

# forest 4.0

## 4.2 Implementation of methodological framework for research projects

### WP4: Scientific excellence and education activities development

Responsible Author: Arianit Kurti, Linnaeus University



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Project Coordinator	Tomas Krilavičius (VMU)
Address	Vytauto Didžiojo Universitetas K. Donelaičio g. 58, Kaunas LT-44248, Lithuania,
Reply to	tomas.krilavicius@vdu.lt

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Reply to	Arianit.kurti@lnu.se
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Contributors	Zenun Kastrati (LNU), Mexhid Ferati (Lnu) Tomas Krilavičius (VMU), Gintautas Mozgeris (VMU), Virginija Kargytė (VMU), Eglė Gerulaitienė (VMU).
Reviewer(s)	Tomas Krilavičius

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## Executive summary

This document outlines the methodological framework for research projects within the Center of Excellence (CoE) Forest 4.0. The framework aims to highlight transdisciplinary research integrating academic disciplines with input from non-academic stakeholders, such as land managers, industry representatives, and the general public. This approach is essential for tackling the complex societal problems associated with managing human-natural systems within the context of smart forestry.

The CoE Forest 4.0, funded by the European Union's Horizon Europe program, seeks to become a national, regional, and global leader in smart forest innovation. The research conducted within the CoE will prioritize applied research, focusing on finding practical solutions for the forestry sector and generating impactful innovations. This document emphasizes the importance of research valorization, which involves translating research results into tangible societal and economic benefits.

To develop the methodological framework, this report draws on several key elements:

1. **Core Competencies of the Research Team:** An analysis of the research team's expertise across seven primary categories and 17 sub-categories ensures a comprehensive understanding of the available knowledge and skills within the CoE.
2. **State-of-the-Art Research:** A review of the scientific literature on integrative research concepts, including disciplinarity, multidisciplinarity, interdisciplinarity, and transdisciplinarity, provides a theoretical foundation for the framework.
3. **State-of-the-Practice Insights:** Examining innovative team organization models used by successful technology companies, such as the "Spotify Model," offers practical insights for structuring research teams within CoE Forest 4.0.

Based on this, the proposed methodological framework for CoE Forest 4.0 adopts a hybrid approach. Researchers are organized into thematic teams aligned with their areas of expertise. Project teams are then formed, drawing members from relevant thematic teams based on the specific problem being addressed. This structure promotes transdisciplinary collaboration while maintaining flexibility and scalability as the CoE grows.

This framework's success is based on a supportive organizational culture that nurtures creativity, collaboration, and a focus on impactful innovation. By combining a well-defined structure with a strong emphasis on organizational culture, CoE Forest 4.0 can drive impactful innovation and achieve its vision of becoming a leader in smart forestry.

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### 1.Introduction

The purpose of this deliverable is the development of the methodological framework for the research projects within the Center of Excellence (CoE) Forest 4.0. As CoE Forest 4.0 addresses a complex societal problem associated with managing human-natural systems there is a need for teams comprised of scientists from multiple disciplines. As research to be conducted as a part of CoE Forest 4.0 will be focused on innovation, it will be more of an applied research nature. In the literature, applied research is defined as research that aims at finding a solution for an immediate problem facing a society, or an industrial/business organization (Kothari, 2008). Contrarily, fundamental research is mainly concerned with generalizations and with the formulation of a theory. Studies have indicated that applied research is important for absorbing scientific knowledge by industry and in this way generating innovation. In a research study by Comin et al. (2019) examining the impacts of the Fraunhofer Society in Germany, empirical evidence demonstrated that applied research organizations represent a promising avenue for innovation policy. In connection to this, Ben Schneiderman (2016) in his book, proposed combining Applied and Basic research to tackle immense problems of the 21st century. He argues that combining scientific methodology, engineering principles, and design thinking can lead to high-impact outcomes. He also claims that evidence is growing that these new guiding principles will enable students, researchers, academic leaders, and government policymakers to accelerate discovery and innovation. Figure 1 describes how this new process of applied research that combines applied and basic research with a blend of scientific, engineering, and design approaches works out.

