D6.4 DFA PROJECTS AND USE CASES

Project Number	101070421
Project Acronym	MUSAE
Project Name	A human-centered factory for a future technological sustainable development driven by arts
Project starting date	1 September 2022
Project end date	31 August 2025
Work Package producing the document	WP6
WP Lead Partner	GLUON
Other Partner(s) involved	POLIMI, ABACUS, UB, MADE, PAL
Deliverable identifier	D6.4
Deliverable lead beneficiary	UB-ART
Due date	31.10.2024
Date of delivery	19.03.2025
Version	0.3
Author(s)	Diego Marchante, Natalia Morales
Classification	PU - PUBLIC
Document Status	Final version

This project has received funding from the **Horizon Europe Framework Programme (HEU)** under grant agreement No 101070412.

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Revision History

Version	Date	Created / modified by	Comments
0.1	31/01/2025	Diego Marchante, Natalia Morales (UB Art)	First draft
0.2	11/03/2025	Maria Bulgheroni (Abacus)	Internal review
0.3	19/03/2025	Diego Marchante, Natalia Morales UB Art	Final version

Executive summary

Deliverable D6.4, "DFA Projects and Use Cases", presents 11 selected projects from the Second Open Call of the MUSAE S+T+ARTS residency programme, which were developed based on the Design Futures Art-Driven (DFA) method. The projects are represented by the future-driven concepts, which were developed by the teams of SMEs and artists from the period of September 2024 until January 2025. These concepts are further being developed into TRL5 prototypes, which will be described in more detail in Deliverables 5.1 and 5.2.

The document is structured to detail the development process of each project represented by the concepts, covering key aspects such as concept description, scenario connection, opportunities and keywords, challenge statements, technological integration, and ethical, social, and environmental considerations. The developed concepts have been developed in various use and tech applications in the area of food systems, tackling the topics such as optimizing agriculture and fermentation; exploring the connection between food, mental health, and cognitive functions, using neuroscience-driven, personalized dietary solutions. Other projects also developed the concepts in the area of regenerative farming to enhance soil health and crops resilience; as well as using bio-inclusive and circular design, transforming waste into biodegradable habitats and medicinal food sources.

As a result, these projects illustrate how the DFA method can foster systemic innovation and interdisciplinary collaboration to reach innovative solutions. By further turning developed concepts into the TRL5 prototypes will show the potential and pave the way for innovative, responsible and ethical tech solutions for the food system.

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0. Introduction

Purpose of the document

Deliverable D6.4 “DFA Projects and Use Cases” provides the development of the Design Futures Art-Driven (DFA) method, through the presentation of the 11 projects selected in the Second Open Call of the MUSAE S+T+ARTS residency programme. The development of the DFA method is the result of a collaborative effort between the Politecnico di Milano (POLIMI), Gluon and the University of Barcelona (UB) in the context of the Horizon Europe MUSAE project.

The report is structured to describe the development process of each of the projects developed in collaboration between artists and SMEs. They appear according to these sections:1. Concept description, 2. Connection to the scenario, 3. Opportunities and Keywords for concept, 4. Challenge statement, 5. Context, 7. Technology, 8. Ethical, social and environmental considerations. This order helps us understand the artists' and SMEs' works as results of the second phase of the DFA methodology . The objective of incorporating The “Opportunities and Keywords" section allows you to translate the opportunities of future scenarios. These presentations provide an overview of the current state of the art, highlighting the potential and importance of the challenges. of collaboration between artists and SMEs. By describing and integrating the Design Futures and Art Thinking methods, reflecting on these results of the DFA organized by all the partners of the consortium, the numerous knowledge generated in the first version of the second phase of the method is shown in the DFA.

1. Bee Sustain

Miljan Stevanovic & Beehold

1.1. Concept Description

BeeSustain is an integrated solution that combines advanced AI technologies, IoT-based hive monitoring, and an interactive Art Book to support sustainable beekeeping, promote biodiversity, and engage communities in ecological preservation. The mobile app provides real-time data and AI-driven insights to optimize hive placement, predict nectar flow, and improve hive management. The Art Book complements the app by educating users on the importance of pollination, local biodiversity, and sustainable agricultural practices, blending artistic storytelling with scientific insights. The role of Art Book was discussed at the beginning of this document, and below is just an illustration of the initial idea.

The concept emphasizes accessibility, making it usable for beekeepers of all technical backgrounds while engaging citizens through educational content and opportunities to contribute environmental data. This dual approach ensures a broader impact, addressing ecological, social, and economic challenges. BeeSustain integrates technology, art, and community participation to redefine modern beekeeping practices and preserve pollinator ecosystems. One of the key features is involving citizens (besides beekeepers of course) because the application allows them to scan pages for interactive learning (Art Book), upload microclimatic data (using IoT devices or manually), and contribute to the open-data ecosystem.

1.2. Connection to the scenario

BeeSustain directly aligns with the scenario PATTERNS THAT PERSIST Biodiversity as the measure of healthy human food systems by addressing the challenges of biodiversity loss, the decline of pollinator populations, and the need for sustainable agricultural practices.
Its design reflects the values identified in the Futures Compass:
- Sustainability of Ecosystems - BeeSustain promotes biodiversity by optimizing pollination, protecting bee populations, and encouraging sustainable practices in beekeeping and agriculture.
- Adaptability to New Conditions - Through AI-powered predictions, the platform helps beekeepers

adapt to climate change and unpredictable environmental conditions, ensuring resilience in the face of global challenges.

BeeSustain provides beekeepers with precise predictions on nectar flow timing at potential hive locations. For example, the app alerts beekeepers if nectar flow is expected to begin in the next 5–7 days at a specific location, enabling them to prepare and relocate their hives on time. This proactive approach helps mitigate the unpredictable effects of climate change on nectar availability, ensuring optimal hive productivity and pollination efficiency.

BeeSustain fosters transparency by enabling beekeepers to share data on hive placement and honey yield with the BeeSustain community. This open exchange of verified data demonstrates the authenticity of honey production, reinforcing consumer trust in real, locally sourced honey. By providing transparent insights into honey yields, BeeSustain not only supports beekeepers but also educates consumers, enhancing the value and reputation of authentic honey in the market.

By enhancing pollination and honey production, BeeSustain plays a critical role in fostering healthier and more reliable food systems. Improved pollination directly leads to better crop yields, higher-quality produce, and a more resilient agricultural sector. This benefits local communities by ensuring food security, supporting small-scale farmers and beekeepers, and creating sustainable economic opportunities. For example, local farmers can achieve better harvests through optimized pollination, while beekeepers benefit from increased honey yields that can be sold in regional markets, boosting rural economies.

At the global level, BeeSustain supports biodiversity preservation, which is vital for maintaining the ecosystems that underpin agriculture and food production worldwide. Bees' contributions to pollination enhance the health of plants and wildlife, promoting ecosystem stability. This, in turn, supports international trade by providing natural, sustainable products like honey, fruits, nuts, and vegetables that meet the growing global demand for environmentally friendly and ethically produced goods. Additionally, transparent honey production practices enabled by BeeSustain build trust in international markets, paving the way for equitable and sustainable trade opportunities.

BeeSustain responds to the scenario by blending technological innovation with ecological and cultural awareness, addressing both immediate and long-term challenges in biodiversity and community engagement.

1.3. Opportunities and Keywords for concept

Bee Sustain's impacts are rooted in its ability to merge traditional practices with innovative solutions. Unlike generic platforms, it is tailored specifically to the needs of beekeepers and the ecological challenges they face in localized settings. Its reliance on verified data, community involvement, and scalable technology ensures that its contributions remain meaningful and impactful without straying from its core mission. This balance of innovation and practicality is what positions BeeSustain as a transformative yet focused tool for the future of sustainable beekeeping. The opportunity of this concept is to leverage AI to enhance beekeeping and farming productivity and environmental impact through precise data utilization and predictive analytics. Our objective is to develop Bee-Sustain, a novel AI system, the first on the market to integrate data from patent-protected Beehold precision beekeeping devices and weather forecasts. This AI will predict nectar flows, optimizing hive relocation for maximum yield and pollination. Additionally, it will track honey production and pollination activity, ensuring consumer trust with verifiable data on honey origin and quantity. This approach boosts yield, provides a platform to measure beekeepers' environmental contributions, and incentivizes them for their ecological benefits.

Beekeeping # Technology # AI # Biodiversity # Ecology # Communities # Preservation # Art

1.4. Challenge statement

BeeSustain addresses this challenge by delivering solutions that enhance hive management through data- driven insights, educate citizens on pollination and biodiversity, and create transparency in honey production to combat synthetic substitutes.
BeeSustain addresses the following critical issues:
- The health of our planet's ecosystems and the stability of global food systems rely heavily on pollinators, particularly bees. However, beekeeping and pollination face numerous challenges, ranging from environmental pressures to economic and technological inequities. Addressing these issues is critical to preserving biodiversity, supporting agriculture, and fostering sustainable communities.
- One of the most pressing concerns is the decline in pollinator populations. Bees play a vital role in pollinating crops and maintaining ecosystems, yet their numbers are dwindling due to habitat loss, pesticide use, and disease. This crisis threatens biodiversity and agricultural productivity, making it essential to develop innovative tools that monitor hive health and ensure ecosystem sustainability.
- Another challenge is the impact of synthetic honey production. The rise of artificial and analog honey products undermines consumer trust in natural honey and financially disadvantages authentic beekeepers. Protecting the integrity of honey production not only ensures fair competition but also preserves the cultural and ecological value of traditional beekeeping.
- Climate change further compounds these issues by introducing environmental stressors that disrupt nectar availability. Unpredictable weather patterns make it difficult for beekeepers to optimize hive placement and productivity, necessitating adaptive strategies and technologies to mitigate these effects.

In addition to these environmental and economic challenges, there is a lack of accessible education and engagement for communities. Many beekeepers and citizens remain unaware of the importance of pollination and biodiversity. Empowering individuals with knowledge and involving them in data collection can enhance ecological monitoring and foster a sense of community responsibility for sustainability.

Finally, the preservation of traditional beekeeping practices is crucial. Small-scale and traditional beekeepers often lack the resources to compete with industrial operations. Bridging the gap between tradition and innovation through accessible tools and support can help these practices thrive in a modern context.

1.5. Context

BeeSustain is designed to deliver value across multiple sectors and domains:
- In the field of beekeeping, Bee-Sustain provides advanced tools for hive monitoring, nectar flow prediction, and hive placement optimization. These innovations empower beekeepers to adopt sustainable practices, optimize productivity, and increase their incomes. Enhanced honey production not only benefits individual beekeepers but also contributes to broader economic and ecological stability.
- For agriculture, Bee-Sustain offers a comprehensive system for pollination management. By facilitating direct communication with beekeepers and optimizing hive placement, the initiative ensures more effective pollination. This, in turn, boosts crop yields, supports agricultural production, and underscores the critical role of pollinators in sustaining food systems worldwide.
- Bee-Sustain's commitment to environmental sustainability is evident in its efforts to protect bee populations and promote biodiversity. By optimizing the ecological role of bees in pollination, the project helps mitigate the impacts of climate change and preserve vital ecosystems. These efforts contribute significantly to global initiatives aimed at fostering sustainable environmental practices.
- The project also prioritizes education and community engagement, recognizing the importance of raising awareness about pollinators and biodiversity. Through interactive tools such as an Art Book and app features, Bee-Sustain educates citizens about the role of bees in maintaining ecological balance. By encouraging participation of citizens, it fosters a sense of collective responsibility for environmental conservation.
- In the consumer goods and food industry, Bee-Sustain addresses the challenges posed by synthetic honey production. By ensuring traceability and authenticity through data-driven insights, the initiative builds consumer trust and supports legitimate honey producers. This not only strengthens local economies but also assures consumers of the quality and origin of their honey.
- Bee-Sustain also integrates technology and innovation into its operations, demonstrating the potential of AI and IoT in sustainable agriculture and biodiversity management. By positioning itself as a leader in precision agriculture and smart environmental solutions, the initiative showcases how technological advancements can drive sustainable practices on a global scale.

1.6. Users

Main Users
- Beekeepers
Beekeepers will use the BeeSustain app to monitor hive health through real-time data on weight,

temperature, and humidity. The app's AI-driven insights help beekeepers optimize hive placement and predict nectar flow, ensuring more efficient and sustainable hive management. Beekeepers can input data manually or use IoT devices to refine predictions, contributing to a collective dataset that benefits the entire community. Actions include analyzing hive metrics, adjusting hive placement based on predictive insights, and reporting local environmental conditions. The impact of this interaction includes improved honey yield, better hive health, and an enhanced ability to adapt to changing climate and environmental conditions, while also supporting traditional beekeeping practices with modern technology.

- Farmers

Farmers interact with Bee-Sustain by collaborating with beekeepers to provide land for hive placement, benefiting indirectly from optimized pollination and improved crop yields. This partnership strengthens the ecosystem services provided by bees, leading to increased agricultural productivity. Farmers experience the benefits of enhanced pollination rates for their crops, contributing to stronger and more sustainable agricultural practices.

Secondary Users

- Citizens

Citizens play a crucial role in supporting Bee-Sustain's mission through citizen initiatives. They report environmental data such as temperature, humidity, flowering patterns, and local nectar sources through the app, contributing to the collective dataset that enhances pollination and hive health predictions. Citizens can also engage with the interactive educational materials in the Art Book, learning about pollinators, biodiversity, and their impact on ecosystems. By participating in data collection and educational activities, citizens increase ecological awareness, foster a supportive community for sustainable practices, and contribute to biodiversity preservation efforts.

- Honey Consumers

Honey consumers benefit from Bee-Sustain by being able to trace the origins and production methods of honey through the app, ensuring that the honey they purchase is locally sourced and produced sustainably. The app provides verified data about the authenticity of honey products, increasing consumer trust in sustainable practices. By supporting small-scale and traditional beekeepers, honey consumers play a part in preserving local economies and supporting ethical production methods.

1.7. Technology

Applied Technology

BeeSustain leverages cutting-edge hardware, software, and artificial intelligence to provide an integrated solution for sustainable beekeeping and biodiversity monitoring. By combining IoT devices, a robust software platform, and advanced AI models, BeeSustain offers an innovative approach to hive management and environmental stewardship.

Hardware:

BeeSustain's hardware ecosystem includes two primary device types that work together to collect comprehensive data for precision beekeeping and environmental monitoring. These devices are integral to the platform, providing real-time insights that support sustainable hive management and biodiversity tracking.

1. Existing IoT Devices for Precision Beekeeping. The first device type in use is an IoT system designed specifically for precision beekeeping. This device is placed underneath the beehive and continuously monitors key metrics essential for hive health and productivity. In the implementation phase data from Beehold and partner devices will be used. The collected data includes: Weight, Temperature, and Humidity.

These IoT devices are solar-powered, enabling them to operate in remote locations without requiring a direct power source. Their design emphasizes durability and reliability, ensuring consistent data collection in various environmental conditions. The integration of these devices into BeeSustain provides a foundation for AI-driven recommendations on hive management, such as predicting nectar flow and identifying optimal hive placement.

2. New Microclimatic Data Collection Device (to be developed). The second device, currently under development, is designed to gather microclimatic data, offering a broader environmental perspective that complements hive-specific metrics. This device will measure:

- Temperature and Humidity: Provides localized environmental data, helping to assess the suitability of a location for hive placement and nectar flow potential.
- Carbon Dioxide (CO2): Indicates the level of vegetation activity in the area, which can correlate with nectar availability.
- Microparticles: Monitors air quality and the presence of pollutants, providing insights into potential risks to bee health and the surrounding ecosystem.

This new device will be equipped with advanced sensors to ensure high accuracy and will be portable, allowing beekeepers to collect data from multiple locations. By combining these microclimatic insights with hive-specific data from the IoT devices, BeeSustain can offer a holistic understanding of the factors influencing hive performance and environmental health.

Integration of Hardware

The data from both devices will be seamlessly integrated into the BeeSustain platform, where it will be processed and analyzed to provide actionable insights. For example, by correlating hive weight data with microclimatic conditions, the platform can identify patterns that predict optimal nectar flow periods and locations. This dual-device approach ensures that BeeSustain supports not only hive-level management but also broader environmental sustainability efforts.

Software:

The BeeSustain platform will include a newly developed mobile application and leverage the existing Beehold backend infrastructure, expanded to support BeeSustain-specific features. This approach ensures a seamless integration with Beehold's current user base, established data flow, and IoT devices while introducing new functionalities tailored to BeeSustain's goals.

Mobile Application

A new mobile application will be developed to serve as the central interface for beekeepers and other users. The app will be designed for usability and accessibility, ensuring that users of all experience levels can benefit from its features. Key functionalities will include:

- Real-Time Monitoring: The app will display real-time hive metrics such as weight, temperature, and humidity from IoT devices, along with microclimatic data like temperature, humidity, CO2 levels, and microparticles. This allows beekeepers to have a comprehensive view of hive and environmental conditions at all times.
- Nectar Flow Alerts: The app will provide alerts to beekeepers when nectar flow is predicted to start in the next 5–7 days at specific locations, helping them plan hive relocations proactively.
- Hive Management Tools: Users will be able to log hive-related activities, such as relocations or yield tracking, directly within the app, enabling them to organize and optimize their operations efficiently.
- Citizen Engagement Features: Citizens will have the ability to submit environmental observations, such as blooming patterns or local weather conditions, contributing valuable data to the BeeSustain platform and fostering community involvement.
- Educational Content (Art Book): The app will include resources to educate users on biodiversity, sustainable beekeeping practices, and the importance of pollinators in the ecosystem, enhancing user engagement and awareness.

Backend Infrastructure

The BeeSustain platform will utilize the existing Beehold backend infrastructure, which already supports data flow from IoT devices and existing users. This backend will be expanded to accommodate BeeSustain-specific features, ensuring smooth integration while minimizing development time. Key enhancements will include:

- Support for New Devices: The backend will be updated to process and store data from the new microclimatic sensors, expanding its capabilities beyond hive-specific metrics to include environmental data.
- Nectar Flow Predictions and Alerts: The backend will manage the data required to generate nectar flow alerts, ensuring accurate and timely notifications are delivered to beekeepers via the mobile app.
- Citizen Science Data Handling: The system will handle data submissions from citizen contributors, integrating this information into the existing dataset to enrich the platform's insights.
- User and Data Management: The backend will continue to support Beehold's existing user accounts and data structures while incorporating the new features specific to BeeSustain, ensuring continuity for current users and seamless onboarding for new ones.

