skills, slowing technological adoption.
- **Some regions advance towards a circular economy, while others lag** behind due to insufficient technology, education, and funding.
- **Polarised European leadership and conflicting national agendas** stall EU climate politics, economic growth, and social equity progress.
- **Global warming exceeds by far +2°C by 2100,** intensifying extreme weather, resource scarcity, and disruptions to food, infrastructure, and ecosystems.

The EU and the world in 2040:

By 2040, Europe is entangled in a **fragmented and turbulent global landscape**. Nationalist policies dominate as countries like China, the United States of America, Russia, and the United Arab Emirates compete for resources, sparking trade wars and disrupting cooperation. Geopolitical tensions rise, with resource security taking precedence over multilateralism.

Polarised governance weakens unity within Europe. National governments, driven by regional interests, pursue conflicting agendas, stalling progress on climate change, economic growth, and social equity. **The EU's circular economy transition falters**, with some regions advancing sustainable models while others struggle due to limited access to technology, education, and funding.

Social inequality widens as wealth increasingly dictates access to education and technology, deepening economic divides and slowing technological adoption. The climate crisis accelerates, **with global warming exceeding by far +2°C by 2100**. Extreme weather and resource scarcity disrupt food production and ecosystems, underscoring the urgent need for unified action.

Digital agriculture and forestry in 2040:

In 2040, **digital agriculture and forestry in Europe face challenges from political fragmentation and uneven technology access.** While some regions adopt AI-driven farming and precision forestry, others lack the infrastructure, funding, and expertise to do the same, leaving rural and disadvantaged areas behind.

We are in a world of **unequal access to digital tools and infrastructure** while the agriculture and forestry system is under climate stress and needs to innovate its practices and approaches to increasingly harsh environmental conditions. **Extreme weather volatility disrupts food and forestry stability**. Uncoordinated digital monitoring and lack of cohesive

data-sharing across Europe and beyond of large-scale weather, pests and disease threats across countries and continents lead to gaps in catastrophe prediction and crisis prevention. This results in deforestation and temporary food shortages. **Geopolitical conflict over food, water and arable land** flares up in crises. In addition, private hedge funds speculate on resource availability in high-frequency spot markets, driving price volatility, increasing income insecurity for farmers and foresters, and making resources temporarily unaffordable for many. In addition, **cyber-attacks and AI-driven geopolitical competition** disrupt digital agriculture and affect food security and supply chains.

Large agribusinesses and forestry businesses thrive on digital precision farming and forestry, particularly in better-off parts of the EU. At the same time, smallholder farmers and poorer regions struggle with outdated technologies and lack the knowledge to adapt to climate change impacts. Joint EU projects such as the Copernicus remote sensing satellites for environmental data are **severely underfunded,** resulting in the need to sell their data insights at a high cost that only a few highly successful businesses can afford. Digital oligopolisation intensifies inequalities as big agricultural and forestry businesses own AI-powered tools and knowledge, sidelining smallholders. Wealthier regions advance, while poorer areas fall further behind, **deepening the digital divide and worsening inequalities.**

There is **high pressure to increase the productivity** of agriculture and forestry to substitute foreign resource imports through a circular bioeconomy, for instance, for bioenergy generation or construction. However, global (resource) trade still plays an important role but is less reliable, as regular disruptions impact supply chains. **Short-term productivity gains take precedence over sustainability**: Digitally enhanced industrial agriculture in large agribusinesses and intensive low-tech farming by smallholder farmers lead to accelerated soil degradation, biodiversity loss and climate vulnerability. **Environmental health is suffering**, increasing the vulnerability of the arable land. On top of that, nationalist tensions discourage labour migrants from moving to other places for work, affecting seasonal work-intensive planting and harvesting phases in agriculture and forestry. Automation is only available for large farms. **Skill shortages and ageing populations** are especially straining smallholder farmers and foresters, who increasingly seek to shift to less work-intensive farm and forest production or introduce production forms where consumers contribute to work-intensive steps (like co-production in planting and harvesting).

Data-driven approaches to land use remain underutilised as **policies focus on short-term profits**. The lack of coordinated EU digital policies leads to fragmented regulations and agricultural and forestry data standards; it creates **interoperability issues**, hindering the effective deployment of digital tools. Technology integration remains inconsistent without standardised policies and cross-border cooperation, preventing a unified response to climate change and resource scarcity. Fraudulent labelling, greenwashing and illegal resource extraction are widespread.

3.3.4 The Corporate Epoch: Multinationals and the New European Order (Scenario 3)

By 2040, multinational corporations dominate Europe's governance, economy, and society. Economic growth and innovation thrive, but rising inequalities, environmental degradation, and tensions between corporations and fragmented governments persist. A few agribusinesses control agriculture and forestry, while monopolised technology deepens digital divides and limits access.

The scenario in a nutshell:

- **Monoculture and climate impacts worsen resource scarcities**, raising prices and volatility, while gatekeeping by resource-rich entities deepens inequalities.
- **Multinational corporations**, especially in tech and resources, **shape political agendas, drive innovation, and control value chains**, sidelining smaller actors.
- Europe's **economy thrives on competition**, driven by fossil-fuel-intensive multinational corporations.
- **Rising inequalities and a shrinking middle class** fuel societal divides, limiting high-tech access to elites and leaving many in precarious jobs.
- **Global warming exceeds +3°C by 2100**, triggering tipping points that devastate coastal and inland areas, causing severe resource and climate challenges.

The EU and the world in 2040:

In 2040, **Europe is driven by performance and competition**, with self-interest shaping societal values. The economy booms, driven by multinational corporations reliant on fossil fuels. These tech and resource giants dominate innovation, shape politics, and control global value chains, sidelining smaller players. Governments depend on them for data and resources, deepening inequalities.

Resource scarcities, worsened by monocultures and climate change, drive price spikes and market instability. Resource-rich entities tighten control, widening global inequalities. EU inequality grows as the middle class shrinks. **High-tech skills remain exclusive**, leaving most in precarious jobs with little upward mobility. Resistance to corporate dominance fuels social divides.

Global warming surpasses +3°C by 2100, triggering **environmental tipping points**. Coastal regions face rising seas and infrastructure collapse, while inland areas suffer desertification, droughts, and agricultural failures, deepening resource crises.

Digital agriculture and forestry in 2040:

By 2040, digital agriculture and forestry are **controlled by multinational corporations using AI and robotics to maximise profits**. These giants dominate global supply chains, sidelining small players and leaving rural workers in low-wage and unstable jobs. Tech-driven practices prioritise yields over sustainability, **causing monocultures and environmental harm.**

A small number of competing multinational corporations dominate the global bioeconomy: the agribusiness from farm to fork (up to the digital cooking device) and the wood processing industry from forest to furniture or building. They structure primary production based on an efficiency- and output-optimised approach, aligning food and wood processing

with Industry 4.0 digitalisation. Even more, the platform **defines the major rules set and governance structure for all producers, consumers, and market partners, replacing the role of public governments**. Competitors build up their own digital monopoles and walled garden platforms with digital software, hardware, and proprietary AI models optimised for internal data exchange in their business ecosystem, but high hurdles for exchange to the competitor's system.