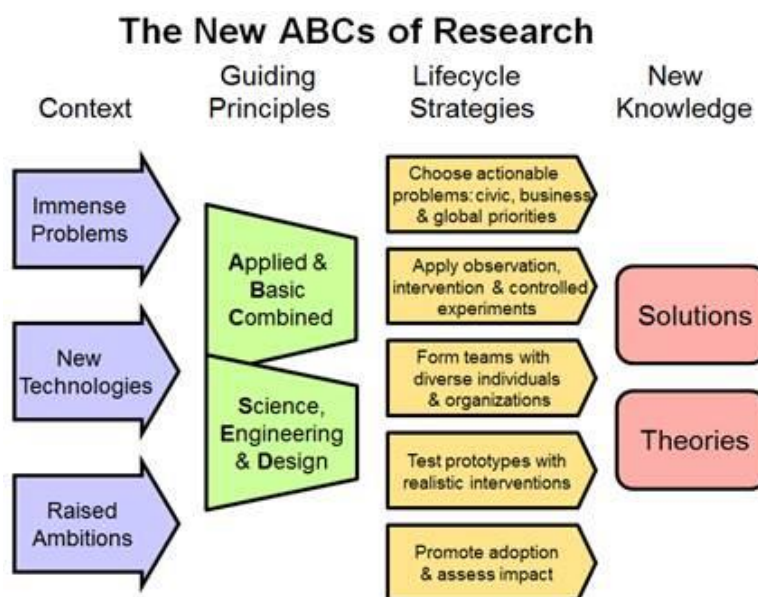


Figure. 1 New Research Process (Schneiderman, 2016)

Based on this process, applied research starts from an immense problem faced by society or industry, the application of new technologies across different domains, or simply raised ambitions for more efficient or effective processes. The working method is to combine expertise from cross disciplines together with relevant stakeholders to come up with a solution to a problem that can be later generalized into theories. This process fits well with the mission and vision of the CoE Forest 4.0 therefore, it will serve as a good guiding principle for the development of the methodological framework for establishing research projects.

Nowadays, we are constantly faced with different challenges that require new and creative solutions. These solutions can and should be inspired by research activities conducted. Therefore, the core focus of the research activities to be conducted as a part of CoE Forest 4.0 will be in the direction of the valorization of research results. Research valorization is defined as “the use of research results, financed by public authorities, for socio-economic purposes and impact” (Lays, 2012). Having in mind the CoE Forest 4.0 vision of being a national, regional, and worldwide leader of smart forest innovation society, valorizing research results into impactful innovations becomes an instrumental activity for working forward. In these settings, applied research has an important role to play, especially since being solution-oriented it can provide demonstrators and prototypes to society and industry connected to forestry and circular forest-based economy. In comparison, the importance of applied research activities for innovation in industry and society has also been supported by the recent publication of Vinnova (Swedish Innovation Agency) emphasizing that renewal of the manufacturing industry can be achieved by more research and development activities.

Having this in mind, in the next section we explain the methodological considerations for developing this deliverable. This is followed by a brief state of the art and start of the practice report. This is followed by the section where we describe the model for developing the research projects to serve as a framework for developing research projects as a part of CoE Forest 4.0

## 2. Methodological Considerations

To get the best methodological framework for the development of research projects in CoE Forest 4.0, we used the following activities:

1. Understanding the core competencies of the research team within CoE Forest 4.0
2. State-of-the-art research when it comes to methods and architectures for developing large cross-disciplinary teams
3. Start of the practice when it comes to innovative team composition

In the subsections below we describe in more detail the outcomes from each one of these activities.

## 2.1 Core Competencies of the Research Team

As a part of the strategy development for CoE Forest 4.0, we assess the vision for the research groups, topics to be researched, and potential products and/or services. Table 1 below summarizes this:

Table 1: Core competencies of the research team

Research Group	Research Topics	Products & Services
IoT and ubiquitous computing for the development of geospatial techniques	Using IoT in a forest for environmental management, natural resources management, disaster management, land information system management, and visualization; Forest IoT network security; IoT-based soft computing-multiagent systems risk evaluation and decision support systems with XAI (explainable AI), creation forest IOT services	Framework and tool for development of Forest IoT devices and services; IoT network management tool; Forest IoT network deployment and Service & Resource Orchestration; Forest risk evaluation tool with XAI
Remote sensing for advanced forest data collection	Advanced methods for capturing information on resources for forest estates, landscapes, regions, or countries utilizing new finer-resolution data sources and developing new data capture/storage/processing concepts, developing new precision silviculture methods by utilizing finest resolution 3D tree level data; advanced frameworks of natural resource inventories based on IoT and remote sensing; exploring spectral properties of vegetation to develop geospatial techniques for climate-smart forestry	Advanced imaging missions for assessing properties of trees, forest stands, and trees outside the forest; tree mapping using pseudolite-driven positioning systems; advanced inventories of natural resources, including modernization of National Forest inventories and greenhouse gas accounting; spectral libraries of vegetation; mapping of vegetation properties, including mobile mapping; development and testing new sensors and data collection routines