The mobile application and backend will work together to provide a cohesive user experience. Data from existing Beehold devices and the new BeeSustain microclimatic sensors will flow into the backend, where it will be processed and organized. The mobile app will then present this data in an intuitive format, allowing users to monitor, plan, and optimize their beekeeping activities effectively.

AI

Datasets

The BeeSustain platform relies on diverse and comprehensive datasets to deliver actionable insights for hive management and environmental monitoring. These datasets include historical hive metrics, environmental variables, and citizen-contributed data, ensuring a robust foundation for accurate predictions and decision-making.

Source and Structure

1- Historical Hive Data:

- The dataset comprises weight, temperature, and humidity metrics collected from 80+ hives over multiple years, totaling more than 100,000 data points.
- These data points originate from existing Beehold IoT devices installed in hives, providing consistent, reliable measurements critical for understanding hive conditions and productivity trends.

2- Environmental and Weather Data:

- Environmental variables such as temperature and humidity will be collected for specific hive locations using free online historical weather services.
- We plan to utilize services like Open-Meteo and NOAA Climate Data Online to access weather data for target regions. These platforms provide historical temperature and humidity data at hourly or daily intervals, allowing us to align environmental factors with hive performance.
- For real-time and predictive weather data, integration with APIs like OpenWeatherMap will enable updates for specific hive locations.

• **Relevance for Prototyping:**

Foundation for Predictive Models: Historical hive data combined with environmental variables provides the basis for developing and testing predictive tools that optimize hive placement and monitor nectar flow.

Generalization Across Conditions: The integration of multi-source data ensures that the system can generalize predictions across diverse environmental and climatic conditions, making BeeSustain adaptable to a wide range of user needs and regions.

Bias Mitigation:

• Data Diversity:

During the testing phase, BeeSustain will utilize hive and environmental data primarily from Serbia and Bosnia and Herzegovina, regions with relatively similar climates. However, data from existing Beehold users across these territories will ensure sufficient variability in environmental conditions and practices to train the system effectively.

To further mitigate bias, efforts will be made to address any geographical gaps in data collection by strategically placing new devices in underrepresented areas. This ensures comprehensive coverage and prevents over-reliance on data from a few specific locations.

• Verification of Citizen-Contributed Data:

Data submitted manually by citizens, such as temperature, humidity, and flowering patterns, will undergo a verification process. Values provided by citizens will be compared against data from online weather services, such as OpenWeatherMap or NOAA, for the same location and time.

Significant mismatches between citizen-submitted data and trusted weather sources will trigger a review or adjustment process to maintain data integrity. This step ensures that citizen-contributed data enhances the system's accuracy without introducing errors.

Machine Learning Models

To deliver precise predictions for hive optimization and nectar flow, BeeSustain utilizes a combination of advanced machine learning approaches, each tailored to specific aspects of the system. These models predict future nectar flow by analyzing changes in hive weight at specific locations, correlating these changes with climatic data and weather forecasts.

Predictive Models for Hive Optimization:

- Model Type: Multivariate Time Series Analysis using VAR (Vector Autoregression). o - Purpose: Forecast hive weight and nectar availability based on IoT sensor data and weather patterns.

- Reason for Selection: VAR effectively captures temporal dependencies and correlations across multiple variables, making it suitable for analyzing historical hive data and environmental trends.

1D Convolutional Neural Networks (CNNs):

- Purpose: Predict nectar flow and optimize hive placement using small, domain-specific datasets.

- Reason for Selection: CNNs are computationally efficient and excel at analyzing sequential and spatial data, such as hive sensor readings. They can generalize predictions better than VAR models, making them ideal for locations with limited historical data.

- Design: The architecture will be shallow to prevent overfitting, especially given the relatively small datasets available.

- Planned Development: A CNN-based approach will be developed and tested alongside the VAR model to evaluate which model is more suitable for production use in the final BeeSustain app.

Next Steps:

- Dataset Preparation: Compile a robust dataset for AI training, including historical hive and climatic data from the 2024 season. This will incorporate both IoT and citizen- contributed data.
- Model Development and Training: Build and train both the VAR and CNN models on the prepared dataset. These models will be tested to predict nectar flow by analyzing changes in hive weight and correlating them with environmental data and weather forecasts.
- Performance Comparison: Compare the accuracy, scalability, and usability of the VAR and CNN approaches. This comparison will determine which model will be implemented in the final BeeSustain app.
- Validation: Test the selected model in live hive environments to ensure practical usability and reliability under real-world conditions.

By comparing the two approaches—VAR, which relies heavily on historical data, and CNN, which can generalize with less past data—BeeSustain aims to identify the best-performing model to deliver reliable and scalable predictions for hive management. This iterative development process ensures the final app meets the needs of beekeepers while maximizing accuracy and usability.

1.8. Ethical, social and environmental considerations

Social Impacts:

- Community Engagement - Ability to engage local communities in environmental stewardship through citizen initiatives. The project encourages individuals to contribute valuable data about local flora, nectar sources, and environmental conditions. By participating in data collection, citizens become an integral part of the solution, helping to preserve biodiversity and promote healthy ecosystems. This active participation fosters a sense of shared responsibility among community members, as they can see the direct impact of their actions on local environmental health.
- Education and Awareness - Efforts to raise awareness about the critical role bees play in maintaining healthy ecosystems. Through interactive tools such as the Art Book as a part of Bee-Sustain app, the project engages a wide audience, especially younger generations and those who may not have specialized knowledge about pollinators. These tools provide a deeper understanding of the interconnectedness of nature, helping individuals realize how pollination affects everything from food production to biodiversity.
- Inclusivity – The Bee-Sustain app ensures that it caters to all users, including older beekeepers or those who may not be familiar with modern technology. By providing simple and intuitive interfaces, Bee-Sustain ensures that even those with limited technological experience can still engage with the platform effectively.

Environmental Impacts:

- Biodiversity Conservation - By supporting the preservation of pollinator populations, the initiative plays a crucial role in maintaining healthy ecosystems. Pollinators, particularly bees, are vital for the fertilization of many plants, including those that produce food for humans and wildlife. The decline of pollinators due to habitat loss, disease, and climate change threatens biodiversity, making their protection a priority.
- Climate Resilience - Through predictive insights such as nectar flow forecasting and optimal hive placement recommendations, the platform helps beekeepers better manage their hives in response to shifting environmental conditions. Climate change has led to unpredictable weather patterns, affecting nectar availability and pollination services. By enabling more precise hive management, Bee-Sustain mitigates the impact of climate change on pollination, ensuring that beekeepers can maintain healthy hives and secure honey production despite unpredicted environmental conditions.
- Sustainable Practices - The Bee-Sustain allows beekeepers to manage their hives more efficiently, reducing the need for harmful chemicals and promoting environmentally friendly practices. By optimizing hive placement and nectar flow prediction, beekeepers can reduce the overuse of pesticides and other chemicals, which can harm pollinators and degrade the environment.

Economic Impacts:

- Support for Beekeepers - By providing advanced tools for hive monitoring and nectar flow prediction, Bee- Sustain enhances hive productivity, allowing beekeepers to produce higher-quality honey more efficiently. Additionally, the platform helps preserve the authenticity of honey production by offering data-driven insights into the origins and methods of honey production, protecting local

producers from the influx of cheaper, synthetic alternatives.
- Consumer Trust - With the rise of synthetic honey and concerns about product authenticity, consumers have become more cautious about the honey they purchase. Bee-Sustain transparent data platform addresses these concerns by providing verifiable information about honey's origin and production methods. By allowing consumers to trace the journey of their honey from hive to jar, the project fosters greater confidence in the product's authenticity.
- Job Creation and Innovation - By bringing together beekeepers, farmers, citizens, the project fosters collaboration that leads to the development of business opportunities. The integration of artificial intelligence, IoT, and other advanced technologies in beekeeping operations opens up new avenues for innovation in precision agriculture and biodiversity management.

Ethical Considerations:

- Data Privacy - Given that the platform relies on citizen science and beekeeper input, it is essential to ensure that all data is handled securely and with respect for participants' privacy. Bee-Sustain implements robust anonymization protocols and secure storage methods to safeguard sensitive information. By prioritizing data privacy, the platform builds trust among participants, ensuring they feel confident in contributing to the collective dataset without fearing misuse or exposure of personal information.
- Equity and Fairness - Many small-scale beekeepers lack the financial means or technological expertise to compete with large industrial producers, which can lead to their exclusion from the market. By offering tools for hive management, nectar flow prediction, and data-driven insights, Bee-Sustain allows these beekeepers to improve productivity, enhance sustainability, and remain competitive.
- Potential Risks - The use of AI-driven insights and IoT devices could lead to a situation where beekeepers and farmers become overly dependent on technology, potentially diminishing their ability to make decisions without these tools. Additionally, those with limited technological experience, particularly older beekeepers, might struggle to navigate the platform. Bee-Sustain will provide the interface is simple and intuitive.

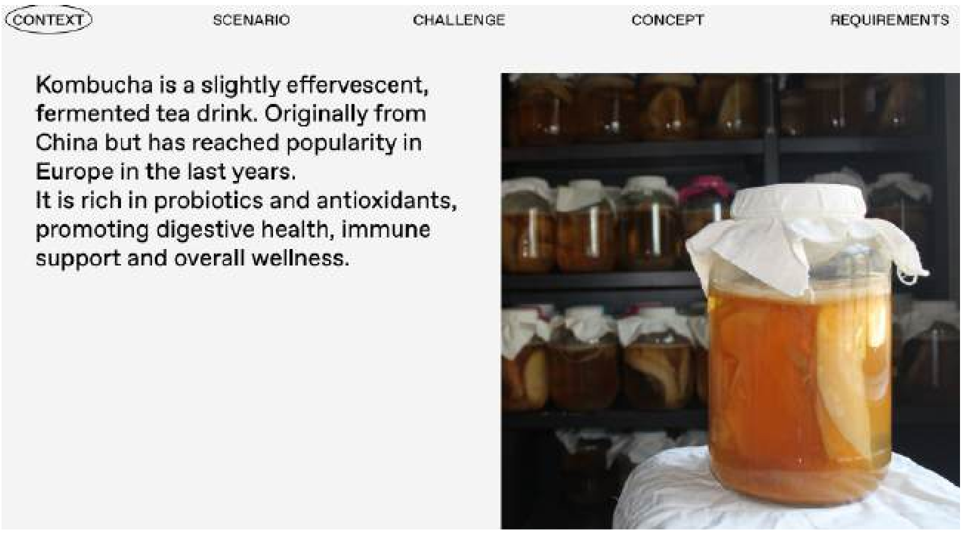
2. Fermenting Traditions

Eleonora Ortolani, Malou Van Der Veld & Crafted Kombucha Beverages LTD

2.1. Concept description

The chosen concept is a fermentation tracking system that's designed with small kombucha brewers in mind. It's a low-tech solution that integrates effortlessly with existing fermentation vessels, offering an affordable and accessible way to monitor microbial activity and ensure safety throughout the brewing process. DIY spectroscopy sensor kit that allows brewers to analyse parts of the fermentation process. This makes it both easy to set up and cost-effective to maintain, ensuring it remains practical for small-scale operations.

The fermentation tracking system will use a user-friendly web-based dashboard, accessible on both desktop and mobile devices, to display the data. This dashboard will provide real-time visualizations, such as graphs and heatmaps, to track microbial activity, fermentation progress, and flavor profiles. Brewers will receive alerts for anomalies or when their kombucha reaches its optimal state, helping them take timely action. A future potential could be that the historical data will be stored indefinitely, creating a SCOBY archive—a growing library of microbial activity and fermentation patterns that could contribute to long-term research and innovation. The interface will be simple and intuitive, designed for those with minimal technical expertise, with options to download reports or back up data as needed. With cloud integration for broader accessibility and offline functionality for local storage, this system ensures small brewers have a practical and effective way to monitor and enhance their craft while contributing to a larger body of fermentation knowledge.



2.2. Connection to the scenario

The concept responds to a future scenario where technological advancements have standardized global food quality, challenging the notion of authenticity tied to geographical origins. The system preserves the authenticity and artisanal nature of kombucha production by emphasizing microbial biodiversity and offering brewers tools to maintain traditional fermentation processes. It aligns with the values of the Futures Compass by promoting health, sustainability, and cultural identity, countering issues like pasteurization and industrial shortcuts that reduce flavor quality and cause more issues to gut health rather than supporting the gut.

2.3. Opportunities and Keywords for concept

Within this concept lies an opportunity not only to preserve the traditions surrounding kombucha production but also to educate consumers on microbial fermentation from a non-human-centered perspective. By offering alternative perspectives on food traceability, we can redefine the concept of food origin beyond mere geography; it becomes a tangible representation of tradition passed down through generations. By establishing a tangible system to trace microbial patterns, consumers can deepen their understanding and appreciation for the cultural significance embedded in their food choices, thereby shifting their perception of values towards microbiome biodiversity preservation. Additionally, this initiative aims to strengthen the company's ability to communicate its values and distinctiveness in the market, with its primary goal being the preservation of traditional production methods while enabling scalability.

Fermentation # System # # Kombucha # Microbial # Accesible # Low-tech # DIY spectroscopy sensor kit # Real time visualization

2.4. Challenge statement

Problem to Solve: Industrialized kombucha production undermines microbial biodiversity through pasteurization and artificial additives, impacting flavor and health benefits. The project aims to equip small brewers with tools for maintaining authenticity and promoting transparency in the fermentation process.

2.5. Context

The project is expected to deliver value in the following domains:
- Food/beverages: Artisanal and health-focused kombucha production.
- Education: Promoting microbial awareness and fermentation science.
- Technology: Advancing DIY robotics and developing a data visualization system.
- Health: Enhancing gut health through biodiverse, authentic products.

2.6. Users

1. Brewers:
- Small-batch artisanal kombucha makers with minimal scientific backgrounds.
- Actions: Install the kit, monitor microbial activity, adjust fermentation to control flavor profiles, and ensure safety through pathogen detection.

2. Consumers:

- Health-conscious individuals seeking transparent, biodiverse, and natural beverages.
- Actions: Access flavor profiles and product details, make informed choices, and gain knowledge about fermentation.

3. Other Impacted Groups:
- Microbial Ecosystems: The project fosters biodiversity and resilience within microbial communities.
- Educational (institutional/communities): Knowledge sharing and fermentation awareness.

2.7. Technology

The DIY spectroscopy sensor kit will allow us to analyze multiple metabolites (e.g., glucose degradation, lactic & acetic acid, glucuronic acid) responsible for the flavour within the kombucha. This will inform the brewer through a simple interface. The interface allows the brewer to set their own parameters and variables, such as thea and sugar usage). A spectrometer is easily buildable with off the shelf products. The analysis models we can develop with the help of London Metropolitan University.

2.8. Ethical, social and environmental considerations

ETHICAL
This project embodies an ethical commitment to preserving the natural integrity of kombucha by prioritizing microbial biodiversity and transparency over industrial shortcuts. It ensures small brewers can maintain their authentic practices while staying competitive, giving them the tools to thrive without compromising their values.

SOCIAL
It builds meaningful connections—between brewers, consumers, and even microbes themselves. By educating people about the role of microbial ecosystems in health and flavor, it fosters a sense of appreciation and responsibility. Consumers become more mindful of their choices, while brewers gain the confidence to share their craft with the world.

ECONOMIC
This system can be a game-changer for small producers. It helps them stand out in a crowded market by adding value to their products through authenticity and transparency. It creates opportunities for niche markets, premium pricing, and even community-driven ventures like fermentation workshops or online platforms.

ENVIRONMENTAL
This project can be a step toward sustainability. By promoting small-scale, biodiversity-friendly production methods, the project counters the environmental impact of industrialized food systems, helping preserve the delicate balance of microbial ecosystems that sustain both flavor and health.

3. Growing Futures

Daniela Amandolese / Basque Biodesign Center, BDC, (Intermedio Montajes)

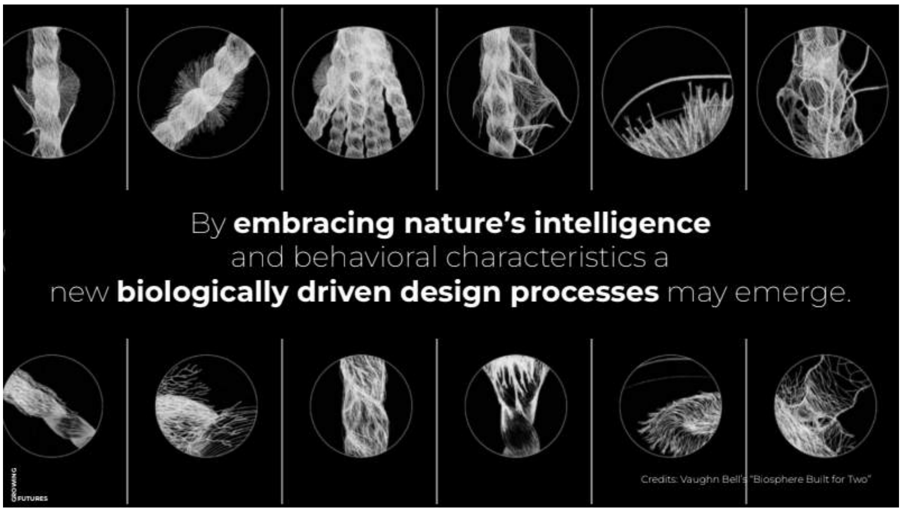
3.1. Concept description:

Symbiotic ecosystem where humans, mycelium and robots collaborate. The Growing Futures project designs a symbiotic ecosystem where humans, mycelium and robots collaborate to create sustainable habitats, products made by mycelium materials. Inspired by nature and the concept of "food as medicine", it transforms local waste into biodegradable and adaptable structures using a process-driven approach. Food isn't just a product—it's part of an ongoing dance of giving and receiving. It represents a circular loop, a continuous flow of connection and renewal. Every meal, every bite, is woven into a much larger system of exchange and transformation, where the resources of one become the lifeblood of another.

The concept model follows a circular approach—or more precisely, a spiral model—that begins with local waste. Through a process of growth and collaboration between humans, mycelium, and robots, local waste is processed and transformed into habitats at various product scales. These habitats, made from natural, biodegradable, and compostable materials, return to the soil, enriching it in the process.

Over the years, a vast amount of interest and research has developed, testing fungi's properties. Fungal mycelium is often considered a sustainable alternative to synthetic materials. This establishes an instrumental relationship with nature, where nature was conceived as the supplier of materials, but rarely invited to participate in the design, and even far less so to have agency and autonomy in the creation of forms.