Data flows within centralised monopolised data spaces that are owned and controlled by the dominant corporation. AI models drive resource allocation, pricing, and production decisions, as well as investments and granting of loans. Market actors must use corporate systems like trade platforms and finance exchange systems. Non-corporate **farmers and foresters remain independent but are pressured into a corporate digital ecosystem** where access to AI-powered advisory systems, robotics, and sensors depends on costly licenses or exclusive contracts. Weather and environmental remote sensing and monitoring are based on corporate satellites and digital infrastructure. **Traceability and monitoring within a digital ecosystem is high**, integrating all types of primary production data into product information, as well as consumer data such as health, income, consumption and dietary patterns into personalised marketing recommendation algorithms.

Multinational agribusinesses and agrochemical firms lead, driving industrialised farming and forestry practices that erode biodiversity and address climate effects rather than causes. Monoculture farming expands to advance AI-driven precision agriculture and logging. Nature must adapt to the machines at the cost of biodiversity loss, soil depletion and risk of ecosystem collapse. **Climate instability and ecosystem fragility** in food and forestry supply chains come with temporary food shortages and forest damage risks. The global activities of corporations allow them to balance risks by importing and exchanging resources globally, while benefiting from temporary sharp rises in market prices. **Digital agriculture and forestry have become both a geopolitical asset and a target for cyber-security threats.**

Rapid innovation driven by big corporations and tech startups deepens inequality, marginalising underserved regions and limiting equitable transformation. **Fully automated agribusinesses and forestry operations replace human labour** using AI-driven precision farming, robotic harvesting, and automated processing. A skilled elite dominates high-tech food and resource production, while low-income workers face job precarity in manual labour sectors.

Rural communities decline as **traditional farming and forestry jobs disappear**, and workers lack access to reskilling programmes controlled by corporate AI platforms. As climate change worsens, resource scarcities drive up prices and widen wealth gaps. Corporations control water, soil, and land data, sidelining small farms. Despite boosting productivity, advanced technologies harm biodiversity and soil health, fuelling social unrest and calls for less invasive, green practices.

3.3 The 4Growth Scenarios in Comparison

While the baseline scenario outlines a future driven by ongoing technological advancement and digitalisation within the existing economic and policy landscape, alternative scenarios explore how different political, economic, and societal shifts could reshape Europe's agriculture and forestry sectors. These scenarios explore the potential impacts of varying levels of international cooperation, market structures, and regulatory approaches, illustrating how diverging pathways could either accelerate or hinder digital transformation and sustainability efforts.

The following section provides an **overview of the three alternative scenarios and the baseline,** highlighting their key differences (see Table 2 for more details on the alternative scenarios[11]).

- *Reimagining Progress* envisions a **sustainability-driven future** marked by **strong multilateral collaboration** and alignment between policy, business, and society. EU-led global climate and biodiversity policies drive change while the **economy shifts to a circular model**. **Open innovation and knowledge sharing** accelerate the development and widespread adoption of sustainable technologies.
- *The Fractured Continent* depicts a **fragmented and unequal Europe**, where ineffective EU governance and national interests dominate. Economic growth varies across regions, while trade disruptions and geopolitical tensions stall globalisation. **Unequal access to technologies and divergent standards** further hinders interoperability.
- *The Corporate Epoch* depicts a **corporate-dominated Europe** where multinational corporations wield significant influence over governance and public institutions. **Technology is monopolised** within their platform ecosystems, leading to increased wealth concentration and a shrinking middle class. The global economy remains dependent on fossil fuels, driving **ongoing environmental degradation**.
- The *baseline* depicts a world of **ongoing technological advancements and digitalisation** while recognising **persistent challenges**, such as uneven economic development in Europe, that influence its development.

The **implications for agriculture and forestry** vary significantly across the scenarios:

- *Reimagining Progress* envisions **regenerative, circular agriculture and forestry**, emphasising agroecology and biodiversity restoration.
- *The Fractured Continent* follows a **market-driven approach** focused on short-term profits, with regional inequalities. Primary sectors play a key role in substituting unreliable foreign resource imports.
- *The Corporate Epoch* is dominated by **high-intensity, monoculture farming and forestry** controlled by corporations. Farms and forestry are just one element in the vast business ecosystems of agri-food, woodworking, and digital industries.

[11] Annex 5 provides further comparison tables of the framework conditions and the implications for agriculture and forestry on the alternative scenarios

- The *baseline* reflects a **continuation of the status quo**, with market concentration increasing in agriculture and, to a lesser extent, in forestry. Large businesses expand, while smallholders gradually decline.

Reimagining Progress: Europe's New Deal with the Planet (Scenario 1)	**The Fractured Continent: Europe's Splintered Circular Economy Under Pressure** (Scenario 2)	**The Corporate Epoch: Multinationals and the New European Order** (Scenario 3)
Despite significant challenges along the way, Europe in 2040 is a **global leader in sustainability, leveraging technological innovation, multilateral cooperation, and transformed consumption patterns** to **respect planetary boundaries** and **curb climate change**. The EU leverages **digital innovation and mission-driven science** to advance sustainable agri-food and forestry practices, foster biodiversity, and promote plant-based diets, supported by **open knowledge sharing and equitable access to high-tech solutions**.	Europe in 2040 is a **continent of contrasts**: innovative in pockets yet fragmented in governance and society. The **strategic transition to a circular economy shows promise but is hampered** by **resource pressures, technological failures**, and **social inequalities**. **Climate change continues to accelerate**, highlighting the urgent need for unified action - a goal that remains elusive in this **polarised and fragmented world.** Agri-forestry practices prioritise **short-term productivity over sustainability**, while **fragmented digital policies and infrastructure** exacerbate inequalities.	In 2040, the European corporate epoch has already more or less established - defined by the **dominance of multinational corporations** that shape governance, economies, and societies. While **rapid economic growth and technological innovation** flourish, they come at the **cost of rising inequalities, environmental degradation, and increasing tensions** between corporate powers and fragmented governmental resistance. Agriculture and forestry are **heavily industrialised and controlled by a few global agribusinesses**, while **monopolised technology** exacerbates digital divides, limiting equitable access and innovation.
Key features of the EU in 2040: • **Respectful of Planetary Boundaries and Policy Evolution** • **Increasingly Sustainable Economy and Consumption** • **Resource Scarcity and Energy Transformation** • **Strong Global Governance and Diplomacy** • **Climate Change Mitigated, Warming Kept around 2°** Agri-forestry and digitisation specific features in 2040: • **High-Tech Innovation and Knowledge Sharing** • **EU World-Leading in Sustainable Agri-Food & Forestry**	Key features of the EU in 2040: • **Increased Nationalism and Resource Insecurity** • **Fragmented European Governance** • **Uneven Circular Economy Transition** • **Increasing Social Inequalities and Polarisation** • **Accelerating Climate Crisis and Environmental Degradation** Agri-forestry and digitisation specific features in 2040: • **Unsustainable Agri-Forestry Practices** • **Fragmented Digital Policies and Infrastructure and Interoperability Challenges**	Key features of the EU in 2040: • **Highly Individualistic Society and Competitive Economic Growth** • **Corporate Dominance in Governance** • **Exacerbated Resource Scarcity and Price Volatility** • **Social Fragmentation and Polarization** • **Escalating Climate Crisis** Agri-forestry and digitisation specific features in 2040: • **Heavily Industrialised Agriculture and Forestry in the Hand of Some Giants** • **Monopolised Technologies**

Table 2. Overview of the three alternative scenarios (Source: Future Impacts).