IoT monitoring and AI prediction techniques for the development of forest management systems and the detection of forest threats

Eco-physiological processes in forest ecosystems aimed to build a scientific frame of smart forestry (e.g. changes in tree transpiration and fluorescence, photosynthetic activity, development of tree annual rings, together with precise recording of environmental conditions); greenhouse gases over the forest canopies to detect the tree response to environment changes and define the resistance and resilience limits; improvement of models for greenhouse gases and CO<sub>2</sub> footprint; processes in forest soils; forest productivity; decomposition of organic matter; forest vegetation under stress conditions; modeling natural hazards and forest disturbances for decision support; interactions between vegetation and CO<sub>2</sub>, O<sub>3</sub> and N regimes under progressive climate warming and associated feedbacks; fundamentals of precision forestry

Better understanding and enhancing the mitigation potential of ecosystems and sectors based on the sustainable management of natural resources, and greenhouse gas accounting according to the requirements of the State environmental monitoring program, with the potential to join the pan-European ICOS network (Integrated Carbon Observation Systems), full detailed models of C-stocks and flows, process-based eco-physiological models of forest ecosystems, also for existing or new forest projection systems

Crowdsourced forest-based data management and visualization

Data and metadata storage infrastructure, exploratory data visualization for early investigation and decision making, anomaly maps for problematic locations detection, anomaly detection for predictive maintenance, optimization of forestry-related logistic processes

Data curation services, pre-processed data/cleaned data, visual exploratory analytics solutions, anomaly maps for early problematic locations identification, optimization of forestry-related logistics, anomaly detection for predictive maintenance, interactive maps for forestry change simulation, forestry data simulation; forest and forestry data management strategies and tools

AI techniques for cognitive sensing and multi-modal signal processing in IoT-based systems for predictive analytics

Analysis of multimodal forest data (using a fusion of any available data: computer vision, spectrum sensing, tree sensor data, etc.) for intelligent predictive production and maintenance (forest "health care," (re)growth, carbon, fire alerts, and so on); modeling and forecasting of biomass supply chains as a dynamic combination of organizations, human resources, activities, information, and biomass resources (bulk residues, chips, bundles) involved in transferring trackable residues from suppliers to end-users; AI-powered cognitive task analysis to foresee the aims of explicating forest user demands, desires, and cognitive capacities for coping with complicated forest bio-economy chain systems; metaheuristics

Conceptual framework(s) for self-services such as AI-driven identification and prediction of forest production and maintenance requirements, AI-driven forest "impact" driver reports, automated analysis and evaluation of the effects of external factors such as weather conditions, operator experiences, and/or operator fatigue on forest production and maintenance costs; Modelling and forecasting of biomass supply chains involved in transferring trackable residues from suppliers to end-users; AI-driven forest logistics optimization, support with an interpretation of remote sensing data; support in geospatial analysis to aid in the AI-driven forecasting, detection and identification of anomalies and disturbances in the forest ecosystem/bioeconomy chain

Development of Decision Support Tools (DSTs) to assess forest management practice

Models for strategic and tactical coordination of precision silvicultural methods with the value chain; development and implementation of modern decision support tools for experimenting with alternative forest management models; methods to account for the diversity of ecosystem services in decision support for sustainable forestry; incorporation of global climate change and market scenarios in forest management; consideration of climate change effects in forest management decisions; landscape-scale decision support; decision support to account for greenhouse gases in agriculture, forestry, and land use sector; new and modified silvicultural management methods devised; social, technological, ecological, economic and political aspects of precision forestry operationalization

Advanced understanding and science to support adaptation and resilience of natural and managed ecosystems, water and soil systems, and economic sectors in the context of the changing climate; a general purpose software solutions and know-how for operational forestry to support adaptive forest management, including a set of tools for dendrometric data processing and forest yield modeling; improved forest management decisions, validated and implemented alternative forest management models, fully functional decision support system(s) adopted for Lithuanian conditions, however, compatible with the international needs; modeling infrastructure for the whole forest sector