Mycelium growth is supported by robots that monitor, nurture and guide its development, simulating natural systems – fungal networks and ant colonies. The result is bio responsive habitats that adapt, repair themselves and contribute to a circular and environmentally responsible future.



3.2. Connection to the scenario

We have selected the scenario by Peter Andersen.
The trends of this scenario that particularly inspired us were:

1. Global warming - The climate radical changes.
2. Hybrid Natures - the connections between Nature and Human through the technologies.

The elements for the future scenario that we selected were:

1. The focus on the organic materials, in particular on the mycelium. By definition Mycelium is the lower vegetative part the mushroom ecosystem or the mushroom body.
2. The cultural context: the coexistence - in our case between human and fungi - mycelium.

Furthermore, within Peter's scenario, one particular phrase was especially significant for us: Fungal structures grow, build and repair themselves.

Starting from the Future Compass tool, we have defined four values that are very important: COLLABORATION – Collaboration between humans, nature (mycelium), and the robotic swarm. A symbiotic ecosystem.

EFFICIENCY – Energetic efficiency in growing these structures. The natural efficiency of mycelium lies in its energy-conscious growth, its ability to search for nutrients, and its remarkable adaptability to environmental changes

ADAPTABILITY – Adaptability because mycelium adjusts to its surrounding environment. Moreover, our project is currently a pilot project that will develop using local mycelium, but the concept is transferable to any environment.

RESPONSIBILITY – Responsibility towards the future.

3.3. Opportunities and Keywords for concept

This shift towards a circular design, utilizing growing materials like mycelium, which naturally regenerate and repair themselves, contain the potential to become computable sensors, offers a sustainable alternative to finite resources. The goal is to exploit the potential of mushrooms, design modules with parametric tools in conjunction with robotics technology, which can perform the function of generative envelopes.

Producing an adaptable supply chain that responds to constantly evolving challenges, without creating production surpluses. A more holistic vision of the production system which becomes a system of exchange of resources and services, an opportunity to live in a healthier environment. Thanks to the BIO LAB I & II - the laboratory at the advanced Technology Readiness Level 3 (TRL3) equipped with state-of-the-art technology, for the development of materials with living organisms - Basque Biodesign Center aims to validate its modules by mycelium in industrial environments.

Mycelium # Mushrooms # Environment # Sustainable # Circular design # Growing materials # Parametric tools # Robotics

3.4. Challenge statement

In 10 years, there will be a symbiotic collaboration between humans, mycelia and swarm robots to construct our habitats using local biological waste.

3.5. Context

Starting from the theme of the MUSAE project, Food as Medicine, we asked ourselves: what does food truly mean to us? Food isn't just a product—it's part of an ongoing dance of giving and receiving. It represents a circular loop, a continuous flow of connection and renewal. Every meal, every bite, is woven into a much larger system of exchange and transformation, where the resources of one become the lifeblood of another.

We are in a critical period characterized by several global phenomena, including:

- The climate crisis
- The excessive use of resources, particularly non-renewable ones. The matter is finite.

Between 400/300 million years ago, there were no trees on Earth, but there were huge forests of fungi. Then, as other life forms emerged, fungi did not disappear—they adapted, becoming the invisible caretakers of the underground. We are now depleting our resources; in a way, we are at the end of the world as we know it.

So, as we look toward the future, we are starting again with fungi—the first organism to emerge after every catastrophe.

3.6. Users

The main actors are: Humans, Mycelia, Robots.
As the authors of this symbiotic collaboration, Humans, Mycelia, and Robots can build on-site using local mycelium and waste, without relying on new resources. And they create a connection not only between themselves but also with the surrounding environment.

Human:
- Roles: Observer, reader, designer, facilitator and interactive participant.
- Interactions: - Observes and reads data from sensors monitoring the mycelium growth environment (temperature, humidity, pH, oxygen levels).
  - Interacts with the system by adjusting parameters like the casting form, type, and quantity of nutrition, and in advanced scenarios, defines design codes for robotic actions.
  - Responds to mycelium's growth behavior by iterating design or nutritional inputs to guide its development.

Robot:
- Roles: Facilitator, actuator, and decision-making intermediary.
- Interactions: -Incorporates sensor data to monitor mycelium growth and execute targeted actions.
  - Moves autonomously or semi-autonomously to distribute nutrition along paths defined by the human user's design code or adjusted based on mycelium growth patterns.
  - Operates within a defined ecosystem alongside human inputs and natural growth tendencies.

Mycelium:
- Roles: Active growing organism, the central entity monitored and influenced by the ecosystem.
- Interactions: - Responds to environmental conditions and nutrient inputs.
  - Influences the system by providing real-time data on growth patterns, which informs human and robotic actions.

3.7. Technology

This project explores the dynamic interactions between mycelium, humans, and robotics, integrating sensors and technology to monitor and influence growth.

In the SETTING 01 - Unconstrained Growth, sensors inside a controlled environment track temperature, humidity, pH, oxygen levels, and potentially infrared data to monitor mycelium's growth patterns, surface expansion, and responses to nutritional inputs. Observations will be converted into data sheets, images, and timelapses for human analysis.

SENSORS INSIDE THE SETTING 01:
- Temperature - GROWING
- Humidity - GROWING
- PH - NUTRITION

- Oxygen levels - LIVING
- Infrared or camera TBD - GROWING

The data collected in this setting is to monitor mycelium
- Growth surface/ in time
- Growth direction - path
- Growth/ based on nutrition type and quantity

In the SETTING 02 - Controlled Casting, the system adds user interactivity, enabling adjustments to the casting form and nutrient variables while continuing to monitor growth.

SENSORS INSIDE THE SETTING 02:
- Temperature - GROWING
- Humidity - GROWING
- PH - NUTRITION
- Oxygen levels - LIVING
- Infrared or camera TBD - GROWING

The data collected in this setting is to monitor mycelium
- Growth surface/ in time
- Growth/ based on nutrition type and quantity

In the SETTING 03 - Robots That Feed introduces robotics, where a sensor-equipped robot not only tracks growth but actively distributes nutrients along growth paths based on collected data, following predefined rhythms and directions.

ROBOTS + SENSORS INSIDE THE SETTING 03:
Robot with sensors incorporated:
- Temperature - GROWING
- Humidity - GROWING
- PH - NUTRITION
- Oxygen levels - LIVING
Infrared or camera TBD - GROWING
The data collected in this setting is to monitor mycelium
- Growth surface/ in time
- Growth/ based on nutrition type and quantity

Robot with movement capacity to distribute nutrition:
Based on the direction information of the sensors, the robot distributes the nutrition.
- capacity to move following one direction defined from the growing data
- capacity to drop the nutrition based on defined rhythm on the path

In the SETTING 04 - Ecosystem combines human-coded design inputs with robotic functions to guide growth paths, allowing adaptive interaction between design intentions and mycelium's natural growth. Across all stages, the human role evolves from passive observer to active designer and collaborator.

HUMAN DESIGNER CODE + ROBOT + SENSORS INSIDE THE SETTING 02:
Robot with sensors incorporated:
- Temperature - GROWING
- Humidity - GROWING
- PH - NUTRITION
- Oxygen levels - LIVING

The data collected in this setting is to monitor mycelium
- Growth direction - path
- Growth surface/ in time
- Growth/ based on nutrition type and quantity

Robot with movement capacity to distribute nutrition.
Based on the inputs of human design code (points), the robot directs the path of the nutrition dropping, mycelium grows following its natural path, and if necessary the design code (points) get modified.

- capacity to move following the direction defined by the data given from the code but may be modified by the direction defined by the mycelium growing data
- capacity to drop the nutrition based on defined rhythm on the path

3.8. Ethical, social and environmental considerations

Thanks to the Futures Wheel tool provided by the Musae project, we have defined an overview of the social, environmental, economic, and ethical impacts of our concept.

Ethical:
- Respect the agency of mycelium as a living material.
- Avoid forcing unnatural growth or exploitation.

Social:
- Embrace non-human contributions to the design/artist process.
- Involve the community in the symbiotic practices with living materials.

Environment:
- Use renewable resources like mycelium and agricultural waste.
- Mycelium-based materials will decompose naturally.
- The system will adapt to local ecosystems, ensuring minimal disruption to natural habitats.
- Construction will take place on-site, reducing transportation emissions and waste.

4. Neuro-Cooking

Anna Rosinke & mbraintrain

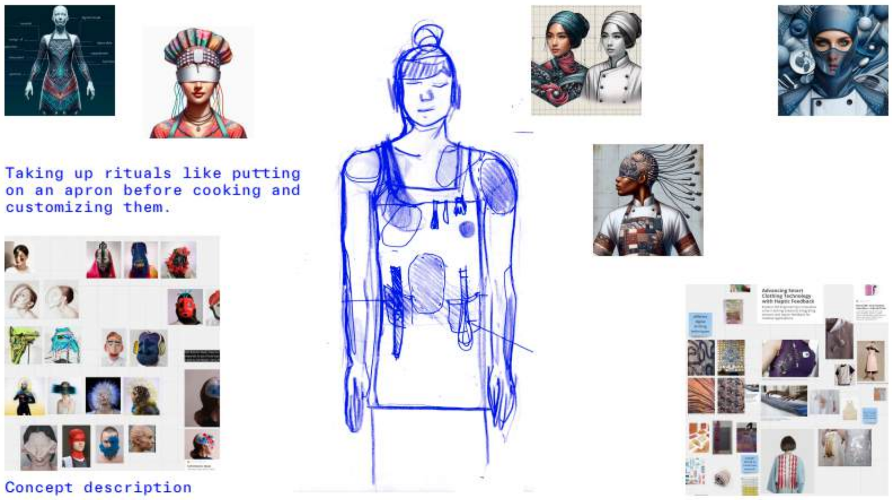
4.1. Concept description

We defined the inspiration for our project in three pillars redefining the umbrella term “food as medicine”: Planetary, Mental, and Physical Health. Cooking affects all our senses, sight, sound, smell, taste and touch. There is especially a lack of tactile input, that is connected even to mental illnesses, like touch hunger. The senses should not be treated individually. They create a symbiosis that forms one holistic experience, leading to balance and orientation. In the inspirational research phase, we were able to broaden our knowledge with relevant case studies connected to food preparation and senses, references, technological knowledge, and visual input that was referring to our challenge statement and clustering inspirations around food, multi-sensorial experience and senses, body, space, and object.

We would like to make a prototype of a wearable that includes EEG, motion, pulse and muscle contraction trackers. With these sensors we are able to analyze the emotional state of the user in realtime and respond with instructions that aim to improve the mental state by different techniques in the field of food preparation.

Different cooking techniques are relaxing, are beneficial in cognitive development as well as in the development of fine motor skills, and so can be used to support certain forms of mental therapy. Our wearable can help to individualize and adapt therapy forms, relating to the analyze of its progress, by creating an emotional image of the user. We will concentrate on our concept of hardware development and on very basic cooking techniques to set a foundation stone in this field.

As food is something not only culturally relevant but also very individual, connected to one’s upbringing, emotional history, and perhaps also physical illnesses - teaching to cook should also be individualized in the same way we try to personalize nutrition.



4.2. Connection to the scenario

The concept picks out one image from the holistic image of the scenario, the mentally beneficial part of food preparation. The aspect of cooking as a meditative and therapeutic practice plays an important role in the concept.
The chosen scenario was the “Cooking Ape Institute”. This concept describes a speculative inter-disciplinary institute focusing on the potentials of food preparation. The process of preparation isn’t seen as a means to an end, but as an elementary part of a holistic approach in the field of “food as medicine”. The cultural technique or aesthetic practice of food preparation is seen in an anthropological context, referring to Wrangham, as well in a physiologically and mentally therapeutic context. The physiological benefits have to be seen in the context of fine motor skills, as well as in the context of the improvement of your skin’s and gut’s microbiome. The mental benefits have to be seen, in the context of multi-sensorial experience, meditative cooking and baking techniques, as well as in the connection of microbial and psychological health.
The scenario describes an optimistic food future, in which we take care more also about the process and mental influence of food and its preparation. With the project Remis, we are taking up the idea of mental health, relaxation and the support of therapies with the help of technology. And try to design a wearable that can help us to reach this aim and fully teach the potentials of the therapeutic aspects of food preparation, as well as having the potential to find a new and better way to teach cooking.
In the future compass, we defined our triangle of planetary, mental, and physical health. The project is focusing on the aspect of mental health, including the other aspects, still we are hoping to grow in another phase (after MUSAE 2) a stronger focus on the inclusion of the other aspects, with the help of AI models.

4.3. Opportunities and Keywords for concept

Medicine evolution # Food as medicine # Therapeutic cooking # Holistic health # Mental health # Psychosomatic disorders # Obesity treatment # Neuroscience # AI # EEG technology # Robotics

4.4. Challenge statement

Our defined challenge statement is: "In 10 years, how might we use EEG and other physiological signals to improve cooking and eating habits?".

Food, mental health and fine motor skills. The challenge is to develop a wearable that can support therapies in the fields of fine motor skills, food and sensual anxieties. By interpreting data to an emotional image, we can add another layer of information that can be much more objective, than a classical questionnaire or a biased personal instruction from a person.

4.5. Context

The areas of our interest in the inspirational research deriving from our challenge statement was in the beginning structured around two main topics: multi-sensory experience of food and its importance for health (inspirations and case studies focusing on taste, sound, touch, smell – gathered by the artist) and technological innovations and case studies connected to senses and EEG (SME). After exploring these topics through discussion and gathering material on MIRO we added research revolving around body (appliances and warbles, masks, gloves), food, object and space. We were trying to find connection on crossovers all those and were explaining context of inspirational projects to each other during meetings. AI was used as a support to find referential case studies, scientific papers and reference art/tech projects. Activities were documented on teams

4.6. Users

Depending on the software development this tool can have different groups of target users but there is one that we would like to concentrate on. These are people using the device as a therapeutical, rehabilitation use.
They were diagnosed with different forms of anxiety, sensual imbalance of tactility and the picky eater syndrome and will start a behavioral therapy (according to studies our lack of sensual - tactile experiences is leading to many health issues including touch hallucinations and those can get worse in the 10 year future perspective) . Besides training with a therapist, this group of target users will get a prescription for the „Remis" wearable to exercise at home.
The main users are interacting be speech and tactile input with the wearable. Meaning, you can talk with „Remis" and „Remis" talks to you. Besides that, „Remis will do tactile input like rhythmic vibrations on your arm, that can relax you or help to adjust speed or movement of your process.
The huge benefit of this tool, compared to a cooking school or a book is, that „Remis" can interpret your emotional state and react to it, to improve your performance in cooking and your mental state in

the context of therapeutic use. But also, in the context of practical learning to cook it can react to stress-levels that are often increasing the risk of injury and help to improve the smoothness of movement, your general motion and speed of cooking.

4.7. Technology

For the Remis project, we will use dry EEG electrodes to detect brainwaves, and the adapted app mentioned above to detect emotions and mood. We will utilize the SMARTING PRO X EEG amplifier, which can capture data across multiple c: EEG, Channels (modalities): ECG (pulse), motion sensors, audio envelope via microphone input, and EMG (muscle contractions).

4.8. Ethical, social and environmental considerations

With the help of MUSAE Future Wheel (see MIRO) we have detected several impacts of the project and discussed methods how we can overcome the negative ones.
We have considerations connected to following issues:

- Invasiveness of the technology in the user experience or a stress of the user connected to wearable.
Methods to overcome the issue: User interaction with the device will be designed to be very gentle (gentle voice, subtle touch, output through different senses,). Design language of the object will make a difference in how the device will be perceived and we approach this task with carefulness and consciousness about this issue. Additionally, we see this project in a 10-year perspective when the society acceptance towards the technology will improve (already now many people are using tracking devices in their watches). Considering rapid development of the technology (including EEG technology) we predict that it will be possible to integrate the EGG and other sensors with the body in much larger scale as it is possible today (wireless, soft, non-invasive)

- psychological dependance from the device
Methods to overcome the issue: The core idea of the project is that it becomes obsolete after a certain time, that is why the “chat-bot” will not be creating personal connection with the user. The “emotions” read by EEG will not be revealed to the user, so that a person is not over- controlling his or hers health through the device

- energy used for the production and CO2 exhaustion of the device – users will be borrowing the device and not owning it. It will be washable and designed with a care about using most sustainable materials of choice. The positive impacts connected to sustainable food choices will overcome the negative ones

5. Nourish

Sanja Šikoparija & StarLab

5.1. Concept description

This concept proposes the development of a versatile tool aimed at reshaping the way individuals and industries perceive the relationship between food and the brain. The tool is designed with a dual purpose: to measure emotional responses to food and to act as a cognitive assessment device, offering insights into cognitive states following food consumption. The tool will empower markets, businesses, and consumers to make data-driven decisions about personalised diets, enhancing emotional well-being and cognitive performance. This aligns with broader societal shifts toward personalised nutrition and the integration of mental and emotional health into lifestyle decisions. Industries such as food technology and nutrition science could utilise these insights to design products tailored to improve emotional and cognitive outcomes, such as foods that enhance focus, reduce stress, or improve mood.

The envisioned tool is designed to integrate effortlessly into existing health and wellness routines, delivering insights through a user-friendly interface. It will rely exclusively on EEG data processed by advanced artificial intelligence algorithms, eliminating the need for supplementary tests or subjective inputs from users. During the development phase, the system will incorporate traditional cognitive assessments and emotional questionnaires to ensure accuracy and reliability. For instance, the EEG-derived metrics will be validated against established cognitive tests and self-reported emotional scales. These processes will provide the ground truths necessary for calibration and validation but will not be part of the tool's final usage. Ultimately, the goal is to create a scalable solution that delivers both emotional and cognitive assessments with minimal intrusion and complexity. By combining cutting-edge neuroscience with practical applications, this tool aspires to make neurofeedback an accessible part of everyday life. Its capacity to measure both short-term emotional reactions and longer-term cognitive effects of food has the potential to revolutionise our understanding of food's impact on mental and emotional health, paving the way for adoption across diverse sectors.

5.2. Connection to the scenario

The Nourish concept aligns seamlessly with the Futures Compass. Its design reflects a forward-thinking approach that responds to societal trends.

Hopes - The tool advances sustainable food practices by encouraging users to make eco-friendly dietary choices based on real-time feedback about emotional and cognitive impacts. It fosters proactive health management by enabling individuals to detect subtle changes tied to eating habits, empowering them to take preventive measures and improve resilience. Additionally, it supports emotional well-being by helping users identify foods that promote balance and positivity, creating healthier relationships with food. Finally, through advanced AI, Nourish bridges the gap between individual health goals and personalised nutrition, ensuring harmony between emotional and physical needs.