The **adoption of digital technologies** varies across scenarios (see Table 3):

- *Reimagining Progress* sees **widespread adoption** of AI, IoT, blockchain, and precision farming with robotics and sensing, **supported by open-access data spaces for knowledge sharing**.
- *The Fractured Continent* experiences **uneven adoption** due to regional disparities, limited infrastructure, national data silos, and **lack of interoperability**.
- *The Corporate Epoch* is **dominated** by proprietary AI, robotics, and automation controlled by agribusiness giants, with **corporate data spaces restricting farm and forest data access**.
- *The baseline* assumes **continuous digitalisation in agriculture and forestry**, driven by startups, agritech firms, and public funding. However, concerns over data privacy, regulatory hurdles, and infrastructure limitations **restrict widespread data sharing**.

While Table 2 outlines each scenario's core ideas, Table 3 examines the impact of digital tool adoption. The baseline scenario falls between the three alternatives and is not included in these tables of the first draft version.

Alternative Scenarios	Reimagining Progress	The Fractured Continent	The Corporate Epoch
Digital Technology Adoption	Widespread adoption of AI, IoT, blockchain, shared open-source platforms	Unequal adoption—some regions invest in smart farming/forestry, others lag	Advanced proprietary AI, robotics, automation, controlled by agribusiness giants
Data Governance	Open-access agricultural data, EU-led standards for sustainability monitoring	Fragmented policies, national data silos, lack of interoperability	Corporations own and control farm/forestry data, and platforms restricting access
Automation & Robotics	Precision farming with AI-driven automation, autonomous machinery	Adoption limited by economic divides; larger farms/forests integrate robotics first	Highly automated farms & forests, but small players lack access to technologies
Sensing and Monitoring	Real-time soil, water, disease & pest, and biodiversity monitoring, EU-mandated sustainability reporting	Limited adoption, uneven access to sensing technologies	Corporate-owned monitoring systems, used for productivity gains
Decision Support	AI-driven climate adaptation tools, digital twins for ecosystem simulation	Uneven access to AI-driven decision tools, wealthier regions benefit first	AI-driven high-yield optimisation, focused on maximising corporate profits
Access to Digital Infrastructure	Universal broadband, public-private partnerships for rural connectivity	Rural connectivity gaps persist, deepening tech divides, gaps in interoperability	High-tech concentration in corporate digital monopoles and walled gardens, low level of interoperability between competing systems

Table 3. Comparison of implications for the use of digital solutions in agriculture and forestry (Source: Future Impacts).

4. Outlook on Next Steps

This **draft report presents the scenarios developed so far** (as of March 2025). In the upcoming steps, the **scenarios will be developed further by incorporating emerging signals and trends from the horizon scanning and new insights** from other 4Growth findings (4Growth Deliverable D3.6). In addition, the **analysis of implications for digital agriculture and forestry** will be deepened and enhanced.

The current set of the scenarios is also forming the basis **for integrating alternative development trajectories into the Market Monitoring and Forecast Tool** (MMFT, 4Growth Task 3.1). The MMFT will identify key variables within each scenario that impact the assumptions and parameters used to estimate the uptake of digital technologies in the agriculture and forestry sectors. Based on this analysis, Future Impacts will continue to work with LE Europe to connect the qualitative insights developed here with the quantitative elements within the MMFT. This will form the basis of the MMFT's forecasts and will **provide a rough numerical illustration of market developments under plausible but disruptive scenarios.**

Comparing the baseline with alternative more disruptive trajectories helps to **outline the range of potential future developments.** Thus, this set of scenarios serve as a **strategic tool to assess how different framework conditions shape the uptake of digital and data-driven solutions** in these sectors. By analysing alternative futures, the scenarios clarify the **fundamental requirements for the adoption of digital technologies** and data infrastructure **under varying conditions**, supporting **anticipatory policymaking** in digital, agricultural, forestry, and bioeconomy policies. Therefore, **policy recommendations** will be identified to guide developments in a preferred direction (linking to 4Growth Task 4.5). The final scenario report is scheduled for delivery in September 2026.

Figure 2 illustrates the process applied in the 4Growth foresight module and positions this report in the context of upcoming foresight steps.

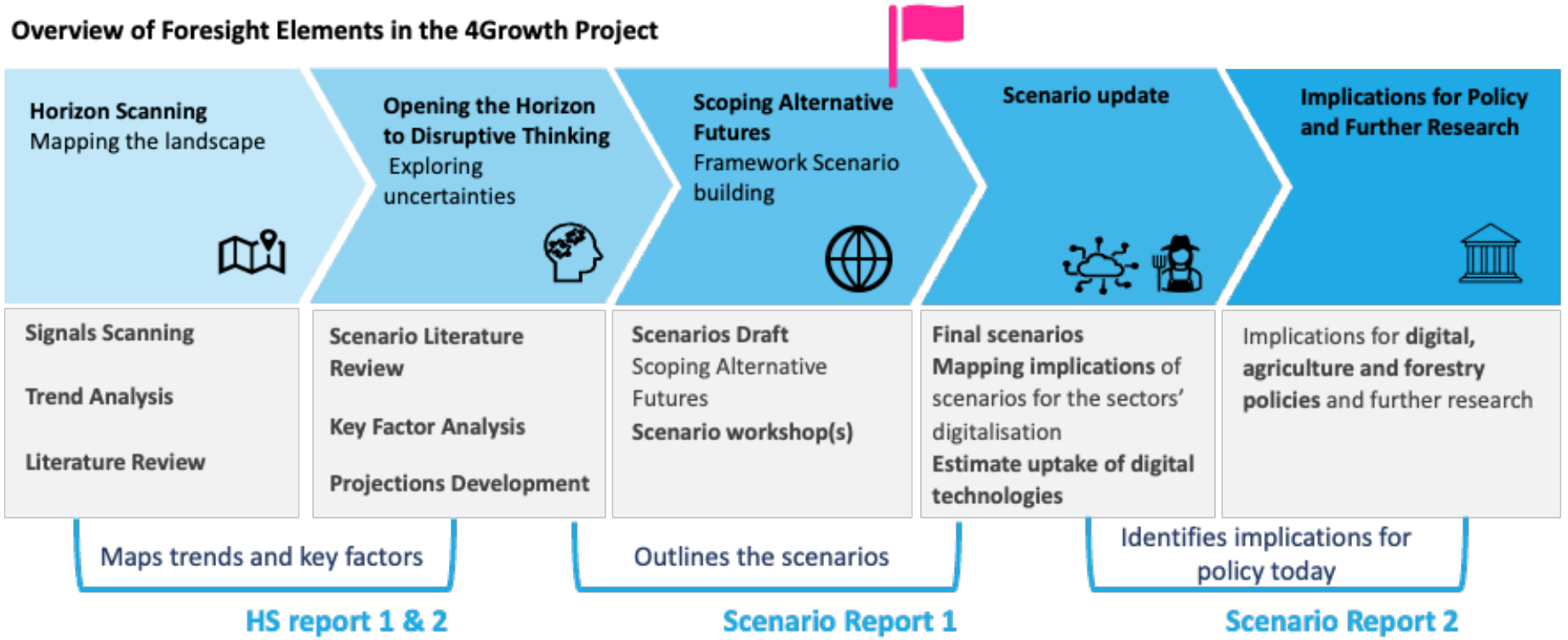

Figure 2: Process logic of the 4Growth Foresight Module (Source: Future Impacts).