Life Cycle Assessment (LCA) and bioeconomic modeling tools for the identification and justification of sustainable forest-based business model innovations

Integration of LCA and bioeconomic for the analysis of products and processes in forest resources-based value chains to improve both environmental and economic performance; environmental sustainability and economic viability of circular economy models applied in forest resources-based business; IoT and AI-driven automatization of data acquisition and analysis for the completion of integrated assessments and simulations concerning forest resources-based products and processes; resilient forest value chains under conditions of local and global change, potential consequences of different forest resilience enhancement strategies on the long-term design of value chains, forest and value chain alternatives to enhance the resilience from societal perspectives, institutional adaptations to take advantage of forest and value chain strategies, and road maps for their implementation

Integrated and automated assessment and simulation tools supporting the development of environmentally sustainable and economically viable forest resources-based businesses; matching tool supporting the development of the circular economy through industrial symbiosis customized for forest resources-based businesses, municipalities, and consultants; approaches and tools to help forest planners and companies to analyze resilience in their forest-based supply chains, forest and value chain resilience strategies for Lithuania and beyond, proposals and analyses of institutional adaptations

Research to be conducted at the CoE can indeed be a bottom-up activity, especially when it involves grassroots-level initiatives and individual researchers driving the process. Therefore, it is in the interest of this deliverable to see where we stand with the individual researchers affiliated with CoE Forest 4.0. To get a snapshot of the key competencies and skills available within the team, we conducted a survey. The survey was responded to by 22 researchers affiliated with 6 institutions as a part of the consortium. Based on the results from the survey the expertise within the team is organized in seven primary categories and 17 sub-categories based on specific skills or areas of knowledge. The outcome of this analysis is depicted in Figure 2, where we can see how the expertise of the researchers affiliated with CoE Forest 4.0 offers a good breadth of expertise across different domains of relevance. The 17 sub-categories, also define the depth available within the team. Furthermore, it highlights the expertise for support activities such as business development and project management that are instrumental for the success of CoE Forest 4.0.