Shared Values - The Nourish tool embodies values such as health, sustainability, equity, and empathy. By delivering actionable insights, it helps users balance mental and physical health, while its eco-conscious design integrates sustainability into everyday decisions. Affordability and inclusivity ensure that its benefits are accessible to diverse populations, promoting equity and reducing health disparities. Furthermore, its user-centric approach respects individual preferences and needs, fostering trust and a sense of care.

Fears - The concept directly addresses concerns about dependence on technology, privacy, inequality, and unintended health outcomes. Its design empowers users by providing insights without dictating choices, and robust data security protocols protect sensitive information. Affordability and accessibility ensure the technology benefits all users, minimising disparities. Finally, its evidence-based approach ensures reliable recommendations, reducing the risk of negative outcomes.

By aligning with these values and addressing key concerns, the Nourish concept reflects a deep commitment to a healthier, more sustainable, and equitable future. It exemplifies how innovative technology can bridge societal needs with individual empowerment, ensuring relevance and impact in the decades to come.

5.3. Opportunities and Keywords for concept

Over recent years, there has been an increasing interest in understanding user experience. Electroencephalography (EEG) has emerged as the preferred electrophysiological measure, surpassing alternatives like electrocardiogram or skin-conductance response, for assessing users' emotional and cognitive states across various contexts. EEG can provide a multitude of insights into the health status of individuals, and research in this field is growing. Advancing the development and refinement of brain-based AI algorithms tailored to recognize food responses, as envisioned in the futuristic scenario "Bio-Intelligent Data," could greatly allow us to comprehend not only how our bodies and brains perceive food but also to utilize this knowledge to advocate for healthier dietary choices and food-related habits, enhancing our overall lifestyle and nutrition profile.

Food technology # Nutrition science # Personalised nutrition #Cognitive performance #Data-driven decisions #Mental health #Emotional health #Food and brain connection

5.4. Challenge statement

Healthcare and Wellness - The concept focuses on helping individuals take charge of their emotional and cognitive health by offering personalised dietary recommendations. It also supports the early identification of subtle cognitive issues linked to nutrition, empowering users to act proactively and improve their overall well-being.

Food and Beverage Industry - This tool provides businesses with actionable insights to create and market products that emotionally and cognitively connect with consumers. By enabling personalised food design, it enhances consumer satisfaction and creates opportunities for innovation in the industry.

Technology and AI Development - The concept pushes the boundaries of artificial intelligence by incorporating bio-signal analytics to deliver precise emotional and cognitive tracking. It also drives innovation in wearable technologies, enabling real-time health monitoring that's both practical and cutting-edge.

Sustainability and Environmental Impact - By empowering consumers to choose foods that align with their well-being and sustainability goals, the concept encourages healthier and more eco-friendly eating habits. It also supports food producers in adopting sustainable practices by leveraging insights on consumer emotional engagement with their products.

The specific challenge lies in developing a tool that seamlessly measures emotional and cognitive responses to various foods, enabling both individuals and industries to make informed decisions that prioritise health, sustainability, and emotional well-being.

This project addresses the need for actionable insights in the intersection of neuroscience, nutrition, and technology. It aims to solve problems such as the lack of accessible, real-time methods for tracking the emotional and cognitive impacts of food, which currently limits personalised dietary interventions and sustainable eating practices.

By combining advanced AI-driven bio-signal analytics, wearable technology, and user-centric design, the project offers solutions tailored to diverse contexts. For individuals, it provides personalised dietary recommendations that enhance well-being and empower proactive health management. For industries, it delivers data-driven insights to create products that emotionally and cognitively resonate with consumers while encouraging sustainable practices. In this way, the project bridges the gap between emerging technologies and practical applications, fostering a healthier, more sustainable future in both personal and industrial domains.

5.5. Context

The Nourish tool has the potential to create significant value across multiple sectors, including healthcare, the food and beverage industry, technology, and environmental sustainability. In healthcare, the tool offers professionals like dietitians, nutritionists, and mental health providers a way to personalise interventions by understanding how specific foods influence emotional and cognitive states. In the food industry, manufacturers and product developers can use the tool to validate claims, optimise product formulations, and enhance consumer satisfaction through targeted innovation.

Additionally, the integration of cutting-edge AI and wearable technologies positions the tool as a driver of advancements in real-time health monitoring and bio-signal analytics, making it highly relevant in the technology sector. Furthermore, the tool's alignment with sustainability goals supports eco-conscious practices in food production, encouraging a shift toward healthier and more environmentally responsible choices.

While the tool's versatility allows it to deliver value across various domains, its primary focus is on two key areas: enabling food manufacturers to test and refine their products by measuring emotional and cognitive outcomes before market launch, and empowering healthcare and nutrition specialists to improve their recommendations.

By offering actionable insights derived from precise bio-signal analysis, the tool ensures that new products meet consumer expectations for both emotional and cognitive well-being. Simultaneously, it enhances the ability of health professionals to tailor dietary recommendations, supporting improved health outcomes and a more informed approach to nutrition. This dual focus ensures the tool's impact is both wide-reaching and deeply integrated into critical sectors.

5.6. Users

The Nourish tool is built with a wide range of users in mind, from everyday individuals to professionals in food, healthcare, and technology. Below, we break down the key user groups and how they'll interact with the tool, highlighting its real-world impact.

Primary Users
Consumers - For individuals wanting to understand how their food choices affect their emotional and cognitive well-being, the Nourish tool offers intuitive feedback. It helps users identify foods that enhance their mood, sharpen focus, or support sustainable habits, empowering them to make choices aligned with their personal goals and values.

Food Industry Stakeholders - Manufacturers, ingredient suppliers, and product developers can leverage the tool to refine their offerings. By measuring how products affect consumers emotionally and cognitively, they can validate claims, improve recipes, and create more targeted marketing strategies. This gives businesses a competitive edge while ensuring their products genuinely connect with consumers.

Healthcare Providers - Nutritionists, dietitians, and mental health professionals will benefit from deeper insights into how specific foods influence their clients' cognitive and emotional states. With this information, they can design personalised interventions, enhancing the effectiveness of their treatments and improving outcomes for their clients.

Secondary Users

Policy Makers and Researchers - The tool's ability to gather large-scale, anonymised data opens up possibilities for tracking population-level trends. Policy makers can use these insights to shape public health strategies, while researchers can uncover new links between nutrition and mental health.

Educators - Teachers and trainers in nutrition and neuroscience can use the tool to bring their lessons to life. By showing the connection between food, brain activity, and well-being, they can inspire students to explore these fields more deeply.

General Public - Even those who don't directly use the tool stand to benefit from its ripple effects. By promoting healthier eating habits and supporting sustainable food systems, the Nourish tool contributes to better overall health and well-being in society.

5.7. Technology

- The Core of the Tool: Artificial Intelligence

At its heart, the Nourish tool is powered by an advanced artificial intelligence system designed to uncover how food affects emotional and cognitive states. By analysing EEG signals, the tool provides real-time feedback on how dietary choices influence mental well-being and performance. Its machine learning algorithms process this data, identifying meaningful patterns that reflect emotional responses like joy or calmness and cognitive factors such as focus or clarity. This information is then presented through an intuitive interface, making the tool accessible to consumers and professionals alike.

The AI-driven technology is the foundation of the Nourish tool, offering a non-invasive, scalable solution for personalised nutrition and dietary optimisation.

-Validation Through EEG Studies

To ensure the reliability and precision of the tool, a comprehensive validation study will be conducted with 30 participants, testing both its emotional and cognitive components.

- Emotional Component

Participants will sample various foods while wearing an EEG device, which will capture brain activity in real time. The system will analyse emotional states using established metrics like valence (positive or negative reactions) and arousal (the intensity of those reactions).

- Setup: Participants will encounter foods specifically chosen to elicit a range of emotional responses.
- Validation: The EEG data will be cross-referenced with subjective emotional questionnaires to confirm accuracy.

- Cognitive Component

This part of the study focuses on how food consumption affects cognitive performance.

- Participants will complete a baseline task, such as a Stroop test, before consuming specific foods.
- Two groups will be tested: one consuming processed foods and the other non-processed foods.
- After eating, participants will repeat the task, allowing the tool to measure changes in focus, memory, and attention.

- EEG Recording Setup

The validation study will utilise the Enobio EEG system, a cutting-edge tool by Neuroelectrics®, to ensure high-quality data collection.

- Wireless Design: Provides participants with freedom of movement and comfort.
- High Sampling Rate: Ensures precise neural activity capture, critical for reliable metrics.
- Ease of Use: A dry electrode setup minimises preparation time, making it practical for studies involving multiple participants.

This system's robust design and neuroscience-focused features make it an ideal choice for the Nourish tool's validation process.

- Artificial Intelligence and Machine Learning

The Nourish tool's AI processes EEG data to extract meaningful insights with a clear and structured methodology:

Preprocessing

EEG data is cleaned to remove noise and artifacts through:

- Band-pass filtering: Focuses on relevant frequency bands.
- Independent Component Analysis (ICA): Removes unwanted artifacts like muscle activity or environmental interference.

Feature Extraction

Key metrics related to emotional and cognitive states are isolated, forming the foundation for deeper analysis.

Machine Learning Models

- Emotional State Classification: Algorithms like Support Vector Machines (SVM) and Convolutional Neural Networks (CNN) identify emotional patterns.
- Cognitive State Estimation: Regression models link EEG features to cognitive task performance.

- The Role and Impact of Integrated Technology

The Nourish tool excels because it integrates wearable EEG technology with advanced AI, offering precise insights into how food influences emotional and cognitive well-being. By leveraging real-time EEG data, it enables users to understand how meals affect their mood, focus, and overall mental state, bridging neuroscience and practical applications effortlessly.

- Scalability and Adaptability
The tool is designed to evolve with advancements in technology:
- Next-Generation EEG Devices: The tool can integrate with new, more user-friendly EEG systems, ensuring ongoing compatibility and enhanced accessibility.
- New Sensor Technologies: Additional data streams, such as heart rate variability (HRV) or skin conductance, can be incorporated to complement EEG-derived insights.

This flexibility ensures the tool remains relevant and effective as technology advances, providing enriched user experiences over time.

- AI-Driven Analysis
The AI core transforms complex EEG data into actionable feedback, relying on validated datasets and pre-trained models to ensure consistency and reliability.
- Precision: The system accurately classifies emotional states and cognitive performance, offering robust, actionable results.
- Flexibility: Modular AI models allow for seamless updates, ensuring adaptability to new datasets or evolving user needs.

- **Enabling Future Demands**
The Nourish tool's modular design ensures it can integrate with emerging hardware and software advancements, keeping it future-proof in a rapidly changing technological landscape.

Sustainability and Societal Impact
By promoting healthier and more sustainable dietary choices, the tool supports individuals and industries in aligning with environmental and societal goals.
Broad Market Applicability
Its versatility allows for applications in healthcare, the food industry, and personalised nutrition, ensuring its relevance across a diverse range of user needs.

- **A Future-Proof System**
The Nourish tool isn't static—it's designed to grow alongside advancements in technology and user expectations. Whether used with the latest EEG devices or emerging biosensors, it remains a scalable, adaptable solution that continues to deliver meaningful insights into emotional and cognitive well-being.

5.8. Ethical, social and environmental considerations

In a world of rapid technological progress and a growing awareness of the intricate connection between diet and mental health, the Nourish tool emerges as a groundbreaking innovation. Combining cutting-edge EEG technology and artificial intelligence, Nourish offers individuals and industries unique insights into how food affects emotions. By doing so, it not only keeps pace with future dietary trends but also addresses the increasing focus on mental health as a key aspect of overall well-being. As societies place greater importance on mental health alongside physical health, Nourish provides a

way to measure the emotional impact of food in real-time. This empowers users to make better dietary choices, enhancing their health and emotional balance. But the benefits extend beyond individuals. The tool has the potential to transform the food industry by driving changes in product development and marketing, ensuring that emotional health benefits become a central focus in new food offerings.Nourish also aligns with broader societal shifts towards sustainability and personalised nutrition. By helping people understand how food influences their moods and cognitive functions, it promotes a move away from generic dietary guidelines towards tailored, emotionally-conscious eating practices. Its ability to merge scientific rigor with user-friendly design makes it accessible to a wide audience, positioning it as a potential disruptor in the market.
Looking ahead, Nourish is poised to become a vital part of proactive health management. It enables users to make dietary choices that benefit their personal health while supporting global sustainability goals. This dual impact highlights its potential to improve individual well-being and contribute to public health initiatives, paving the way for a future where tech-driven, emotionally-intelligent dietary planning becomes the norm.

6. Open Agrobiodiversity Accounting Kit OAAK

Genomic Gastronomy & NICETRAILS

6.1. Concept description

OAAK is a digital tool that facilitates participatory, place-based, species-quests for agricultural biodiversity accounting on small scale farms. OAAK is designed to reconnect eaters and farmers, in the process of generating meaningful and useful data sets that can be used to meet biodiversity standards or participate in biodiversity credit schemes as they emerge in the next decade. The tool combines AI and citizen-science 1 to facilitate ongoing assessment and care for agricultural biodiversity in Europe, creating the digital infrastructure to empower many actors in the agricultural green transition.

OAAK is a service for agritourism agencies that bring people to farms as a day activity. Farmer registers to OAAK and inputs contextual information: location, size, crops, and available dates. The farms than becomes available on the app. Agency registers to OAAK with group size, and available dates. OAAK welcomes the visitor and provides contextual information using a mix of information registered by the farmer information and geolocalized data, defines quest variables specific to them and triggers the visitor with challenges.

The tool can measure species diversity focuses on cataloging species (plants, animals, fungi) at specific locations and times, temporal changes through continuous assessments can allow tracking changes in biodiversity over time and the environmental context through existing data on regional and site-specific biodiversity enriching OAAK performance.

6.2. Connect to the scenario

We started with the scenario “Biodiversity as the measure of healthy food systems” and the key assumption that top-down regulation or a biodiversity credits market will implore or encourage farmers to measure biodiversity. Small-scale farms have less resources to do this than large-scale conventional farms do, and farmers are already very busy and overwhelmed with paperwork. The task of measuring biodiversity needs to be simplified.

After identifying the values we held like pleasure, optimism, openness, resilience, adaptability, commitment, and equity, we asked ourselves the critical question: “What future are we building?” When we look at the (agro-)tech market, we see the development of smart machines, and the de-skilling of humans. Humans are more and more isolated by alienating technologies. In contrast to this, OAAK aims to build a future that is: convivial, community-oriented, re-skilled, healthy, and resilient. Thus, we want to build a technology that is: social, embedded, multi-purpose, and cooperative.

6.3. Opportunities and Keywords for concept

A market for biodiversity credits is starting to emerge, and it is unclear how these new financial instruments will be tied to biodiversity on farms. The opportunity is to explore and experiment with the technologies that will be used in the emerging biodiversity credit framework. There are already some companies developing the technologies and systems for measuring and reporting biodiversity, but their focus is on larger conventional farms where there is a stronger business case to be made using proprietary systems. They are interested in building a tool that is useful for smaller and alternative farms, who will not be able to afford proprietary systems, but already have decades of experience in cultivating biodiverse agroecologies.If food is medicine, first it should do no harm. How can small-scale and local farmers who are already transitioning towards biodiverse modes be included in the development of tools, markets and technologies for valuing biodiversity?

Agricultural sustainability # Agricultural biodiversity # Small-scale farms # Participatory approach # Green transition # Place-based species quests # Eaters and farmers connection # Digital tool # AI integration

6.4. Challenge statement

Specific Challenge:
If in the future biodiversity is the measure of a healthy food system, agrobioversity needs to be measured effectively. To do this, our prototype should address the challenges and findings from our primary research. Through stakeholder interviews, we learned more about the wants, needs, and challenges of small-scale farmers in terms of biodiversity measurement and tech. We learned that:
- farmers are already using AI to help with agricultural paperwork,
- timing matters and farmers don't want to type in data at 2am after loading the delivery truck.
- Social hybrid models with human + chatbot helpers worked for engaging farmers with new tech.
- DIY counting and measuring techniques are used to assess biodiversity in food forests using printed PDFs with community protocols for assessing biodiversity, but this requires a lot of human resources.
- Automating some parts of biodiversity counting would be helpful, but farmers don't want to involve tech on the farm just for tech's sake. It has to be simple, meaningful, and impactful.

Problems it addresses:
- In the future it will be necessary or advantageous for farmers to measure the biodiversity on their farms, but this adds an additional managerial and reporting task to their workload.
- Biodiversity is dynamic and needs to be measured throughout time to get an accurate picture and to see change over time.
- There are currently various citizen science platforms for counting species in the wild, but fewer initiatives are doing this for agricultural sites.

6.5. Context

FARMERS: Facilitates biodiversity assessment, brings potential consumers on site (for direct sales opportunities or future relationships). The farm becomes a site of knowledge production.

AGROTOURISM: Provides an agro-tourism experience and brings people to the farm under the umbrella of leisure.

CITIZEN SCIENCE: Bridges wild biodiversity citizen science approaches with food systems and farming.

EDUCATION: Creates an offering for formal and informal educational organizations at many age ranges. This is an offering that can be more carefully developed after the creation and testing of the more general citizen science prototype. It is an off-shoot of citizen-science, ie. a way of introducing citizen science within a formal educational setting.

SOCIAL, CULTURAL & ECOLOGICAL EXPERIENCE & KNOWLEDGE: brings eaters to the farm to reconnect with the landscapes of production and re- skills a population who is otherwise alienated from agricultural practices.

DATA: It tailors biodiversity assessment specifically to agricultural settings and a specific farm, and incentivises ongoing assessment, creating a rich data set for interested data brokers.

HEALTH: Promotes environmental health through promoting agrobiodiversity. Promotes human nutritional health by highlighting the importance of biodiversity on the farm and therefore in the human diet. Promotes secondary health benefits (ie. air quality) through ecosystem services created by agrobiodiversity. Secures human health by promoting local agrobiodiversity that insures food supply chain security.

6.6. Users

1. EATERS (ex. CITIZEN SCIENTISTS / AGRO TOURISTS / STUDENTS / ACTIVISTS)

Eaters will visit a farm, use OAAK to sense the biodiversity, and experience a fun quest. (Interaction described at 3A).
Besides the experience, the visitor gets a comprehensive data-driven visual memento of their experience. (To be designed)

2. FARMERS (ex. FOOD FORESTS, FARM IN TRANSITION, BIOLOGICAL FARMS)

Farmers will enroll their farm to OAAK, and host “data foragers” to periodically assess the biodiversity of their farm and see how it is doing over time and in comparison with the region.
Farmers get a web-based list of species found and possibly present on their farm, presented in a dynamic way that allows for intuitive and holistic comparison and visualization of the gathered data.
OAAK intentionally does not provide advice on biodiversity strategies based on the data found.