Annexes

Annex 1: Key Factors

Key factors, highly influential contextual determinants that shape the future of digitalisation in agriculture and forestry, are the main descriptors of the scenario field. Derived from a **STEEP** (Society, Technology, Economy, Environment, Policy) perspective, they move from a broad global view to sector-specific insights. Table 4 lists the ten key factors with a high degree of uncertainty in their evolution up to 2040, their scope, and the corresponding STEEP category.

Key factor title	Scope	STEEP
Shifting societal values and behavioural change	Societal values cover the overarching mindsets regarding political orientation (e.g., conservative vs. progressive), individual value preferences, and societal shifts (e.g., self-centred vs. community-oriented). Values and mindsets shape consumption behaviour to a certain extent (e.g., caring about aspects like price, brand values, quality, and sustainability).	Society
Economic developments in Europe and international trade	This factor covers developments of the economy in Europe, transformation in the EU economy, and international trade relationships	Economy
Changes in resource availability and prices	The factor covers the availability and prices of resources in Europe and globally. Resources include bioeconomy materials (food, feed, wood products), energy, and other raw materials. The availability and costs of land for agriculture and forestry are further addressed.	Economy / Environment
Geopolitical developments	The factor covers the functioning and institutional setup of global governance and multilateralism. It includes tensions, geopolitical power playing between countries and blocks, and related security issues.	Policy
Climate and environmental policies	This factor covers the ambitions on climate and environmental policies of the European Union and its Member States as well as the international situation of other nations and blocks. Relevant topics include energy system transformation and biodiversity.	Policy / Environment
EU policies and institutional setup of the EU	The role and direction of EU policies and institutions are related to the multilateral global level as well as the national level of the EU's Member States. It entails policy priorities, the degree of coherence of policies across different domains, and the coordination of EU policies at the national and international levels. It further covers the question of EU enlargement.	Policy
Technological progress and	Innovation rate and diffusion of new technologies in Europe, the role of public and private investments in	Technology

advancements in digitalisation	research and developments, advancements in digitalisation and AI, and provision of new solutions that have possible spill-over effects for agriculture and forestry sectors.	
Shifting inequalities	Access to wealth, income, education and skills acquisition as a precondition for working in good jobs.	Society
Climate change impacts	Degree of long-term climate warming expectations, concrete climate impacts on extreme events and effects on infrastructure, arable land, agriculture and forestry. Societal reactions in terms of mitigation and adaptation measures, like behaviour change, energy system transition, etc.	Environment
Digital policies and infrastructure	The direction and type of digital policies, advancements in spatial distribution and quality of digital physical and software-based infrastructures, and the ownership and controlling power of data.	Technology / Policy

Table 4. Key factor list
(Source: Future Impacts.)

An additional key factor with relatively low uncertainty until 2040 is **demographic development, which is treated** as a "given" with a single future projection.

Givens title	Scope	
Demographic development	Growth of the EU's and the global population. Ageing, share of working age population and related workforce gap. Urbanisation	Society

Table 5. List of givens (important key factor with low uncertainty)
(Source: Future Impacts).

The key factor projections outline alternative developments in Europe and globally by 2040. The morphological box (Figure 2) presents the 10 key factors alongside their potential future development projections for 2040. The lines indicate plausible combinations used to construct the three scenarios, ensuring plausibility and consistency in their development.

Figure 3. Morphological box of key factors, alternative projections for the year 2040 and consistent scenario combinations
(Source: Future Impacts).

Annex 2: Horizon Scanning Insights Underlying the Scenarios

Insights from the ongoing **horizon scanning** process were integrated into the scenario development. Table 6 outlines the trends and signals informing each alternative framework scenario (see Störmer et al. for details on the respective trends and signals).

Alternative Framework Scenario	Underlying trends and signals as identified in 4Growth horizon scanning (short trend and signal title)
Reimagining Progress: Europe's New Deal with the Planet	**Post-war, enlarged EU:** Post-war rebuilding of Ukraine's agriculture and forestry sector / EU enlargement to redefine Common Agricultural Policy **Biodiversity loss:** Farmers could grow a larger variety of crops on their land, supporting biodiversity **Bio-nanotech:** Cultivation of climate adaptive plants, animals / Bio-sensor technologies for real-time understanding of local environment / Novel nanomaterials revolutionise fertilisers **Technology solutions to deal with climate stress:** Geoengineering: carbon storage **Controlled environments:** Controlled environment production of alternative proteins / Algae as a resource **Digital data management and spaces:** On-farm data spaces for decision-making / Data spaces for policymaking and reduction of bureaucratic burden **Consumer demand:** Healthy, organic, home-cooked food trending on social media / Nutrition labelling
The Fractured Continent: Europe's Splintered Circular Economy Under Pressure	**Glocalisation:** Export limitations / Europe's wood import independence / Fertiliser dependency **Biodiversity loss**: China's ties to foreign agricultural land affecting biodiversity **Cybersecurity issues:** Espionage enabling equipment / Cyber-attacks on food processing / Connectivity risks due to reliance on single networks and providers **Technology solutions to deal with climate stress:** Microclimate management / Leaps in low energy consuming water desalination **Consumer demand:** Food supply chain management startups
The Corporate Epoch: Multinationals and the New European Order	**Biodiversity loss:** Spoonbill population threatened by agricultural activity **Bio-nanotech:** Cultivation of climate adaptive plants, animals / Bio-sensor technologies for real-time understanding of local environment / Novel nanomaterials revolutionise fertilisers **Controlled environments**: Giant vertical farm project / Controlled environment production of alternative proteins **Digital data management and spaces:** Corporate companies driving data spaces **Market power shifts:** Concentrated agribusiness sector / Vertically integrated forest companies / Increasing influence of food companies and fossil fuel energy companies through carbon markets

Table 6. Horizon scanning trends (bold text) and signals used in the scenario generation (Source: Future Impacts; trends and signals refer to content in Störmer et al., 2024).

Annex 3: Foresight Literature Review Informing the 4Growth Framework Scenarios

The alternative framework scenarios are informed by a **systematic literature review** of existing scenarios relevant to future digitalisation in agriculture and forestry. Using a **criteria-led approach**, key foresight scenario publications were identified to incorporate relevant insights from previous research.

This set of relevant existing scenarios addresses agriculture, the agri-food sector, forestry, and the bioeconomy at both European and global levels. In the initial phase of this draft review, scenario studies focused on **framework development** were considered[12]. The **core assumptions** from previous scenario research – alongside horizon scanning insights and additional research – were analysed to develop the **4Growth key factor projections and scenario cores**. The in-depth review included the following publications:

- EU-AGRI-SSPs: Shared Socioeconomic pathways for European agriculture (2020, Europe focus, agriculture, looking into 2050) (Mitter et al., 2020)
- IPCC: IPCC's Shared Socioeconomic Pathway scenarios for climate change (2017, global focus, looking into 2100) (Riahi et al., 2016; IPCC, 2023)
- IUFRO: International Union of Forest Research Organizations (IUFRO) 3 forest scenarios (2024, Europe focus, forestry, looking into 2050) (Eggers et al., 2024)
- JRC Farmers / Ref Scenarios: JRC transformative Futures for farmers and rural communities scenarios (2023, Europe focus, agriculture and rural areas, looking into 2040 - based on overarching JRC Foresight Reference Scenarios) (Barabanova and Krzysztofowicz, 2023; and Vesnic-Alujevic et al., 2023)
- STOA PA: STOA Precision agriculture and the future of farming in Europe, explorative scenarios (2016, Europe focus, agriculture, looking into 2050) (Van Woensel et al., 2016)
- JRC Bioeconomy: JRC Bioeconomy scenarios (2021, Europe focus, bioeconomy, looking into 2050) (Fritsche et al., 2021)
- ISI Fox: Food sector scenarios (2020, Europe focus, agri-food, looking into 2035) (Moller et al., 2020)
- FAO FOFA: FOA, Future of food and agriculture FOFA (2022, global focus, agri-food, looking at 2050-2080) (FAO, 2022)

Table 7 highlights the scenario studies from the literature review that contributed relevant insights to the development of each 4Growth scenario.

[12] There are further specific digital agriculture scenarios available, such as Ehlers et al., 2021, Alexandra-Stefanova et al., 2023, Flemming et al., 2021, Doenitz et al., 2020, Wepner et al., 2025, Sorvali et al., 2024, Krzysztofowicz et al., 2020. They were not integrated into the in-depth analysis at this stage, as they did not focus on context developments and framework key factors but mainly on the sector's internal requirements and logic for the uptake of digital solutions. They will be taken up in the next phase when deepening insight into digital agriculture and forestry.

Alternative Framework Scenario	Insights from the scenario studies literature review informing the 4growth alternative framework scenarios
Reimagining Progress: Europe's New Deal with the Planet	**IPCC:** SSP 1 (scenario SSP 1-2.6); **IUFRO:** Environmental sustainability first (scenario 1); **EU-AGRI-SSPs:** Agriculture on sustainable path (scenario 1); **JRC Bioeconomy:** Do it together (scenario 2); **STOA PA**: Global sustainable development (scenario 2); **J** **JRC Farmers / Ref Scenarios:** Reclaiming digital sovereignty / struggling synergies (scenario 3); **FAO FOFA:** Trading off for sustainability (TOS); **ISI Fox:** Policy secures sustainability (scenario 1)
The Fractured Continent: Europe's Splintered Circular Economy Under Pressure	**IPCC:** SSP 3 (scenario SSP 3-6.0); **IUFRO:** Bioeconomy in a divided world (scenario 2); **EU-AGRI-SSPs:** Agriculture on separated paths (scenario 3); **JRC Bioeconomy:** only in parts related to: Do it ourselves (scenario 3); **STOA PA**: Regional competition (scenario 3); **JRC Farmers / Ref Scenarios (JRC DA-RS):** Resilient roots to withstand the shocks / opposing views (scenario 4); **FAO FOFA:** Adjusted future (AFU); **ISI Fox:** no suitable scenario
The Corporate Epoch: Multinationals and the New European Order	**IPCC:** SSP 5 (scenario SSP 5-6.0); **IUFRO:** Fossil economy first (scenario 3); **EU-AGRI-SSPs:** Agriculture on High-tech path (scenario 5); **JRC Bioeconomy:** only in parts related to: Do what is unavoidable (scenario 4); **STOA PA**: Economic growth (scenario 1); **JRC Farmers / Ref Scenarios (JRC DA-RS):** Navigating storms / storms (scenario 1); **FAO FOFA:** tendentially going towards Race to the bottom (RAB); **ISI Fox:** no suitable scenario

Table 7. Insights from the scenario studies literature review that informed the 4Growth scenarios (Source: Future Impacts).

Annex 4: The Baseline Scenario in Detail

This section is provided by Rasmus Flytkjaer, Ellesha Dunn and colleagues from LE Europe based on their findings from Task 3.1. The details refer to the baseline described in an overview in section 3.2, scenario 0: baseline.

Purpose of this section:

To contribute to Task 3.2 – Foresight module, LE Europe has developed a baseline scenario in collaboration with Future Impacts that draws on the development trajectories of the uptake of technologies in the agriculture & forestry sectors in Europe and the rest of the world.

General market characteristics:

Various factors, such as economic development, globalisation, geopolitical climate, technological advancements, climate change and consumption habits influence the integration of digital technologies in agriculture & forestry. To forecast the future uptake of digital technologies in both sectors, the Market Monitoring and Forecast Tool (MMFT) includes various assumptions that shape the core development of the baseline scenario in the future to 2040.

Baseline scenario for agriculture & forestry:

The global population is forecast to grow to 9.2bn by 2040 (13% relative to 2025), but the amount of utilised agricultural area is expected to shrink in Europe, so will not match this growth rate. Therefore, farmers globally will need to improve efficiency and ensure a greater output with the same resources. The forestry sector, too, faces increased demand for more sustainable construction methods (using wood). Moreover, biodiversity is on the agenda, and it requires that areas of silviculture be converted to untouched nature. Individually, both sectors need to produce more efficiently against a backdrop of shrinking areas of productive land.

Digitalisation in agriculture and forestry continues to develop, marked by the integration of AI, remote sensing, IoT, and automation to optimise resource use, improve decision-making, and ensure long-term sustainability. In agriculture, digital solutions such as precision farming, AI-driven analytics, and GNSS-enabled systems are helping farmers navigate declining farm incomes, shifting consumption habits, and growing food security concerns. However, demographic shifts, particularly the ageing farming population, present challenges in technology adoption, requiring targeted training and incentives to bridge the generational gap.

Similarly, in forestry, digital twin technologies, satellite imaging, and real-time analytics are enhancing forest monitoring, optimising harvesting, and improving carbon sequestration. Despite regional disparities in investment and regulatory adaptation, digitalisation is becoming essential in both sectors for improving efficiency, ensuring compliance with environmental policies, and enhancing resilience. As economic and geopolitical factors continue to shape global trade and supply chains, digital tools will play a critical role in ensuring food and resource security while promoting sustainable land and forest management practices.