3. DATA BROKERS (ex. ACADEMIA, POLICY MAKERS, ENVIRONMENTAL NGOS)

Data Brokers will use the aggregated biodiversity indices found in farms to shape policies, research and planning.
OAAK in full launch, implementation and adoption would generate a useful dataset of biodiversity species found on small farms. For the scope of MUSAE and the TRL5 horizon, we are aware that the amount of data generated by the prototype during testing will be limited.
Data will be reviewed and cleaned before releasing the dataset.
This dataset will be published according to the open datasets and contribute to the data.europa.eu2.
Subsequent versions of the dataset will be released as new data is generated by OAAK.

6.7. Technology

OAAK plans to use the following technologies in our TLR-5 Prototype:

- AI Vision Models / to identify species. This has yet to be determined if the tool relies on a specialized species detection model or if we use the image recognition capabilities of multi modal LLMs.
- LLMs / to build a dynamic guide based on user inputs, location, and specification of the expectations of the farmer.
- DATA APIs / to gather existing contextual data. The iNaturalist API has been tested and is strongly considered.
- AI Embeddings / to compare and propose visualisations of the gathered data in an intuitive and holistic way.

The tool gathers a site-specific collection of data that might be composed of visuals (photos), knowledge (found species) and metadata (location and time).
The tool aims to be a visually conversational contextual interface that guides the user to seek out species in certain places or using certain methods. Example: "since you found plant X [photo], you can dig a hole in the soil and look for insect Y [photo], which normally lives nearby".
The tool compiles a growing crowdsourced agrobiodiversity dataset of species, location and time.

6.8. Ethical, social and environmental considerations

- 1st Order Impacts

- Ethical Effects:
-Farms without biodiversity can't fake it.
- Social Effects:
- People spend more time together on farms.
- Farmers host more visitors on their sites.

- **Economic Effects:**
- Species on farms are counted, and farmers can use this info to report on biodiversity to avoid penalties or get credits.

- Environmental Effects:
- We have a better understanding of what species can be found on site.
- Some species are damaged because of visitor foot traffic

- 2nd Order Impacts

-Ethical Effects:
- Eaters know the real physical context of the food.
- We help people to reconsider their impact on living creatures around them.

- Social Effects:
- People can feel more connected to the biodiversity that surrounds them and cultivate a more intimate relationship with living organisms.

- Farmers focus on farming and not paperwork.
- **Economic Effects:**
- Generating valuable data for policymaking and research.
- Shortening supply chains: Consumers/eaters buy directly from new vendors.
- Overburden: Visitors are one more thing for the farmer to manage
- **Environmental Effects:**
- Biodiversity is measured across time so that improvements can be made.
- Scientists can use the data to conduct research and build bigger datasets.

<u>- 3rd Order Impacts</u>

- **Ethical Effects:**
- Eaters know the real physical context of their food.
- Biodiversity measurement isn't framed as policing.
- Promoting environmental health.
- Including wild non-humans in accounting.
- Agricultural / Ecological Transparency.
- **Social Effects:**

Forming a community of citizen scientists interested in biodiversity by visiting other people's profiles.

- People can learn about the ecosystems their foods come from.
- **Economic Effects:**
- Value exchange: Farmers get data, eaters get an experience.
- Citizen science data could be appropriated for profit.
- **Environmental Effects:**
- Bad behavior: Visitors to the farm make a mess or trample over the growing plants.

7. Remedy Garden

Baum & Leahy & Blast Studio

7.1. Concept description

Remedy Garden is a bio-inclusive architectural system cultivating medicinal food for urban holobiont health. This vertical garden is constructed from reclaimed clay and bricks 3D-printed into biomorphic modules tailored to organism-specific needs and inspired by the morphology of the human digestive system. Designed as habitats for diverse plants and insects, its multi-layered structures foster interspecies relationships while ensuring efficient water irrigation, creating a sustainable, low maintenance ecosystem.

Built in connection with urban health and medical facilities, such as GP's, pharmacies, hospitals and herbalists, Remedy Garden offers a sensorial, aesthetic experience while exemplifying future systems where microbiodiversity and knowledge of 'food as medicine' is integrated in our cities.

Communication about the project as well as information on the different species and recipes is integrated into the site. As well as the modules designed to host plants and insects, 3D-printed seating elements invite visitors to rest and engage sensorially with the garden. The species within each garden are site specific, yet all share the aim of nurturing holobiont health by taking into account both micro- and macroscopic dwellers. Examples include Calendula (Marigold) which is anti-inflammatory and supports gut health, and Garlic, which is high in prebiotic compounds such as inulin that feed beneficial bacteria.

7.2. Connection to the scenario

As we design the system itself we aim to manifest the values presented in the Holobiont Gardens scenario and identified in the Future Compass.

The sentences in italics are from the scenario and then the text below expands on how these values translate into our current work:
We're in 2034. The world has been transformed by our understanding of all living organisms as holobionts.
Value #1: Education – we wish for the Remedy Garden to have educational value by creating embodied experiences of knowledge about holobiont health, both physically in the garden, and through a digital representation with further descriptions.
Symbiosis is the algorithm, biophilia is the experience, biodiversity is the ongoing goal.

Value #2: Sustainability – we wish to inspire sustainability on many scales, from the intimate and sensorial, to the personal and social, to the planetary and long term.
Our systems and practices are rooted in traditional ecological knowledge – TEK, environmental justice and interdisciplinary research into food as medicine.

Value #3: Personal and planetary health – we wish to build on both TEK and new technologies, engage with social aspects of its implementation.
In this world sacred practices are cherished and encouraged as part of our everyday lives and systems of health.

Value #4: (Multispecies) Community care – we wish to foster communal experiences across cultures, species and disciplines.

In addition, our core values for this process are Accessibility and Long term perspective - asking ourselves as we design it what influence do we aim for this to have in the future?

7.3. Opportunities and Keywords for concept

There are opportunities for agrotech companies specializing in the development of agricultural technologies that are compostable or biodegradable, minimizing waste and environmental impact; technological firms that focus on the creation of hardware that is designed to have a minimal environmental footprint and can be integrated back into the earth without harm; waste management enterprises focusing on the transformation of electronic and plastic waste into useful materials for agricultural or technological purposes; companies specialized in green technologies aiming at powering agricultural technologies without contributing to pollution or waste; tech firms creating smart packaging solutions that integrate with digital systems to monitor freshness, reduce waste, and improve the supply chain's efficiency and transparency.

Bio-inclusive architecture #Urban health # Micro Biodiversity # Medicinal Food # Holobiont Health # Prebiotic Compounds # Vertical Garden # Water Efficiency # Sustainable Ecosystem # 3D-printed biomorphic # Interspecies Relationships # Sensorial Experience

7.4. Challenge statement

In 10 years, how might we build public infrastructure that can nurture biological and social relationships between humans & non-humans?

7.5. Context

The Remedy Garden delivers value across multiple domains and sectors, addressing critical challenges in public health, biodiversity, and sustainable urban development. By combining bio-inclusive design, healthcare innovation, and community engagement, the project bridges diverse fields and offers a holistic approach to urban health and well-being.

Domains
1- Public Health and Complementary Medicine – The Remedy Garden integrates medicinal plants and natural remedies into healthcare environments, supporting a shift toward preventive care and holistic healing. By providing patients access to medicinal plants and fostering a calming, biophilic

environment, the garden enhances mental and physical well-being.
2- Local Medicinal Food Supply – The system promotes the local production of medicinal plants and herbs directly within healthcare and community environments. This aligns with the concept of “food as medicine”, enabling on-site access to plants like garlic (for prebiotics) and calendula (anti-inflammatory benefits) that can support personal and community health.
3- Biodiversity Conservation – By introducing bio-inclusive modules that create habitats for insects, plants, and microbes, the Remedy Garden supports biodiversity in urban areas. It encourages multi-species coexistence and contributes to global efforts to reverse biodiversity loss.
4- Architecture and Urban Planning – The project supports integrated, modular, and nature-based infrastructure that can be embedded in urban healthcare facilities, community gardens, and public spaces. By using local waste materials and 3D printing, it introduces new methods of circular material use and parametric design, providing inspiration for future architectural projects.

Sectors
1- Healthcare – The primary sector for the Remedy Garden is healthcare, with applications in GP clinics, hospitals, pharmacies, care homes, and herbalist centers. It offers a biophilic, low-maintenance design that enhances the healing environment, supports mental well-being, and offers patients access to medicinal plants as part of a preventive healthcare strategy.
2- Community Engagement – The Remedy Garden fosters community involvement and environmental education by encouraging interactions with holobiont health, biodiversity, and "food as medicine". Through educational workshops and interactive signage, communities learn about medicinal plants, local biodiversity, and sustainable urban living. This sector includes schools, community centers, and public gardens where hands-on learning can take place.
3- Health, Nutrition, and Food Environments – The project supports a broader shift toward food security and local food production by enabling the growth of locally sourced medicinal plants and herbs. It aligns with broader efforts in sustainable food systems, enabling healthcare environments to become sites of local food production, thereby supporting the growing interest in natural remedies, gut health, and microbiome support.

The Remedy Garden operates at the intersection of health, biodiversity, and community empowerment. By embedding medicinal plant systems within healthcare, architecture, and food production, it offers value to key stakeholders in both the public and private sectors. This multi-dimensional approach ensures that the project delivers impact on a local, community, and systemic level, with the potential to redefine healthcare spaces, public green infrastructure, and food environments.

7.6. Users

The Remedy Garden serves a variety of users, with a primary focus on healthcare facilities such as GP clinics, hospitals, pharmacies, and care homes. It is designed to benefit healthcare workers, patients, and facility managers, while also supporting biodiversity through non-human users like plants, insects, and microbes.

Primary Users

1- Healthcare Workers (nurses, doctors, support staff)

- Role: Healthcare workers benefit from the calming, nature-driven design of the garden, which enhances recovery spaces and waiting areas in hospitals, GP clinics, and care homes.
- Actions: Their role is largely passive, as the system is low-maintenance and self-regulating. Healthcare workers may also facilitate therapeutic activities with patients, using the garden as a space for sensory engagement.

2- Patients (hospital patients, GP visitors, care home residents)

- Role: Patients are the main beneficiaries of the biophilic environment. Exposure to nature is known to reduce stress, promote relaxation, and enhance mental well-being.
- Actions: Patients interact with the garden by observing, touching, smelling, and learning about medicinal plants. For those receiving preventive care or alternative therapies, the garden may provide access to fresh medicinal plants like calendula and garlic, supporting a natural approach to health and healing.

3- Facility Managers and Maintenance Staff

- Role: While the system is self-sustaining and low-maintenance, facility managers ensure it remains operational, clean, and visually appealing.
- Actions: Maintenance tasks include periodic checks, pruning, and removal of dead plants, which can be composted on-site. The use of water-resistant biomaterials and passive design significantly reduces the amount of maintenance compared to traditional gardens.

4- Non-Human Users (plants, insects, and microbes)

- Role: Plants, insects, and microbes are essential to the concept of the holobiont garden. The system provides habitats, food, and shelter for these organisms, while they support biodiversity and sustain the ecosystem.
- Actions: Plants grow within adaptive modules made from moisture-retaining biomaterials. Pollinators and insects use the system as a refuge, supporting the pollination of plants, while microbes decompose organic material, enriching the soil and supporting healthy plant growth.

Secondary Users

Urban Residents and Passers-by

- Role: Residents, visitors, and passers-by interact with external-facing modules located in semi-public spaces near healthcare facilities (like courtyards, public walkways, and waiting areas).
- Actions: Their interactions are mostly passive, such as observing the plants, touching foliage, or engaging with educational materials like QR codes that provide information on biodiversity, microbial health, and medicinal plants.
- Impact: By encountering the Remedy Garden in public spaces, passers-by develop a greater appreciation for nature and biodiversity. This indirect engagement may inspire advocacy for green spaces and support bio-inclusive urban environments.

Other Potential Users (Future Expansion)

While the current focus is on healthcare environments, the Remedy Garden has significant potential to expand its impact:

- Urban Garden Networks – Community garden networks can integrate the system into shared green spaces, supporting local food sovereignty and education.
- Private Users – Over time, the system could be made available as a modular product for home use, allowing individuals to create at-home bio-inclusive gardens.
- Educational Institutions – Schools, universities, and community learning centers could use the Remedy Garden as an educational tool for biology, ecology, and sustainability learning.

Summary

The Remedy Garden focuses on healthcare facilities as its primary user context, where the system's impact is most profound. It offers significant benefits for healthcare workers, patients, and facility managers, while also supporting biodiversity through plants, insects, and microbes. Secondary users like urban residents and passers-by engage with the system in public spaces, promoting education and awareness of biodiversity and natural remedies. As the concept evolves, it has the potential to scale into urban gardens, public spaces, and private homes, creating a network of holobiont gardens that support health, biodiversity, and community well-being.

7.7. Technology

Summary of Key Innovations

Our technological development is based on three key innovations that span materials, design, and production. Together, these innovations enable the creation of bio-inclusive, sustainable, and scalable architectural systems.

1. Material Innovation

- Locally sourced waste streams are revalued into functional biomaterials.
- We develop two types of biomaterials: plant-supporting blends for internal modules and water-resistant blends for external durability.

2. Design Innovation

- Our generative design algorithm produces plant-specific geometries using parameters like sunlight, water, and drainage.
- Each module is customized for specific plants and adapted to local environmental conditions, ensuring that form follows function.

3- Technological Innovation

- We are developing a patentable extruder system that supports the use of bio-based materials.
- Key features include anti-clogging, continuous material flow, shrinkage compensation, and compatibility with standard robotic arms.

These technological innovations allow us to achieve a scalable, circular, and site-specific approach to bio-inclusive design. By leveraging waste-based biomaterials, generative design, and robotic 3D printing, the Remedy Garden offers a blueprint for future-oriented, low-impact architectural production. This system has the potential to be replicated in urban centers worldwide, supporting biodiversity, community health, and circular manufacturing.

7.8. Ethical, social and environmental considerations

The Remedy Garden is designed to have a positive ethical, social, and environmental impact by fostering biodiversity, supporting community well-being, and promoting sustainable material use. Guided by the principles of accessibility, equity, and sustainability, the project addresses key issues in public health, environmental protection, and community engagement.

Ethical Considerations

The ethical foundation of the Remedy Garden centers on equity, accessibility, and inclusion. By prioritizing universal access and shared responsibility, the system ensures that the benefits of biodiversity and well-being are available to all, regardless of socioeconomic status.
- Accessibility for all socioeconomic groups – The Remedy Garden aims to prevent the creation of exclusive green spaces accessible only to privileged communities. By embedding these gardens in healthcare facilities and public spaces, it offers equal access to nature, medicinal plants, and educational experiences for diverse communities.
- Decentralized production and local sourcing – By sourcing materials from local waste streams, the project supports the use of regional materials, creating a localized supply chain that benefits the local economy while reducing transportation-related carbon emissions.
- User-centered design – The design of the system is based on a low-maintenance, passive approach, which reduces the need for high-skill technical intervention. This approach ensures that healthcare workers, community members, and urban gardeners can all engage with the system without requiring specialized knowledge or tools.

Social Considerations

The Remedy Garden has a significant social impact on education, health, and community engagement. It is not only a physical infrastructure but also a platform for fostering human-nature relationships, supporting mental well-being, and promoting active learning.
- Education on biodiversity and natural remedies – The system serves as an interactive educational tool for local communities, schools, and healthcare visitors. By showcasing the role of medicinal plants, fungi, and microbes in personal and planetary health, it raises public awareness of "food as medicine" and encourages biodiversity-conscious behavior.
- Community stewardship of urban green spaces – The Remedy Garden offers an opportunity for community-driven co-management. Through partnerships with urban garden networks and local communities, the system invites collective care and shared responsibility, encouraging people to engage in the maintenance and use of green spaces. Community participation also promotes a stronger sense of ownership and connection to local biodiversity.

- Mental health and well-being – By creating bio-inclusive, biophilic spaces in healthcare environments, the system contributes to improved mental health outcomes. Exposure to nature has been shown to reduce stress, anxiety, and depression. The Remedy Garden provides a space for reflection, sensory stimulation, and emotional recovery for patients, visitors, and healthcare workers alike.

Environmental Considerations

The environmental impact of the Remedy Garden focuses on waste reduction, circular design, and biodiversity enhancement. It turns waste streams into valuable resources, supporting circularity while encouraging the regeneration of urban biodiversity.
- Reduction of urban waste – The system transforms waste materials from construction, coffee cups, and sawdust into valuable biomaterials used to create modules. By revaluing waste materials, it reduces landfill waste, avoids virgin material extraction, and supports a local circular economy.
- Biodiversity enhancement – The bio-inclusive design creates habitats for pollinators, plants, and microbes, supporting the health of urban ecosystems. By incorporating spaces for beneficial insects, like pollinators, and fostering the growth of diverse plant species, the system contributes to local biodiversity and ecosystem health.
- Climate resilience – By supporting local food production and medicinal plant cultivation, the system contributes to urban food security. It also encourages passive water retention and the management of rainwater.
- Sustainable material sourcing – The use of local recycled materials (like clay, sawdust, and coffee cups) ensures a low-carbon production process, further reducing the environmental footprint of the Remedy Garden. This supports the decarbonization of the construction and manufacturing sectors, as less energy is required to transport and process materials.

Economic Considerations

The economic impact of the Remedy Garden is linked to its role in waste revalorization, cost-effective production, and job creation. It supports local economies by using local waste streams and providing low-cost infrastructure solutions for public and healthcare spaces.
- Reduction of production costs – By using locally sourced waste materials, the cost of material acquisition is significantly reduced. This localized production model eliminates the need for raw material imports, reducing costs and transportation-related carbon emissions.
- Job creation and skills development – The adoption of modular 3D printing technology and circular material production can generate jobs related to local material collection, biomaterial processing, and system assembly. This contributes to local employment and the development of skills in circular design, 3D printing, and ecological stewardship.
- Reduction in maintenance costs – The low-maintenance nature of the system ensures that healthcare facilities, urban gardens, and community spaces do not need to allocate significant resources to upkeep. The passive design features (e.g., water collection, pest control, and self-regulating growth) reduce the need for intervention, lowering maintenance-related costs.