Detailed variables for the baseline scenario:

- **Economic development**: the global economy continues to follow a moderate growth trajectory, with Europe experiencing steady but uneven economic development. While some regions benefit from increased investment in digital agriculture and forestry, others lag due to financial constraints and slower policy adaptation. The EU continues to promote

the digitalisation of these sectors. Emerging markets in Asia, Africa, and Latin America see rapid adoption of digital technologies due to lower entry costs and leapfrogging of traditional methods. The economic viability of digital technologies is increasingly recognised, which is driving more targeted investments and subsidies.

- **Globalisation:** trade and international cooperation remain key drivers of digital technology adoption. The agriculture and forestry sectors are increasingly interconnected, with multinational companies investing in digital solutions to optimise supply chains. Regional disparities still exist due to expected geopolitical tensions, which continue to create sticky technology dissemination in regions outside of Europe. Global trade policies significantly impact the adoption of digital technologies in agriculture and forestry.

- **Supply chain dependencies (imports/exports):** Europe will continue to rely on imports for certain key agricultural inputs, but investments in automation and precision agriculture help mitigate some risks. Forestry supply chains also integrate digital monitoring systems to track deforestation and sustainable sourcing.

- **Climate action:** Governments and industries increase their commitments to climate targets, pushing for sustainable and digitalised farming and forestry practices, as climate change worsens. Precision agriculture and smart forestry management systems gain traction to optimise resource use and reduce emissions as a result. Policy incentives drive the adoption of climate-smart technologies, while carbon pricing mechanisms encourage the integration of AI-driven analytics for carbon sequestration and biodiversity monitoring. However, adoption rates vary based on regional regulatory frameworks and access to funding**.**

- **Technology developments (R&D):** Research and development in digital agriculture and forestry continue to accelerate, driven by public and private sector investments. AI, robotics, satellite imaging, and sensor technologies become increasingly sophisticated, allowing real-time monitoring and automated decision-making (for example digital twin-like technologies and mass integration). Startups and Agri-tech firms play a crucial role in bringing innovation to market but continue to need funding from public institutions. However, regulatory hurdles, data privacy concerns, and infrastructure limitations pose challenges to widespread adoption.

- **Land grabbing** (IPES-Food, 2024): The number of small farms declines due to consolidation, while large-scale farms leverage digital efficiency solutions. In developing regions, digital tools enable smallholders to increase productivity, though access to technology remains uneven. Land-use conflicts and competing demands for agricultural and forestry land could increase. Land inequality continues to increase as a result, and the extent of land concentration and the pace of change varies considerably between regions.
- **Food security:** Digital technologies play a crucial role in enhancing food security by improving yield predictions, reducing food waste, and optimising supply chains. However, land grabbing and farm consolidation are reducing the number of smallholder farmers, raising concerns about equitable access to food production and distribution. At the same time, a rising global population is increasing the demand for food, while land scarcity limits agricultural expansion. This makes the efficient use of available land critical, driving the need for digital solutions to maximise, and ensure food security.

- **Consumption/nutrition habits/building and constructing materials** (PWC, 2024): Consumer demand for sustainably sourced products is influencing agricultural and forestry practices. Digital traceability solutions, including blockchain technology, are being implemented to provide transparency regarding the origins and sustainability of food and materials. This shift is driven by consumers' increasing awareness and desire for products that align with environmental and ethical standards.

- **Energy sector using bioenergy** (FarmtoFuel, 2025)**:** The transition to bioenergy is gaining momentum, with digital technologies optimising biomass supply chains. By enhancing the efficiency of bioenergy production and distribution, these technologies contribute to the broader goal of sustainable energy solutions. The EU's policies and funding programmes support the integration of bioenergy into the energy sector, promoting research and innovation in this field.

- **Demographics and the ageing farming population:** The average age of farmers is increasing, particularly in regions such as Europe (European Commission, 2017), North America (USDA, 2023), and parts of Asia (World Bank, 2018). The adoption of technologies depends on digital literacy, access to funding, and government incentives. While younger generations are generally more open to using advanced tools like AI, robotics, and data analytics, bridging the gap remains a challenge. In some regions, targeted training programmes and subsidies aim to facilitate the transition.

- **Resource scarcity:** Resource scarcity – particularly in water, arable land and forestry products – continues to play a role in sustainable agriculture and forestry management. Water-efficient irrigation systems, AI-driven soil monitoring, and automated pest control reduce input waste and increase resilience. In forestry, remote sensing and big data analytics help prevent illegal logging and optimise sustainable wood harvesting.

Annex 5: Alternative Scenarios in Comparison

The following tables offer a **structured comparison** of key differences among the **three alternative scenarios**:

- Table 8 outlines the **framework conditions** shaping Europe's future.
- Table 9 interprets these framework **implications for the agriculture and forestry sectors**.

The tables were co-produced using the generative AI tool ChatGPT, then reviewed, edited and enriched for accuracy and depth by a researcher from the project team.

Alternative Scenarios	Reimagining Progress: Europe's New Deal with the Planet	The Fractured Continent: Europe's Splintered Circular Economy Under Pressure	The Corporate Epoch: Multinationals and the New European Order
Key idea	Sustainability-Driven Europe	Fragmented & Unequal Europe	Corporate-Dominated Europe
Governance	Strong multilateralism, EU-led global sustainability policies, Green Deal	Weak EU governance, national agendas prevail, policy fragmentation	Corporations dominate governance, sidelining public institutions
Economic Model	Circular economy, resource efficiency, green innovation, balanced trade – sustainable trade	Unequal economic growth, some regions thrive, others struggle, trade disruptions - protectionism	Competitive economy driven by multinational corporations (MNCs), fossil-fuel reliance, MNCs control value and supply chains
Social Equity	Inclusive policies, high investment in education and reskilling, low inequality	Widening wealth gap, education and technology access restricted to wealthy	Extreme inequality, shrinking middle class, concentration of wealth
Innovation and Tech	Open knowledge sharing, public-private collaboration in R&D, sustainable technology	Uneven access to technology, innovation hindered by financial barriers	Tech monopolisation, innovation controlled by MNCs, limited public access
Environmental Policies and Action	Strict sustainability policies, carbon neutrality, biodiversity restoration	Climate action stalled by political conflicts, fragmented implementation	Environmental degradation, greenwashing by corporations
Climate Outlook	Near net-zero emissions, warming stays close to **+2°C**, ecosystems slightly recovering	Global warming exceeds by far **+2°C**, extreme weather disrupts ecosystems & infrastructure	Warming exceeds **+3°C**, tipping points triggered, rising seas & desertification
Energy and Resources	Green energy dominates, circular economy reduces resource needs	Uneven green transition, resource security policies drive competition	Fossil fuel dependence, resource extraction controlled by private entities
Resilience and Adaptability	Strong institutional resilience, and climate adaptation policies in place	Weak institutional coordination, crisis responses delayed	High-tech corporate resilience, but broader society left vulnerable
Power and Influence	Policymakers, industries, and society collaborate for sustainability	Power concentrated in national governments, regional disparities in influence	Multinational corporations set global agendas, and governments depend on them

Table 8. Comparison of the three alternative scenarios (Source: Future Impacts).

Alternative Scenarios	Reimagining Progress: Europe's New Deal with the Planet	The Fractured Continent: Europe's Splintered Circular Economy Under Pressure	The Corporate Epoch: Multinationals and the New European Order
Agriculture Model	Regenerative, circular agriculture, agroecology, biodiversity restoration	Market-driven with short-term profit focus, disparities between regions, different levels of circular bioeconomy	Monoculture-dominated, high-intensity farming, corporate-controlled
Forestry Model	Climate-smart forestry, afforestation, ecosystem restoration	Fragmented forestry policies, unsustainable logging in some regions	Industrial forestry, optimised for profit, biodiversity loss
Market Structure	Decentralised, cooperative networks, support for small & medium farms, forestry	Polarised market—some regions support local producers, others rely on imports	Agribusiness monopolies dominate, small farmers struggle or disappear
Supply Chains	Transparent, blockchain-tracked, circular economy models	Unreliable supply chains due to trade wars, disrupted global sourcing, partly circular bioeconomy	Hyper-efficient, corporate-controlled global supply chains, opaque pricing
Economic and Social Inclusion	Farmers and foresters benefit from fair-trade models, digital co-ops	Widening gaps—large farms thrive, small producers struggle	Farmers are dependent on corporate platforms, limited bargaining power
Climate Resilience	Focus on carbon farming, soil regeneration, ecosystem services	Climate adaptation fragmented, limited incentives for sustainable practices	Yield maximisation over resilience, monocultures more vulnerable to extreme weather
Digital Technology Adoption	Widespread adoption of AI, IoT, blockchain, shared open-source platforms	Unequal adoption—some regions invest in smart farming / forestry, others lag	Advanced proprietary AI, robotics, automation, controlled by agribusiness giants

Table 9. Comparison of implications for agriculture and forestry (Source: Future Impacts).

References

Alexandrova-Stefanova, N., Nosarzewski, K., Mroczek, Z.K., Audouin, S., Djamen, P., Kolos, N. ans Wan, J. (2023). Harvesting change: Harnessing emerging technologies and innovations for agri-food system transformation – Global foresight synthesis report. Rome. FAO and Cirad. https://doi.org/10.4060/cc8498en

Barabanova, Y. and Krzysztofowicz, M. (2023). Digital Transition: Long-term Implications for EU Farmers and Rural Communities. doi:10.2760/093463

Bishop, P. C. (2017). Baseline analysis: The epistemology of scenario support. World Futures Review, 9(2), 83–92. https://doi.org/10.1177/1946756717705962

Bressan, S., Nygård, H.M. and Seefeldt, D. (2020). Forecasting and foresight. EU-LISTCO Working Paper Series 2. https://refubium.fu-berlin.de/bitstream/handle/fub188/26356/EU-LISTCO%2bWorking%2bPaper%2b2%2b-%2bForecasting%2band%2bForesight.pdf

Daheim, C. (2023). Mutual learning exercise: R&I foresight: an introduction to the current state of play: thematic report, European Commission: Directorate-General for Research and Innovation & Publications Office of the European Union. https://data.europa.eu/doi/10.2777/528500

Doenitz, E., Voglhuber-Slavinsky, A. and Moller, B. (2020). Agribusiness 2035 – Future of farmers. https://publica-rest.fraunhofer.de/server/api/core/bitstreams/8e134e86-d39b-4f73-a982-347a9f1a4c5d

Egger, C., Grima, N., Kleine, M and Maja Radosavljevic (eds.). (2024). Europe's wood supply in disruptive times. An evidence-based synthesis report. IUFRO World Series Volume 42. URL: https://www.iufro.org/publications/world-series-vol-42-europes-wood-supply-in-disruptive-times

Ehlers, M., Finger, R., Benni, N. E., Gocht, A., Sørensen, C. a. G., Gusset, M., Pfeifer, C., Poppe, K., Regan, Á., Rose, D. C., Wolfert, S., and Huber, R. (2021). Scenarios for European agricultural policymaking in the era of digitalisation. Agricultural Systems, 196, 103318. https://doi.org/10.1016/j.agsy.2021.103318

European Commission. (2017). Young farmers in the EU – structural and economic characteristics. https://agriculture.ec.europa.eu/system/files/2019-11/agri-farm-economics-brief-15_en_0.pdf

FAO. (2022). The future of food and agriculture – Drivers and triggers for transformation. https://doi.org/10.4060/cc0959en

FarmtoFuel. (2025). Steady And Secure Supply Of Biomass From Vietnam. https://farmtofuel.eu/

Fisher, G., Wisneski, J. E., and Bakker, R. M. (2020). STEEP. In Oxford University Press eBooks (pp. 36–45). https://doi.org/10.1093/oso/9780190081478.003.0006

Fleming, A., Jakku, E., Fielke, S., Taylor, B. M., Lacey, J., Terhorst, A., and Stitzlein, C. (2021). Foresighting Australian digital agricultural futures: Applying responsible innovation thinking to anticipate research and development impact under different scenarios. Agricultural Systems, 190, 103120. https://doi.org/10.1016/j.agsy.2021.103120

Fritsche, U., Brunori, G., Chiaramonti, D., Galanakis, C., Matthews, R. and Panoutsou, C. (2021). Future transitions for the Bioeconomy towards Sustainable Development and a

Climate-Neutral Economy - Foresight Scenarios for the EU bioeconomy in 2050. Borzacchiello, M.T., Stoermer, E. and Avraamides, M. editor(s). doi:10.2760/469550

Galvin, B. (2025). The role of foresight in public policy: lessons from deliberative democracy and perspectival realism. European Journal of Futures Research, 13(1). https://doi.org/10.1186/s40309-024-00246-0

Gausemeier, J., Fink, A., and Schlake, O. (1998). Scenario management. Technological Forecasting and Social Change, 59(2), 111–130. https://doi.org/10.1016/s0040-1625(97)00166-2

Hirsch, S., Burggraf, P., and Daheim, C. (2013). Scenario planning with integrated quantification – managing uncertainty in corporate strategy building. Foresight, 15(5), 363–374. https://doi.org/10.1108/fs-09-2012-0064

Hobday, A. J., Boschetti, F., Moeseneder, C., Stephenson, R. L., Bessey, C., Bulman, C. M., Contardo, S., Cvitanovic, C., Dambacher, J. M., Dutra, L. X., Fulton, E. A., Lenton, A., Little, L. R., Mapstone, B., McDonald, K. S., Plagányi, E. E., Pethybridge, H., Rothlisberg, P., Strzelecki, J., . . . Van Putten, I. (2020). Quantitative foresighting as a means of improving anticipatory scientific capacity and strategic planning. One Earth, 3(5), 631–644. https://doi.org/10.1016/j.oneear.2020.10.015