Summary

The Remedy Garden addresses ethical, social, environmental, and economic challenges through its design, production, and operational model. It ensures accessibility for all socioeconomic groups, provides educational and mental health benefits, and promotes biodiversity and circular economy principles. By using local waste streams, decentralized production, and low-maintenance systems, the Remedy Garden presents a model for sustainable, inclusive, and future-ready urban design. This impact spans community engagement, mental well-being, and the creation of new green spaces within healthcare and urban environments.

8. S.O.I.L.

Letizia Artioli & Uptoearth Italia

8.1. Concept description

Grounded in the exploration of soil as a living entity within the framework of Bio-Intelligent Data, the project investigates the profound interconnection between the human body and the soil through sensory and proprioceptive processes embedded in an innovative wearable technology. Central to this exploration is the concept of attunement, where the wearer aligns iteratively with the dynamic rhythms of the soil, fostering an embodied awareness of its health and vitality.

By translating environmental data into tactile and sonic stimuli, it amplifies the wearer's awareness, creating a symbiotic relationship with the earth's skin: soil as a living, breathing entity. The aim is to foster a reimagined engagement with the environment through sensorial stimuli that reconnect humans with soil's intrinsic value. This holistic approach frames soil as "S.O.I.L.—Sensing Outer Identities Landscape," emphasizing its central role in ecological and sensory regeneration.

8.2. Connection to the scenario

The concept of a wearable technology that can enhance and merge the human proprioception with soil's data is inscribed in the chosen scenario of BIO INTELLIGENT DATA.

From the century where media are considered as environments, the future scenario offers entire environments as media. The project weaves an intrinsic connection and new languages for the flow of bits and atoms that runs between the starting point of the food chain (soil and landscape) and our own sensing (our body). The aim of the project is to amplify and connect the human body to data sensed from the environment. By translating these data collected into haptics and impulses, a new language based on sensorial stimuli re-weaves our connection with earth.

In a future where the rhizosphere's biodiversity is compromised, and at the same time the limit between physical and digital world is blurred due to the increasing data production, Bio intelligent Data is a Hybrid landscape between the human body + identity and the environment. By using the constant fluxes of data as a design matter, the project plays on the dichotomy of bits and atoms that we constantly exchange with the environment. Using data as the responsive tapestry that interlinks humans and the environment, by translating the bits that decodes soil's health (data), into experienceable stimuli (sound and vibration) on the human body, a further connection between the human body and the environment is established. This nexus gives voice to the hidden part of the nutrition chain, the starting and ending point of every food we eat, the soil. To hear the soil microbiome, and to feel the shivers of the soil's thirst, puts a bio-responsive communication at the center of the balance between humans and non-humans. The developed tools could make the human body as the main sensor and filter through which we perceive the environment and the ecosystems we are part of, by a symbiotic horizontal flow of data that shows non-human exigencies (soil is a living entity) and invisible patterns. The project aims to unveil and give voice to the "voiceless" surface that lays under our feet, overlooked and exploited for centuries (SOIL acronym: Sensing Outer Identities Landscape).

The chosen perspective of the scenario has several implications:
1.Human body as a source for decision-making, (Leveraging biological intelligence).
2.LIVING DATA deeper understanding of the biological world. An organic and emotion-based network connects people to their environment, rooted in living data.
3.Transitions between data and reality blurred, between visual (and physical) representation of this data and natural environment (responsive tapestry).

8.3. Opportunities and Keywords for concept

The team recognize the project's potentialities as applicable in 3 main areas:

I.HUMAN-SOIL NEXUS /hybrid ecosystem
The project fosters a profound connection between humans and the environment through experiential and sensorial stimuli. By establishing a deeper, horizontal and un-subjective (objective-free) language it becomes a tool for identity shaping and informed decision-making.

This connection creates a physical feedback loop between the "soil symphony" and behavioural changes, paving the way for a Farmer-Soil Nexus 4.0 - a new paradigm for sustainable agricultural practices.

II.DATA

The concept addresses the complexity, uncertainty, transparency and reliability of data by creating a direct channel of communication between the human body and the soil ecosystem. By experiencing DATA FLOWS, users can bridge knowledge gaps across the DIKW-A (Data, Information, Knowledge, Wisdom – Action) Chain. This interactive approach transforms raw data into meaningful insights, fostering informed decision-making and a deeper understanding of ecological systems.

III.INTERACTION (TECHNOLOGY)

The concept enables real-time monitoring and interactions tied to specific place, seamlessly connecting scales:

- Macro to Micro: linking the human body to the intricate, non-human ecosystems living within the soil
- Micro to Macro: extending from the body to an entire territory and landscape

A radical transformation in how the quantity and quality of data flows are managed and ecosystems representations are conceived, leveraging wearable interaction technologies and smart agriculture systems. This approach establishes a dynamic feedback loop that fosters attunement and meaningful interaction between humans, technology and the environment.

Building on these foundational areas, the project unlocks additional future-oriented potentialities, with keywords such as:

- **Sustainability and Regeneration**

The concept actively supports regenerative agriculture, promoting biodiversity, restoring soil health and contributing to climate action.

- **Educational Impact and Public Awareness**

By visualizing soil data and facilitating interaction, the project raises awareness among diverse audiences about soil health's vital role in sustainable food systems.

- **Scalability and Adaptability**

Its modular and flexible design ensures applicability across diverse contexts, from smallholder farms to industrial operations, ensuring long-term viability.

- **Policy Influence and Standards Development**

The data-driven methodology offers transparent insights that can shape agricultural policies and environmental standards, fostering systemic change.

- **Empowering Local Communities**

Grounded in real-world case studies, the project empowers local communities with sustainable practices and strengthens their role as innovators and stewards of the environment.

- **A Model for Cross-Disciplinary Innovation**

Through its transdisciplinary methodology, the project showcases the potential of combining art, science, and technology to tackle complex challenges and drive innovation across domains.

8.4. Challenge statement

The project S.O.I.L. aims to be a tool for expanding human sensing and unveiling the hidden state of health of the rhizosphere. Between the human body and the surrounding landscapes where food is produced there is a constant data flow, just like the constant exchange of molecules and nutrients we have in/out our physical bodies. Data flows weave the stimuli and the invisible variations that characterize the ecosystem around us and transmit them amplified, embedded and ready to be embodied to the human soma. The project tackles the challenge of transducing data in a way that could establish an intimate and tangible connection between human health and soil health (S.O.I.L.=Sensing Outer Identities Landscape). In an over-datafied future where data are a responsive tapestry of reality between digital and physical realms, designing a deeper connection between our body and the surroundings ecosystem by making the exchange of data tangible (transduction, embedding, embodying of data input and output, data physicalization and sonification). The human body becomes itself a landscape (bodyscape) that experiences and senses the invisible variations that happen in the ecosystems surrounding us.

Invisible to the eyes, the critical loss of biodiversity and nutrition capacity of the soil is key and foundation of food chain production. The fragile balance between PH and several indicators that are specific of different soils, could be translated in a sonic & vibro-tactile language that speaks directly to the human body, composing and being composed to re-establish a holistic and balanced human-soil nexus. The wearable connects the human sensorial apparatus to the hidden data of soils' health state, translating them into sound and vibrations.

8.5. Context (Target domain description)

Agriculture and the production of high-quality food is the sector in which this project is expected to deliver significant value, particularly in a future-oriented vision. As the global demand for sustainable food production grows, the role of soil data will become increasingly critical. Reliable soil data will enable farmers to make informed decisions, optimize resource use, and minimize environmental impacts.

According to the 2024 report by ISPRA (Rapporto consumo di suolo, dinamiche territoriali e servizi ecosistemici), Italy's soil consumption and degradation are pressing issues that threaten ecosystem services and agricultural productivity. The report highlights that in 2023, Italy experienced a loss of over 72.5 square kilometers of soil, equivalent to the combined area of the buildings in Turin, Bologna, and Florence. This loss continues at a rate of approximately 20 hectares per day, surpassing the decade-long average of 68.7 square kilometers per year. The reduction in the soil's "sponge effect"—its ability to absorb and retain water—has resulted in an estimated annual economic cost of over 400 million euros.

This underscores the urgent need for innovative solutions that promote sustainable soil management. By integrating soil monitoring systems with wearable technologies, this project aligns with the goals of preserving soil health while fostering sustainable food systems.

Moreover, the integration of artificial intelligence (AI) and robotics in agriculture holds great promise for the future. However, as every technological advancement and innovation it holds uncertainty about the future implications, as a totalitarian tech-based agrifood sector poses the risk of distancing farmers from direct interaction with the soil, decreasing awareness and decision making. The tactile and sensory connection to the land, which has been at the heart of agriculture for centuries, could be lost.

This project aims to counterbalance this trend by re-establishing a direct, intuitive connection between farmers and the soil through wearable devices. By translating soil data into sensory experiences, sound and vibrations, it seeks to empower farmers with real-time insights while fostering a renewed perspective for the land they work. This approach not only supports sustainable practices but also ensures an enhanced human-soil connection in the future of agriculture.

The project aims to target farmers and citizens to promote a behavioral shift through a more respectful, sustainable and ethical use of soil as a living entity. By facilitating the interaction with the rhizosphere's state of health, giving the soil a voice, the invitation is to "listen" and "compose" with the soil.

8.6. Users

The scenario considers a major shift from the role of the "consumer" to the "explorer and listener of the invisible world". The user, whether in urban or rural area has access to gateway doors of knowledge and connection to the intricate mesh of reality that characterizes soil ecosystems.

The Team identified two main users' categories: farmers (primary) and urban citizens (secondary). These groups interact with the wearable device and its ecosystem in distinct ways, addressing their specific needs and fostering broader societal impacts.

Primary Users: Farmers
Farmers, especially next generation "smart farmers," who are embracing innovative methods and technologies in agriculture, are at the core of the project, leveraging innovative tools and methods to enhance precision agriculture.

Interactions:
Farmers interact with the wearable device and soil sensors to monitor key soil parameters (e.g. pH, moisture, nutrient levels) in real time.

- Tactile feedback: the wearable translates soil data into sensory stimuli, such as vibrations or sounds, creating a sensory "map" of the soil. This intuitive feedback mechanism allows farmers to assess soil conditions without needing complex interfaces,
- Data Visualization: farmers who prefer traditional data analysis can access a user-friendly digital interface (digital landscape) to visualize and interpret soil data in detail thus ensuring flexibility in how they engage with the information

Actions permformed:

- Make data-informed decisions about soil management, irrigation and crop treatments
- Enhance productivity by responding quickly to environmental changes
- Participate in training sessions using the wearable to learn and tech precision agriculture techniques

Impact:

- Improves operational efficiency and reduces resource use (e.g. water, fertilizers)
- Supports the transition to sustainable agricultural practices
- Encourages knowledge transfer and innovation through educational use cases

Secondary Users: Urban Citizens
Urban residents, often disconnected from rural ecosystems, are engaged through a scaled version of the device to reconnect them with the source of their food and the ecosystems sustaining it.

Interactions:
Urban citizens can encounter wearable or related devices in public spaces such as farmers' markets, educational farms, or community events. The devices translate environmental data (e.g., soil conditions, crop health) into sensory feedback, offering a direct and tangible connection to the soil.
Actions Performed:

- Explore environmental data linked to the origin of their food.
- Participate in interactive learning experiences focused on sustainability and ecosystem health.
- Adjust personal habits based on insights into food production and its environmental impact.

Impact:

- Raises eco-awareness and promotes sustainable consumption behaviors.
- Bridges the gap between rural food production and urban lifestyles.
- Supports community-driven environmental education initiatives.

Societal Impact
Beyond the immediate user groups, the project impacts a broader audience:

- Educational Institutions: The wearable becomes a tool for STEM education, teaching students about IoT systems, environmental monitoring, and data-driven decision-making.
- Environmental Advocates: Offers a tangible way to demonstrate the interconnectedness of human behavior and environmental health.
- Policy and Industry Stakeholders: Provides a replicable model of how technology can address global challenges like food security, climate change, and sustainable resource use.

This dual-focus user approach ensures that the concept is not only functional for its primary users but also inspires and educates secondary users, fostering a societal shift towards sustainable living and ecosystem stewardship.

8.7. Technology

The technology underpinning the project integrates two interconnected components: **IoT systems and wearable devices.**

These elements are designed to function cohesively within a comprehensive data chain, facilitating seamless communication and feedback between the physical environment and the human body. The IoT component gathers real-time data from the soil, capturing critical environmental metrics, while the wearable device interprets and conveys this information directly to the user. The data chain scheme below illustrates this dynamic flow, emphasizing the continuous exchange between the natural world and the individual, creating an integrated system that enhances situational awareness and decision-making. This approach positions the user as an active participant within the broader ecological and technological network.

8.8. Ethical, social and environmental considerations

The project is defined by a set of multidimensional advantages that align with ethical, social, environmental, and economic imperatives. Foremost is its commitment to transparency, ensuring ethical data practices that respect both users and the environment. By fostering horizontal accessibility to soil health, technology democratizes critical insights, empowering diverse stakeholders to engage with and care for their land. The system strengthens the human-soil nexus, emphasizing an environmental approach that nurtures mutual interdependence between people and ecosystems. Users benefit from informed decision-making processes that integrate social, ethical, and economic considerations, enhancing both soil productivity and resource management. The emphasis on a ”gentle technology” approach ensures minimal ecological disruption, reinforcing an ethos of environmental stewardship. By enriching the interaction between humans, data, and the environment, the project situates data as landscape, promoting an ethical framework where information serves as a shared resource rather than an extractive commodity. Through its radical attunement approach to wearable technology, the design challenges conventional notions of extractivism, offering a new paradigm for harmonizing technology with the living world.

9. Soil.AI

Michael Wallinger & Microfy Systems

9.1. Concept description

The concept SoilAI is an accessible *cyberphysical* system (easy-to-use and affordable) that allows automated analysis of the microbiome in soil samples by a non-lab user, with image processing and Artificial Intelligence. The device, built from a scanning digital microscope + desktop App + AI module + dashboard, can scan a glass slide with a soil sample that has been collected and prepared very easily, only with some water dilution and pipetting.

The device is a digital microscope (with a digital camera integrated) that scans the glass slide with the sample in X-Y planes, and also is able to scan on z plane, in order to look for the most focused pictures and dismiss those that are blurred. The pictures obtained in the scanning stage are uploaded to the cloud, where different computer vision algorithms and AI models are able to process the pictures to identify different types of microorganisms present in the soil. The microorganisms must be classified in different functional groups, and also in the case of Nematodes, identify if they are dead. For all the functional groups, it is important that microorganisms are post-clustered into if they are beneficial or pathogenic for the soil, based on different characteristics of their shape.

The system must be able to recognize bacteria, fungal biomass, nematodes, ciliates, flagellates, amoebas, tardigrades, acaris and rotifers.Once the analysis is concluded, the results of the counting and further assessment are provided to the user in a report that the end-user can clearly understand, also including some useful comments/information about the outcomes, depending on the type of crops grown in that soil samples.

9.2. Connection to the scenario

The scenario we have chosen is "Patterns that persist". This scenario draws a utopia in which biodiversity becomes the new benchmark for a healthy food system after a new law by the European Union. But it also draws a polarized future between early adopters and people who feel left behind. While the scenario and a large part of the discourse pays a lot of attention on increasing the population of pollinator insects, the invisible but much larger biodiversity of soil microorganisms sometimes seems to be a bit out of focus. Our team has selected this scenario because it is seriously concerned about the overall food system's health and sustainability and how food production & consumption will compensate each other over the years to come, considering Earth's growing population combined with a future lack of resources. Our concept focuses on soil microorganism communities and aims to support the transition to healthy i.e. regenerative soil ecosystems. As an accessible decision support system, it helps to assess agro-ecological and other biodiversity-friendly practices based on indicators of soil biodiversity.

The concept responds to the following values identified in the Futures Compass:

- Responsibility
- Resilience
- Learning
- Knowledge
- Curiosity
- Efficiency
- Autonomy

9.3. Opportunities and Keywords

Soil biodiversity (bacteria, fungi, ciliates, amoeba, nematodes,..) is a cornerstone of sustainable agriculture, as it leads directly to healthier plants and increased yields. Land use intensification from all developed countries results in the decline of ecosystem functions, as plant diversity and nutrient cycling/retention, which negatively affect food ecosystem on which society depends.

In this context, there has been a growing interest in soil biodiversity improvement over the last decade, as demonstrated by last EU policies, awareness programs and global scale projects lately launched. However, it is challenging to promote regenerative policies if there are no fast, simple, and affordable techniques to assess their suitability, and benefits promoted by the actions done.

As previously pointed out, the EU Soil monitoring law will become a reality and will force thousands of farmers to migrate to regenerative practices and also to better monitor the quality of the land. Unfortunately, there is a clear lack of alternatives to monitor the biodiversity status of these agricultural soils and SoilAI could become a game-changer, since it will be much simpler and affordable than molecular techniques.

Molecular techniques are mainly used by the research community, but there is still lot of work to do to discriminate at species level, and the price is (and still will be) very expensive. SoilAI is intended to be simpler than molecular techniques, and also more affordable solution.

In the future, SoilAI would be expanded with:

- Real-time connection with weather data with public APIs to correlate the values of the analysis with the incidence and concentration of rain.

- Correlation with data measured directly in the soil with IoT devices integrated in probes.

Different values like moisture, pH, conductivity, enzymes and even acoustic (Monitoring soil fauna with ecoacoustics -https://royalsocietypublishing.org/doi/10.1098/rspb.2024.1595) in the future could help to better monitor the positive impact of biodiversity growth in the soil.

- Integration with an AI-expert (like Siri or Alexa) to provide the results to the end-user instead of doing it with a PDF or dashboard.

- Soil sample extraction will be done by robots working in the field and doing farming operations such as fruits collection or weeds extraction. Sample gathering is a manual exhausting technique nowadays, but in 10 years' time will also become automated somehow.

- Affordable and easy-to-use automated extraction system for Nematodes in the sample. https://www.nature.com/articles/s41598-021-82261-w

Cyberphysical system # Microbiome analysis # Artificial Intelligence # Digital microscope #Desktop app #Soil health # Soil samples # Beneficial and pathogenic microorganisms # Bacteria # Fungal biomass # Ciliates # Nematodes # Flagellates # Amoebas # Tardigrades # Acaris # Rotifers

9.4. Challenge statement

In 10 years, how might we .develop an accessible decision support system to assess agro-ecological and other biodiversity-friendly practices based on biodiversity indicators.

Soil organisms, namely soil biodiversity, supports and regulates soil processes, contributing to ecosystem functioning and fertile food production on farms by growers. It is known that anthropogenic activities that degrade the agricultural ecosystems and reduce the microbiological biodiversity in ecosystems have generated a breakdown in the microbial balance of the soil, and threaten ecosystem performance and a healthy food supply chain. Biodiversity loss has become a global concern as evidence accumulates on how negatively impacts agriculture ecosystem on which society depends. Therefore, there is a growing demand for soil biodiversity knowledge and enhanced monitoring methods worldwide, even though soil biodiversity assessments are by far less commonly used than traditional physicochemical analysis. This is because soil biodiversity assessments techniques are complex, costly and time-consuming, limiting the extent and frequency of sampling and analysis within fields and lands.

Precision and regenerative farming are gaining significant adopters nowadays, since the benefits promoted in farms/lands are widely tested. It is well known already that regenerative practices are key to migrating to ecological farming with reduced use of pesticides and chemicals, therefore traduced in healthier foods for consumers.

Soil biodiversity analysis becomes crucial for understanding and enhancing the health and fertility of soil, to increase the crop yields and overall food quality.

Our challenge is to develop a system that is accessible in use and affordability and supports individuals in the transition from unhealthy soil conditions to regenerative soil ecosystems. This complex transition often from chemical to biological management must be tailored for every location and soil. To get a comprehensive assessment of soil health and biodiversity, we always need a combination of different assessment methods. Our solution must be reliant and based on scientific knowledge. While sustainable agriculture has a long history, tradition and effective practices, we still have very little empirical knowledge on the effectiveness and efficiency of beneficial practices in restoring soil biodiversity and resilience. Thus, currently there are no clear guidelines or manuals on best practices yet and this is also due to the lack of long-term monitoring data. The large European monitoring projects are working on comprehensive sampling methodologies and data on soil health and biodiversity around Europe, but are also limited in sampling frequency and resolution, not necessarily bringing direct benefits to practitioners due to a lack of representativity on a local level.

Microscopy is an affordable approach to identify a vast number of species and thus generally complements more advanced research techniques, like molecular analysis, to safe resources but also because for some microorganisms like nematodes, it still is often the most reliable and faster assessment and used to improve other methods. It is a very versatile approach in the sense that it not only can assess the presence of most of the known microorganisms and if their alive, it also is still central for developing, improving and verifying other methods and technologies regarding unknown organisms.

Currently, its major disadvantage is that it requires intensive human labor and high expertise to identify microorganisms, making it often inefficient for assessing the biomass and biodiversity on larger scale. This is what our solution aims to mitigate.

9.5. Context

The project is expected to bring value in the sector of agriculture and soil consultancy by supporting the transition to regenerative practices. It allows to independently and frequently monitor the effectiveness and efficiency of agro-ecological practices to restore soil biodiversity. This, by extension, contributes to mitigating the climate crisis and to regaining resilience to environmental disasters.

In addition, visual assessment via a microscope and the identification of microorganisms by AI makes life forms visible that are otherwise invisible. This visualization can provide didactic and sensitizing value in raising awareness of the importance of healthy soil ecosystems in the general public.

9.6. Users

At the beginning of the project, the idea was to develop this concept only for end-users in the agricultural farming context, so farmers. However, during the project and thanks to the DFA method our team clearly discovered that there could be 2 different end-users of the system.

Since the implementation of the Soil Monitoring Law, there will be a growing market in EU of different companies/entities/freelancers offering different services to farmers.

These Soil Services Suppliers are consultants or companies that appear in the market to bridge the gap between traditional farmers and researchers/scientists who generate knowledge. The reality is that farmers do not have the time, nor the knowledge to scout all the information and publications that universities and research centers publish with useful information on regenerative practices for farming and monitoring options. In that sense, soil consultants are those that assist the farmers to easily implement those practices by means of clear guidelines and actions. They are the experts who bring knowledge to the farmers and help them to implement the directive and improve yields without using so much pesticides/chemicals. There also other different entities, mostly innovative companies, who are starting to offer different services to farmers to help them with those sustainable practices, let’s say companies renting robots to carry out different activities on the field, companies selling additives and microorganisms for farming, or even software for weather and disease forecasting. This is a growing market that will have a huge impact on farming in 10 years team and they will definitely need different tools to effectively monitor and quantify the benefits provided by their actions, mostly based in biodiversity recovery. So the SoilAI device is designed to be useful for those Soil Services Suppliers to monitor the evolution of the crops that they help managing somehow, and also to a specific group of farmers of high added value products, such as wine and olive makers who already care in soil and already have internal laboratory and soil technicians.

It is expected that the results/information are provided in an accessible and easy-to-understand way, with a clear summary of results described in a PDF document. The layout conceived will be as shown in the image.

9.7. Technology

SoilAI integrates both hardware and software. The hardware is an automated microscope that includes basic robotics in specific elements to allow the device to be "autonomous". And the software is built from different algorithms that process the pictures in the cloud to assess the biota of the soil sample analyzed.

So the overall prototype includes 4 different concepts: Device + APP + Dashboard + Datasets/AImodel.

➢ Device: Automated microscope that is connected to user's laptop and allows autonomous scanning of the sample and collection of pictures through an integrated digital camera.

There are 3 objectives considered to work at 100, 400 and 1000 magnifications.

➢ APP: it is installed in the laptop of the end-user and controls the device and communicate with the cloud where the AI models are integrated (movement, acquisition of picture and communication with the cloud)

➢ Dashboard of users: Allows visualization of the results.

➢ Datasets and AI model: Allows processing of the images and recognition of species. Also measuring size of fungal biomass. The organisms considered to be recognized are: bacteria, fungi, nematodes, ciliates, flagellates, amoeba, acari, collembola, microarthropods, tardigrades and rotifers.

The concept for MUSAE prototype include different developments for robotics and AI, while the final concept of SoilAI would integrate more complex/sophisticated ones in the future.

Robotics

In the MUSAE prototype there is one part that must be automated:

- Sample holder – In order to allow autonomous scanning of the sample, the sample holder must move in XY directions thanks to high precision stepper motors. Also, there must be control on the Z plane, which directly correlates with the focus of the images.

In the future, SoilAI should also include two additional automated components:

- A sample loader with 24 samples autonomy, so the microscope can work autonomously during at least one day without any human intervention.

- An automated revolver, so during the analysis, the change of the objective (x10, x40, x100) can be done automatically, without any human intervention.

AI

The Artificial Intelligence of SoilAI will include 2 different elements:

- **Traditional Computer Vision algorithms (image processing)**

There are different steps that can be done with opensource libraries from OpenCV, such as for instance assessment of contrast and shape edges to identify the most focused images. Different algorithms analyzed for edge detection are Canni, Laplacian and Sobel. Also there are operations like RGB colour measuring and measurement of dimensions of masks that are useful in some steps of the analysis.

• **The Sobel Edge Detector**

Using the Sobel operator, we can compute gradient magnitude representations along the x and y axis, allowing us to find both horizontal and vertical edge-like regions.

• **The Laplacian Edge Detector**

The Laplacian edge detector uses only one kernel. It calculates second order derivatives in a single pass. Working with second order derivatives, the laplacian edge detector is extremely sensitive to noise. Gaussian blur can be used to reduce noise. Laplacians are computationally faster to calculate (only one kernel vs two kernels).

• **The Canny Edge Detector**

The Canny edge detector is a multi-step process. It involves blurring the image to remove noise, computing Sobel gradient images in the x and y direction, suppressing edges, and finally a hysteresis thresholding stage that determines if a pixel is “edge-like” or not.

- **Deep learning models for detection and classification.**

In this specific probably the models to be used will be FastRCNN/MaskRCNN for detection with mask (required to correctly measure dimensions) and EfficientNET for classification of Nematodes in pathogenic/beneficial.

The datasets used will be custom made for this project in order to reduce the variability of the hardware used to acquire the pictures. It is expected that 500 instances, at least, will be annotated for each functional group considered.

The Datasets required to be created to train the models will be:

1) Different images of different backgrounds of different soil samples (ground truth), at x10, x40 and x100.
2) X10 – datasets of Nematodes, collembola, tardigrades, microarthropods. Different images from different soil samples including variability of species and shapes.
3) X40 – Datasets of Nematodes (4 different types + dead class), fungal biomass, amoebas, rotifers, ciliates and flagellates. Include negative classes also.
4) X100 – Datasets for bacteria. Different morphology can be used to discriminate if they are pathogenic.
The annotations will be done with the annotation software Darwin, from V7 Labs (https://www.v7labs.com/darwin).

9.8. Ethical, social and environmental considerations

SOCIAL
- The visual assessment via a microscopy and the identification of microorganisms by AI makes life forms visible that are otherwise invisible. This visualization and classification can provide didactic and sensitising value in raising awareness of the importance of regenerative soil ecosystems in the general public.

ETHICAL
- There are currently too few empirical studies for concrete agro-ecological instructions based solely on the visual assessment of soil microorganisms to be able to recommend them without doubt or in an automated manner. In addition, soil management generally requires a strategy adapted to the respective localities and conditions.
- Although the management of soil ecosystems according to regenerative practices is the most sustainable alternative according to the current state of knowledge, our empirical knowledge of soil ecosystems is still fragmented and thus its manipulation still carries the risk of an anthropocentric biodiversity, which, for example, can even reduce biodiversity through the overrepresentation of certain ("beneficial") organisms.

- AI classification models tend to amplify existing misrepresentations in their datasets in the form of biases and inevitably produce false positive and false negative interpretations to some degree. These technological limitations can affect the reliability of such a system, especially when the targets to be identified are very similar to each other or can be obscured by external factors such as sample pollution or image noise.

ENVIRONMENTAL
- AI and especially training models are very energy and water consumption intensive. Processing data locally instead of in the cloud could mitigate some of these effects to a certain amount.
- Taking into account that biodiversity is fundamentally harmed by human interventions such as soil disturbance, the aim is to reduce this impact as much as possible by supporting the transition to

regenerative practices. Nevertheless, the risk of anthropocentric biodiversity remains, especially in cultivated soils.
- With the potential to morphologically identify specific microorganisms such as nematodes at the taxa level, AI microscopy can support scientific efforts in soil monitoring by providing an economical alternative to molecular methods.

ECONOMIC
- In the transition to regenerative practices, temporary economic losses occur that will be compensated in the future. By assessing the efficiency and effectiveness of the respective practices, these losses can be optimised.
- By automating manual microscopy work, a considerable amount of work is no longer required for soil experts. This in turn may mean that fewer individuals will be able to manage larger areas. Although the expected increase in demand in the field of soil assessment due to legal requirements should counteract a resulting loss of jobs, this may affect the emergence of new job opportunities in this field.

10. Sprout to Flourish

Magda Mojsiejuk & Odd Data & Design Studio

10.1. Concept description

The Algorithmic Simulator for Designing Regenerative Farming Practices will focus on companion planting, offering a practical tool to optimize small to medium scale sustainable farming systems. This simulator will enable users to design planting layouts that enhance biodiversity, improve soil health, and support natural pest control by suggesting intelligent crop pairings based on ecological principles. It will generate dynamic layouts by incorporating data on plant relationships—such as nitrogen fixation, pest resistance, and growth patterns.

Grounded in regenerative agriculture and permaculture, this design tool will provide a user-friendly interface to plan farm layouts that maximize ecological benefits, helping farmers make informed, sustainable decisions within a streamlined development timeline.

10.2. Connection to the scenario

Problems that were raised by the scenario: Complicated Design Practices, Ideological Polarization, Farmers feeling disenfranchised. Our Algorithmic Permacultural Planning Simulator aligns closely with the Patterns that Persist scenario, addressing key challenges like complicated design practices, ideological polarization, and farmers feeling disenfranchised. Streamlining complex decisions in planting and harvesting, empowers farmers to create biodiverse, climate-resilient systems, similar to the thriving food forest described in the scenario.
It bridges traditional agroecological practices and advanced tools like AI and environmental analysis, helping bioregions transition from extractive agriculture to regenerative models while fostering collaboration and inclusivity in design.

Direct quotes from the scenario which correspond and are addressed by Sprout to Flourish concept:
- Algorithmic Planting: "I developed an algorithm for helping with a complex task of timing and coordination when planting and harvesting a food Forest the land is now thriving a thriving food farm Forest where we cultivate crops I grow 200 species all adapted to the changing climate conditions of the region" - STF is aiming to create first step towards the realization of the algorithmic planting, it is a tool for simulating and designing planting plans for food farm forests.
-Transforming Bioregion: "My goal is working with others in Italy to transition as much arable land as possible towards agroecological systems that are less susceptible to exploitation or extraction while some air gap agriculture practitioners Embrace traditional methods others experiment with AI and environmental DNA analysis" - As a regenerative farming tool- STF is based on bioregion principles and corresponding plant species

10.3. Opportunities and Keywords

The Algorithmic Permacultural Planning Simulator is inherently future-oriented, designed to respond to critical challenges such as the aging farming population, climate change, and the need for sustainable food systems. Its potential lies in reshaping landscapes, enabling the development of computational agroecology, and attracting a new generation of regenerative farmers. By fostering ecological intelligence, it supports a shift toward holistic agricultural practices.

However, its adoption also carries risks: the possibility of turning farms into data-driven operations prioritizing information over crops, fragmentation of small farms reducing their political influence, and the potential loss of traditional human knowledge sharing. Balancing technological advancements with ethical considerations and community-centric approaches will be critical to realizing its transformative potential.

Regenerative agriculture # Permaculture # Biodiversity Enhancement # Sustainable Farming # Companion planting # Soilheal Improvement # Natural pest control # Crop pairings # Nitrogen Fixation # Pest Resistance # Growth patterns # Algorithmic simulator # User-friendly interface

10.4. Challenge statement

1rst challenge statement developed during Kick off in Milan: In 10 years how might we interact with systems managing our food system 2nd, revisited challenge statement: In 10 years how might we lower the barrier of transition towards regenerative practices with algorithmic tools?

The transition to regenerative farming in Europe is essential to combat climate change, restore biodiversity, and ensure food security. With 57.6% of EU farmers aged 55 or older, a new generation of farmers must be empowered to adopt sustainable practices. However, regenerative farming involves complex design processes, requiring knowledge of biodiversity, soil health, and crop interactions. This complexity discourages many from switching. Our project addresses this by creating a simulator to simplify planning, enabling small-scale, part-time, and younger farmers to embrace regenerative methods and support local European food systems.

10.5. Context

The Algorithmic Simulator for Designing Regenerative Farming Practices is expected to deliver significant value across multiple sectors within agriculture, rural development, and sustainability. This includes:

1. Agriculture and Farming:
- With 57.6% of farmers in the EU over the age of 55, many of them are approaching retirement by 2030, which presents a critical gap in the agricultural workforce. The simulator can support the transition to younger, tech-savvy farmers and assist those looking to adopt regenerative practices. It can also help small-scale farmers (63.8% of EU farms are less than 5 ha) to optimize their operations using efficient and sustainable methods, even on limited land.
- For semi-subsistence farmers (3.3 million EU farms with a standard output below EUR 2,000), the simulator can provide valuable guidance to improve productivity and diversify income sources without the need for major capital investments.
- The tool can bridge the knowledge gap in agricultural training, with 72.3% of farm managers lacking formal education. It can provide them with insights on regenerative techniques, crop management, and

farm design based on practical experience, without requiring advanced technical knowledge.

2. Rural Development and Communities:
- In countries like Romania, where early school dropouts are high and many farmers operate on small plots, the simulator can empower local communities to adopt more sustainable farming practices that improve soil health and yield without requiring formal education or substantial capital investment. It can also contribute to reversing rural decline by attracting younger generations to farming.
- By improving farm productivity and sustainability, the tool could help stabilize rural economies, reduce migration to urban areas, and provide employment opportunities in the agriculture sector.

3. Sustainability and Environmental Sectors:
- The simulator aligns with the EU's goals of promoting regenerative agriculture and sustainability. It can help reduce environmental impacts by suggesting farming practices that improve soil health, enhance biodiversity, and mitigate climate change effects. It supports the local food production sector, which is gaining increasing importance in European food systems and policies.

4. Technology and Innovation:
- As more farming operations in Europe embrace technology-driven solutions, the simulator acts as an entry point for integrating AI and digital tools into the agricultural sector. It caters to the growing trend of integrating technology with agriculture, making sustainable farming practices more accessible and attractive to a younger, tech-savvy generation, yet there is a clear gap of easy to use tools, and tools that allow for easy entry tools into regenerative farming, this will be exactly the aim of Sprout to Flourish. This tool is also addressing the new form of farming- part time farmers, which don't have time for steep learning tools. As the older farmers are retiring we need to bridge the knowledge gap for new generations, which STF will address with automation.

In summary, the project is expected to bring value across agriculture, rural development, sustainability, and innovation by empowering the next generation of farmers, supporting the transition to regenerative farming practices, and contributing to the resilience of small-scale and marginal farming in the EU. By addressing the challenges of an aging farming population and increasing access to technology, the tool can play a key role in modernizing and diversifying European agriculture.

10.6. Users

Algorithmic Simulator for Designing Regenerative Farming Practices will primarily consist of younger farmers, part-time farmers, and those within the European context who are seeking ways to transition to regenerative and organic farming. These users may be motivated by the need to modernize their farming practices, increase sustainability, or differentiate themselves in the marketplace. Many will be interested in optimizing their land for local, organic production, as regenerative farming methods can give them a competitive edge, particularly in a European market that increasingly values locally grown, eco-friendly produce.

In addition to newcomers to farming, this simulator will also serve farmers who are looking to switch to regenerative practices, helping them make the transition from conventional farming methods to those that emphasize soil health, biodiversity, and sustainability. In the context of Europe, where local food production is becoming a key concern for sustainability, this shift can offer significant advantages, including resilience to climate change, improved soil quality, and access to premium markets that demand organic and regenerative-certified products.

By providing a tool that makes it easier to design regenerative farming systems—particularly through intelligent crop pairings and dynamic planning—the simulator supports these farmers in adopting more sustainable practices that align with European agricultural goals. It can contribute to a more sustainable, self-reliant food system by empowering local European farmers to produce organic, regenerative food that meets the growing demand for locally sourced, environmentally-conscious products.