Inayatullah, S. (2023). The Futures Triangle: Origins and iterations. World Futures Review, 15(2–4), 112–121. https://doi.org/10.1177/19467567231203162

IPCC. (2023). *Climate Change 2023: Synthesis report* (Core Writing Team, H. Lee, & J. Romero, Eds.; pp. 35–115). https://doi.org/10.59327/IPCC/AR6-9789291691647

IPES-Food. (2024). Land squeeze. https://ipes-food.org/wp-content/uploads/2024/05/LandSqueeze.pdf

Kosow, H and Gaßner, R. (2008). Methods of future and scenario analysis. https://www.researchgate.net/publication/258510126_Methods_of_Future_and_Scenario_Analysis_Overview_Assessment_and_Selection_Criteria

Krzysztofowicz, M., Rudkin, J., Winthagen, V. and Bock, A. (2020). Farmers of the future, doi:10.2760/5237

Marthaler, F., Gesk, J. W., Siebe, A., and Albers, A. (2020). An explorative approach to deriving future scenarios: A first comparison of the consistency matrix-based and the catalog-based approach to generating future scenarios. Procedia CIRP, 91, 883–892. https://doi.org/10.1016/j.procir.2020.02.245

Mitter, H., Techen, A., Sinabell, F., Helming, K., Schmid, E., Bodirsky, B. L., Holman, I., Kok, K., Lehtonen, H., Leip, A., Mouël, C. L., Mathijs, E., Mehdi, B., Mittenzwei, K., Mora, O., Øistad, K., Øygarden, L., Priess, J. A., Reidsma, P., . . . Schönhart, M. (2020). Shared Socioeconomic Pathways for European agriculture and food systems: The Eur-Agri-SSPs. *Global Environmental Change*, *65*, 102159. https://doi.org/10.1016/j.gloenvcha.2020.102159

Moller, B., Voglhuber-Slavinsky, A., and Dönitz, E. (2020). Three scenarios for Europe's food sector in 2035. URL: https://www.fox-foodprocessinginabox.eu/brochure-three-scenarios-for-europes-food-sector-in-2035/

Monteiro, B. and R. Dal Borgo. (2023). Supporting decision making with strategic foresight: An emerging framework for proactive and prospective governments. OECD Working Papers on Public Governance, No. 63, https://doi.org/10.1787/1d78c791-en

Muench, S., Stoermer, E., Jensen, K., Asikainen, T., Salvi, M. and Scapolo, F. 2022. Towards a green and digital future. https://data.europa.eu/doi/10.2760/977331

OECD. (2024). Global Trends in Government Innovation 2024: Fostering Human-Centred Public Services.OECD Public Governance Reviews. https://doi.org/10.1787/c1bc19c3-en

Peterson, G. D., Cumming, G. S., and Carpenter, S. R. (2003). Scenario Planning: a Tool for Conservation in an Uncertain World. Conservation Biology, 17(2), 358–366. https://doi.org/10.1046/j.1523-1739.2003.01491.x

PWC. (2024). Consumers willing to pay 9.7% sustainability premium, even as cost-of-living and inflationary concerns weigh: PwC 2024 Voice of the Consumer Survey. https://www.pwc.com/gx/en/news-room/press-releases/2024/pwc-2024-voice-of-consumer-survey.html

Reynolds-Cuéllar, P., and Salazar-Gómez, A. F. (2023). Nature-Robot interaction. *HRI '23: Companion of the 2023 ACM/IEEE International Conference on Human-Robot Interaction*, 30–39. https://doi.org/10.1145/3568294.3580034

Riahi, K., Van Vuuren, D. P., Kriegler, E., Edmonds, J., O'Neill, B. C., Fujimori, S., Bauer, N., Calvin, K., Dellink, R., Fricko, O., Lutz, W., Popp, A., Cuaresma, J. C., Kc, S., Leimbach, M., Jiang, L., Kram, T., Rao, S., Emmerling, J., . . . Tavoni, M. (2016). The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview. *Global Environmental Change*, *42*, 153–168. https://doi.org/10.1016/j.gloenvcha.2016.05.009

Sorvali, J., Varho, V., Rikkonen, P., Kaseva, J., and Peltonen-Sainio, P. (2024). Farmers' futures: an application of the Delphi method in the context of Finnish agriculture. European Journal of Futures Research, 12(1). https://doi.org/10.1186/s40309-023-00224-y

Störmer, E., Daheim, C., Jöster-Morisse, C., Prendergast, J. and Bunte, F. (2024). 4Growth Deliverable D3.5 Future of Digital Agriculture and Forestry – Horizon Scanning Report (first report. (Under review, forthcoming)

Tõnurist, P. and Hanson, A. (2020). Anticipatory innovation governance: Shaping the future through proactive policy making. OECD Working Papers on Public Governance, No. 44. https://doi.org/10.1787/cce14d80-en

UNDP Regional Bureau for Asia and the Pacific. (2022). Foresight Playbook. https://www.undp.org/asia-pacific/publications/undp-rbap-foresight-playbook

USDA (US Department of Agriculture). (2023). 2022 Census of Agriculture Impacts the Next Generations of Farmers. https://www.usda.gov/about-usda/news/blog/2023/02/22/2022-census-agriculture-impacts-next-generations-farmers

Van Woensel, L. (2024). Foresight in EU policymaking: Purpose, mindsets and methods. European Law Journal, 30(3), 361–381. https://doi.org/10.1111/eulj.12522

Van Woensel, L., Kurrer, C., Tarlton, J., Schrijver, R., Poppe, K., Daheim, C., Bol, E., and Hartog – De Wilde, S. D. (2016). Precision agriculture and the future of farming in Europe. In European Parliament & Science and Technology Options Assessment (STOA) Panel, *Scientific Foresight Study*. European Union. https://doi.org/10.2861/020809

Vesnic-Alujevic, L., Muench, S. and Stoermer, E. (2023). Reference foresight scenarios: Scenarios on the global standing of the EU in 2040. doi:10.2760/490501

Wepner, B., Neuberger, S., Hörlesberger, M., Molin, E. M., Lampert, J., and Koch, H. (2025). How can digitalisation support transformation towards sustainable agri-food systems? Scenario development in Lower Austria. Agricultural Systems, 224, 104251. https://doi.org/10.1016/j.agsy.2024.104251

Wilkinson, A., Kupers, R., and Mangalagiu, R. (2013). How plausibility-based scenario practices are grappling with complexity to appreciate and address 21st century challenges. 10.1016/j.techfore.2012.10.031

Wintermann, O., Wintermann, B., Jöster-Morisse, C., Daheim, C. and Wirz, J. (2022). Doppelte Transformation zur Nachhaltigkeit. Eine Annäherung an Zukunftsperspektiven. https://colab-digital.de/wp-content/uploads/2022/09/Doppelte_Transformation_zur_Nachhaltigkeit.pdf

World Bank. (2018). Fostering a vibrant farming sector with a next generation of farmers. https://documents1.worldbank.org/curated/zh/800451554278267779/pdf/Fostering-a-Vibrant-Farming-Sector-with-a-Next-Generation-of-Farmers.pdf