Societal Impact:
The simulator's design is particularly relevant considering the demographic challenges in farming. Only 5.6% of European farms are run by farmers under 35, while more than 31% are managed by those over 65 (source: Eurostat). Automation and tools like this simulator can lower the barriers for young people to enter farming by simplifying and enhancing the process, offering them the flexibility to focus on creative and strategic aspects while automating more routine tasks. By doing so, the simulator can help bring more young people into farming, encourage part-time farming, and contribute to food being seen as essential infrastructure in both cities and their peripheries

10.7. Technology

The system is designed as a "closed-loop" framework for algorithm-assisted design and planning, emphasizing adaptability and collaborative intelligence. Rather than relying on a static model, the system is built to evolve, focusing on how its components interact to form a cohesive whole. It is designed to work with incomplete or unverified data—a common starting point—and to refine its understanding over time through use. This system is not an initial expert but a capable learner, with processes that thrive on the synergy between human input and algorithmic analysis.

Data Flow and System Architecture
At the core of the system is an interconnected flow of data, managed through four foundational databases:
1. Macro Context Database: Contains large-scale contextual data such as GIS data, geography, weather history, and other environmental metrics.
2. Micro Context Database: Focused on localized measurements and sensor data, including soil health, humidity, air quality, and UV index. This database is not part of the TRL5 prototype, data will be populated incrementally as pilot projects are conducted in future iterations.
3. Species Database: Houses information about plants and organisms relevant to the design. Initial data is sourced from permapeople.org and floraveg.eu
4. Relationship Graph Database: A graph database that maps the relationships—both positive and negative—between species. Initial data is derived from the permapeople.org, floraveg.eu databases and articles processed with a large language model (LLM).

Design Guidelines
The system operates using a set of "design guidelines" that dictate how the algorithms make decisions. These guidelines range from:
- Hard rules: Explicit constraints, such as ensuring the design includes at least three different species.
- Soft rules: Flexible preferences, like positioning species A near bodies of water.
Initially, these guidelines are curated with the help of domain experts. Over time, they may become

user-configurable via a simplified interface, allowing customization based on objectives and preferences.

User Inputs
Before initiating a simulation, users provide key inputs:
1. Geographic location and area: The user draws a polygon on a map to define the target area.
2. Design objectives: Goals such as soil regeneration, crop nutrition, yield optimization, profit maximization, or other user-driven priorities.
3. Preferred crops: Users can start with a system-generated recommendation and specify crops to prioritize or exclude.

Simulation Workflow
The system integrates user inputs with data from its databases and executes a multi-step simulation process:
1. Optimization: Linear programming is used to calculate the optimal mix of species to achieve the user's goals. The output is a species list with recommended proportions.
2. Relationship Optimization: Graph analysis evaluates the relationships among the selected species, producing a matrix that indicates which species should be placed near or away from each other and existing land features (e.g., water bodies, hills).
3. Generative Landscape Layout Design: Using outputs from the previous steps, a genetic algorithm generates a spatial layout. This step ensures compliance with design guidelines, relationship matrices, and species proportions, iteratively refining the design until a satisfactory solution is achieved.

Results and User Interaction
The simulation's output is displayed as a layered design map over the user-selected area. Additional statistics and insights may also be presented. Users can adjust inputs and re-run the simulation iteratively until they achieve a satisfactory design.

Technology and Deployment
The entire system—from data storage to computational processes—operates on a Google Cloud instance. The user interface for inputting parameters and visualizing outputs will be implemented as a web application. Depending on exhibition requirements, alternative media formats may also be explored.

10.8. Ethical, social and environmental considerations

(-) - negative consequence
(+) - positive consequences
(?) - neutral
(!) - insights and opportunities

Ethical:
(-) Algorithm leads to middle-of-the-road designs, no one benefits.
Second-order: Loss of innovation and creativity in farming practices.
Third-order: Farmers become dependent on AI, reducing their own decision-making autonomy.

(-) Replacement of current experts.
Second-order: Loss of traditional knowledge and skills.
Third-order: Shift towards more data-driven farming, potentially undermining artisanal farming traditions.

(-) Farmers become only a source of data.
Second-order: Farmers' roles may diminish, focusing on data collection rather than holistic decision-making.
Third-order: Alienation of farmers from their relationship with the land, reducing the sense of ownership and responsibility.

(+) Empowerment of farmers with advanced technology.
Second-order: Increased adoption of regenerative practices by farmers who feel they can manage them.
Third-order: Greater alignment between farming practices and ecological ethics, leading to long-term environmental benefits.

(?) Algorithmic decisions might not align with local cultural practices.
Second-order: Potential resistance from local communities who prefer traditional farming methods.
Third-order: Pushback could lead to division between high-tech and traditional farming communities.

Social:
(+) Lowering the entry barrier into permaculture.
Second-order: More people from diverse backgrounds enter the farming sector, including urban dwellers and young tech-savvy individuals.
Third-order: This could result in a shift in the public perception of farming as a career, making it more appealing and diverse.

(+) Opens up farming for the more tech-savvy generation.
Second-order: This could encourage the development of new tech-driven agricultural startups and innovations.
Third-order: The influx of younger generations could drive more competitive local food markets.

(-) Potential loss of traditional farming knowledge.
Second-order: Communities may lose valuable wisdom passed down through generations.
Third-order: A generation gap in farming practices, leading to cultural disconnection between urban and rural communities.

(?) AI-driven farming might create digital divides.
Second-order: Farmers without access to technology might fall behind.
Third-order: This could exacerbate inequalities between rural and urban areas, as well as between rich and poor communities.

(!) Need for educational systems that bridge technology with permaculture knowledge.
Second-order: New training programs could arise to teach both tech and traditional farming skills.
Third-order: These programs could become a new sector for rural and urban collaborations.

Environmental
(?) Non-linear/non-grid landscapes for farms.
Second-order: This could lead to new farming practices that mimic natural ecosystems, but also potential logistical challenges in managing such irregular layouts.
Third-order: These landscapes might support local wildlife, leading to more integrated ecosystems.

(+) Better soil maintenance compared to monoculture.
Second-order: Increased carbon sequestration and overall improvement in soil fertility.
Third-order: More resilient ecosystems that require fewer external inputs like fertilizers and pesticides.

(-) Test phase might generate a lot of waste.

Second-order: Overproduction of prototype systems and failed designs could create environmental pollution.
Third-order: This could lead to calls for better sustainability in agricultural tech development.

(+) Higher biodiversity.
Second-order: Reduced reliance on chemical inputs, fostering healthier environments.
Third-order: This could increase resilience to pests and diseases and improve ecosystem services.

(?) Limited supply of seeds and available species.
Second-order: It could restrict farmers' ability to experiment with diverse, locally-adapted species.
Third-order: A move towards larger, more industrialized seed banks may homogenize local agricultural systems.

(+) Less depletion of soil nutrients and water.
Second-order: Decreased need for artificial irrigation and fertilizers, reducing the carbon footprint.
Third-order: A significant improvement in long-term land sustainability, reducing environmental damage.

(-) Algorithm biases towards specific behaviors or climates.
Second-order: Climate-specific models may be less applicable to diverse regions, leading to uneven results across Europe.
Third-order: Marginalized regions may struggle to benefit from AI-driven practices.

(!) Need for local seed banks and seed distribution networks.
Second-order: Increased interest in preserving native species for regenerative farming.
Third-order: The rise of community-led initiatives that focus on local seed sovereignty.

(+) Inclusion of new species in the farming system.
Second-order: More resilient and diverse farming systems that mimic natural ecosystems.
Third-order: This could foster a culture of biodiversity-focused agriculture that benefits both the environment and the local economy.

Economic
(+) Efficient use of land.
Second-order: Better use of underutilized land, increasing food security and productivity.
Third-order: Increased competitiveness of local farming against industrial agriculture.

(?) More/different forms of produce preservation are needed.
Second-order: This could open opportunities for innovation in food storage and processing technology.
Third-order: Increased market demand for sustainable and local preservation methods, potentially creating new industries.

(+) More variety of produce.
Second-order: Diversification in local markets, which can attract higher-value products.
Third-order: A shift in consumer behavior toward supporting more diverse and sustainable food options.

(?) Many smaller producers.
Second-order: A fragmented market could increase competition, especially for smaller producers to scale.
Third-order: This could result in higher product prices due to a smaller volume of goods being produced, which may limit accessibility.

(-) Supermarkets are not buying from small producers.
Second-order: Smaller producers may struggle to access larger markets, affecting their profitability.

Third-order: The rise of farmer's markets and direct-to-consumer sales could address this gap.

(!) Need for new forms of cooperation and distribution.
Second-order: Collaborative models such as cooperatives or shared supply chains could become more prevalent.
Third-order: This could radically shift the structure of local food economies towards more community-based systems.

11. Symphony of Solace

Robin Jonsson & Dyno Robotics

11.1. Concept description

The selected concept to proceed with in the project is the desktop robot. There are multiple reasons for choosing this concept. One big reason is the key word Affordable from the challenge statement. Selecting a desktop robot keeps the price at a level that can be afforded by a much bigger part of the population, rather than selecting a bigger robot platform. This makes it easier for people to provide the product for their elderly relatives, or for the municipalities to supplement the product.

Another reason was that it gives the Artist good opportunities to make key contributions to the product, in designing the ways of human robot communication, to help create the human robot relationship we are aiming for. Compared to the other concepts this allows for much more flexibility in designing the robot character, movement and other key features. It also keeps the focus on the robot, and not leaning too much into the technology field of AI that could for the other concepts take too big of a place.

We also find the two key factors for a good meal for the elderly, described below in the Challenge Statement to be of highest importance, while also being somewhat of low hanging fruit, to buy in relation to the other concepts being easily implemented.

11.2. Connection to the scenario

This connects to the scenario of a world where deteriorated health among all generations and pandemics contributes to an increasing part of the population living in isolation, with few to none social interactions. Trends show that the world population is aging rapidly, at the time of the scenario in 2030, 1 in 6 people in the world will be over the age of 60, calling for a society that is better and rapidly adapted for a fast growing elderly population in need of care and support (World Health Organisation, 2024). The concept addresses first hand the values from the Futures Compass in regards to Resilience, Care, Health and Equality. Increasing social resilience for the isolated elderly, being one piece of the Care of our elderly, helping them retain good health and being a cheap product for everyone to ensure equality. In second degree the robot also assists with Knowledge, as the robot is always close at hand, and can assist in providing good factful information.

11.3. Opportunities and Keywords for concept

The concept focuses on something interesting at its core, can a cheap toy robot be used to add value for a vulnerable group of people, being the isolated elderly. It is uniquely positioned to address current challenges while adapting to future societal trends, including the aging population, healthcare system strain, and advancements in AI and robotics. With its ability to disrupt traditional elderly care approaches and contribute to long-term well-being, the companion robot represents a transformative solution with significant potential for positive impact on individuals and society.

The hope of the project is not to produce a product that will solve all issues within elderly care, but rather to show that it is possible to tackle these challenges with a low cost approach. Hopefully this project, together with other projects within the field, can create a spark to continue working towards solving this increasing issue of caring for our growing elderly population.

Human-robot communication # Elderly care # Meal assistance # Municipalities # Robot design flexibility # Desktop robot # Movement design # AI technology #Product accessibility

11.4. Challenge statement

The challenge statement is: Can we develop an affordable nutrition companion for isolated elderly?

The more specific challenge the concept addresses is based on two of the factors established by the Swedish Food Agency (Livsmedelsverket, 2019) as crucial for a good food intake for isolated elderly (Image to the right is redesigned and translated for the purpose of this report).

The first is to have a pleasant meal, where a big part is to feel companionship during the meal, while the other is to eat nutritionally.

Can a cheap desktop robot help the user have a pleasant meal through interaction, and also nudge the person to better eating habits by suggesting intake of fruit, vegetables, fluids and dietary supplements. The approach is to do this through a mix of gamification and a friend/pet-like relationship between the robot and user.

Including gamified elements in products that motivate the user to make progress by for example collecting points or achievements have been proven to enhance engagement, inspiration and education among their users (Deterding et al., 2011). Studies show that gamifying elements that introduce competition, rewards and social interaction are a very promising approach among the older generation to sustain a long term motivation and combat feelings of loneliness (Zhou & Salvendy, 2019). Gamification of products is also an effective method to activate cognitive skills among older people, highlighting the importance of staying mentally active with age and decreasing the risk of loss of cognitive function (Zhou & Salvendy, 2019).

11.5. Context

The project is aimed at delivering first degree value in elderly care, specifically related to food and nutrition. At a second degree level, better food relationships for the elderly can have effects of better health, leading to a less pressure on public healthcare, and a better overall health of the increasing elderly population.

11.6. Users

The target end user is alone and isolated elderly, with the lower limit at 65 years of age. The users will start the robot when they want to have its company, and can easily turn it off when they feel like it. This is an important feature, to increase the privacy for the elderly. When turned on, the robot will be a companion, whenever this is during meals or in other parts of the day. The robot will gently nudge the users to eat fruits and drink fluids, or be a conversation companion. When the robot is switched on, but not interacted with, it will keep itself busy with other tasks or entertainment, to achieve a somewhat pet-like relationship.

Relatives to the user can possibly get some alerts from the robot on the status of the elderly person. However the amount of information will be limited to the bare necessities, as discussed further in the ethical considerations section later in this report.

11.7. Technology

The technical focus of the project is robotics, although some use of LLMs will be needed, but the main focus remains on how a robot can interact with the users and create value. The approach is to use a desktop robot, and to change it and add to it to change the behaviour of it. One of the reasons for selecting a desktop robot is the low price, making it affordable for the end user, also means that the price for the hardware for development is lower. It allows us to not be locked to one model, but rather to buy a few different desktop robots, and test their functionality before selecting the final platform.

This approach allows us to start designing one main part of the system being the LLM interaction, and testing how this can be used to add value to the end user within nutrition. At the same time a few different desktop robots are ordered, and then tested for which ways of communication there are. The Artist will together with the SME evaluate and select the platform during the first few iterations of the development process.

Another big advantage of ordering and testing multiple desktop robots is to see what different approaches they have for interaction and creating a relationship with the user. It will be a good source of inspiration for the artist, as they are created to be fun for their user. However this doesn't mean that the interaction part is complete, as the behaviour needs a lot of adaptation to fit our target users and to provide nutrition assistance.

There are a few requirements for the platform to be a possibility for the project. These are:
- Microphone (to detect speech)
- Speakers (to communicate with the user through sounds and speech)
- WiFi connection (to use LLMs and be connected to the database)
- Programmable (we need to be able to change its code to change the behaviour)
- Some controllable movement (to be used for the interaction, to express emotions)

Then there are some features that are nice to have for the robot, and having at least some of these would be needed to have a good robot human interaction. However not all these might be needed, depending on how the available features can be utilized:
- Simple screen (to show simpler symbols or face features)
- Better screen (to show complete face, images and other content)
- Wheels/legs (to move around slightly for reactions or smaller features of the robot living its own life)
- Arms (to express emotions)
- LEDs (to express emotions)
- Touch sensor (to interact in the physical medium)
- Other moving parts (to express emotions)
- Possibility to connect multiple robots to each other

These requirements will be used when sourcing the robot platforms to test, and will be used to evaluate them together with how they are perceived.

A few different platforms have been looked into during the inspirational research, and some of the best candidates are:
1. LeTianPai Rux from LeTianPai
2. https://living.ai/emo/ from LivingAI
3. Eilik from Energice Lab
4. AIBI from LivingAI (available on pre-order so might not be possible for this project)

After the platform has been selected the team will continue iterating on the platform, adding more features and testing new ways of communicating and creating value for the user. Then looking into how the platform can be changed to fit our very specific target audience, as well as iterating on the methods for assisting with nutrition.

11.8. Ethical, social and environmental considerations

Social
The social impacts of the robots have both possibilities and risks. One positive first order impact that we hope for the future is for the robot to assist in increasing social resilience. Meaning that alone and isolated elderly get some interactions every day through the robot, and that this works as a good backup till the next real social encounter. It can also provide a good base for those without close family or friends.
A closely related risk, on the second order, is that the robot further limits the social encounters, either that the elderly feel like the robot is enough, or that relatives are less likely to visit as they see the robot as a means of taking care of their elderly. The change of this might increase even more if family members can get reports from the robot, or have some control over it, leading to a sense of taking care of the elderly.

Ethical
Ethical considerations focus mostly on data privacy. Should the family members be able to get data about the elderly person? It could be of use, but also a big breach of privacy, especially if the elderly is less aware of how the robot works, and more uses it per request of their family. Therefore it is important to limit the information being sent to relatives to possibly only include crucial information like signs of being ill, hurt or not taking prescribed meditation.
Another ethical aspect is data privacy in regards to the companies in control of the product. No information from the user can be used in an unethical manner, and there is the issue of privacy by using cloud based LLMs. For the scope of this project, the focus will be on the use and interaction with the robot, rather than trying to solve the privacy issues with LLMs, as this is a huge task. It is however important to keep this in mind to generate ideas on how to address this issue later in the product development after the MUSAE project.

Environmental
In a similar manner there are a lot of issues with LLMs related to environmental aspects. Several of the biggest tech companies are reported to be failing their environmental goal of net zero emissions to be part of the LLM race (Huggingface.co 2024). This is also an important aspect to keep in mind, but not something that can be solved within the scope of the project.

12. Conclusions

The 11 projects collectively demonstrate how innovative prototypes can pave the way for healthier and more sustainable food systems. These projects leverage a combination of technology, community engagement, and ecological awareness to reimagine food production, consumption, and their relationship with human and planetary well-being. By integrating AI, IoT, and sensory-responsive tools, projects such as BeeSustain, Soil.AI, and Fermenting Traditions optimize agricultural and fermentation processes, ensuring efficiency, biodiversity, and accessibility. Meanwhile, projects like Neuro-Cooking and Nourish explore the deep connection between food, mental health, and cognitive function, offering wearable and neuroscience-driven solutions that personalize and enhance dietary habits. Similarly, Sprout to Flourish provides data-driven insights for regenerative farming, fostering sustainable agriculture by designing intelligent companion planting systems that improve soil health and crop resilience.

Other projects push the boundaries of bio-inclusive and circular design, redefining how food and materials interact within ecosystems. Growing Futures and Remedy Garden explore symbiotic relationships between humans, fungi, and technology, transforming waste into biodegradable habitats and medicinal food sources. S.O.I.L. and Open Agrobiodiversity Accounting Kit (OAAK) highlight the importance of understanding soil as a living entity and tracking agricultural biodiversity, empowering both farmers and consumers to make informed environmental decisions. Finally, Symphony of Solace introduces a human-centered approach to food accessibility, particularly for elderly populations, using robotic companionship to enhance meal experiences. Together, these prototypes illustrate the potential of the DFA method of shaping a world where food sustains not just bodies but entire ecosystems, reinforcing the notion that healthy eating is a deeply interconnected, systemic endeavor.