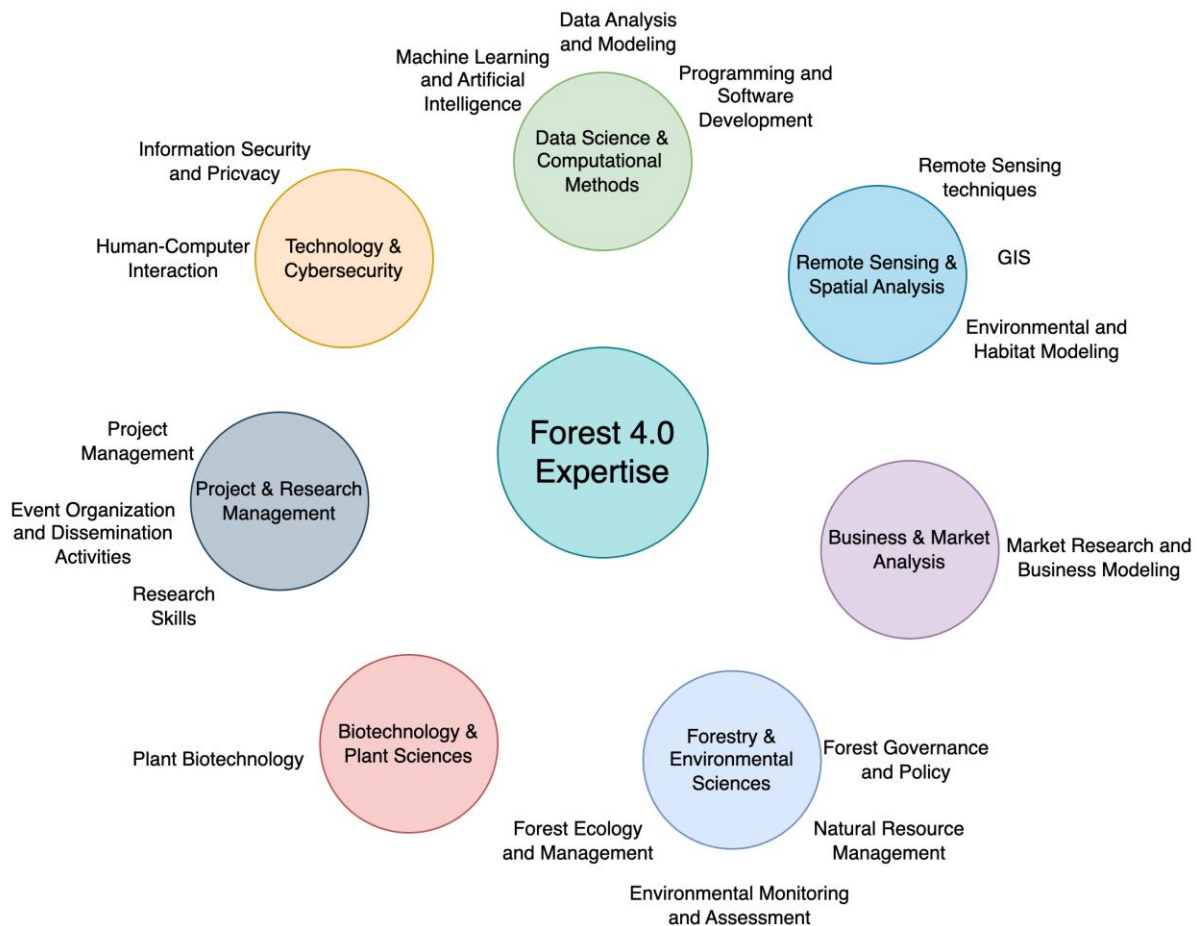


Figure 2. The organization of the expertise of the individual researchers affiliated with the CoE Forest 4.0

## 2.2 State of the Art

Organizing cross-disciplinary teams effectively involves several key strategies to ensure collaboration and productivity. This becomes especially important keeping in mind that CoE Forest 4.0 aims to address complex societal problems, that require often large teams comprised of researchers from multiple disciplines. Having this in mind, we conducted a literature review of scientific sources to understand the core concepts of integrative and associated research such as disciplinarity, multidisciplinarity, interdisciplinarity, and transdisciplinarity. In the scientific literature, these concepts are typically defined based on their degree of disciplinary integration and involvement of non-academic stakeholders. In the work by Tress et al. (2005), these concepts are defined as follows:

1. **disciplinary** research is defined as projects that take place within the boundaries of currently recognized academic disciplines, while fully appreciating the artificial nature of these bounds and the fact that they are dynamic.

2. **multidisciplinary** research represents the efforts of different academic disciplines that relate to a shared goal, but with multiple disciplinary objectives.
3. **interdisciplinarity** research represents involving several unrelated academic disciplines in a way that forces them to cross subject boundaries. The concerned disciplines integrate disciplinary knowledge to create new knowledge and theory and achieve a common research goal.
4. **transdisciplinary** research is projects that involve academic researchers from different unrelated disciplines as well as non-academic participants, such as land managers, user groups, and the general public, to create new knowledge and theory and research a common question.

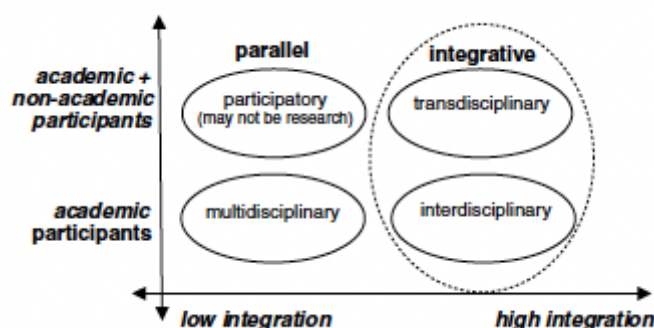


Figure. 3 Degrees of integration and stakeholder involvement in integrative and non-integrative approaches. (from Tress et al. (2005))

Figure 3 above depicts the key concepts of integrative research based on the level of integration as well as the level and type of stakeholder participation. In the context of CoE Forest 4.0, we foresee that there will be a need to pass through all these stages of research with the aim of achieving transdisciplinary research toward a transformative impact in a smart forest innovation society.

In this aspect generating innovative science results with transformative impact in the smart forestry requires a transdisciplinary. Addressing the complex challenges that are associated with managing both natural as well as technological systems requires research approaches that mirror the complexity of these systems (Morton et al. 2015). Transdisciplinary teams offer opportunities to construct a synthesis of knowledge systems that can develop actionable science to address socially relevant issues affecting complex interacting human and natural systems (Lyall et al. 2014).

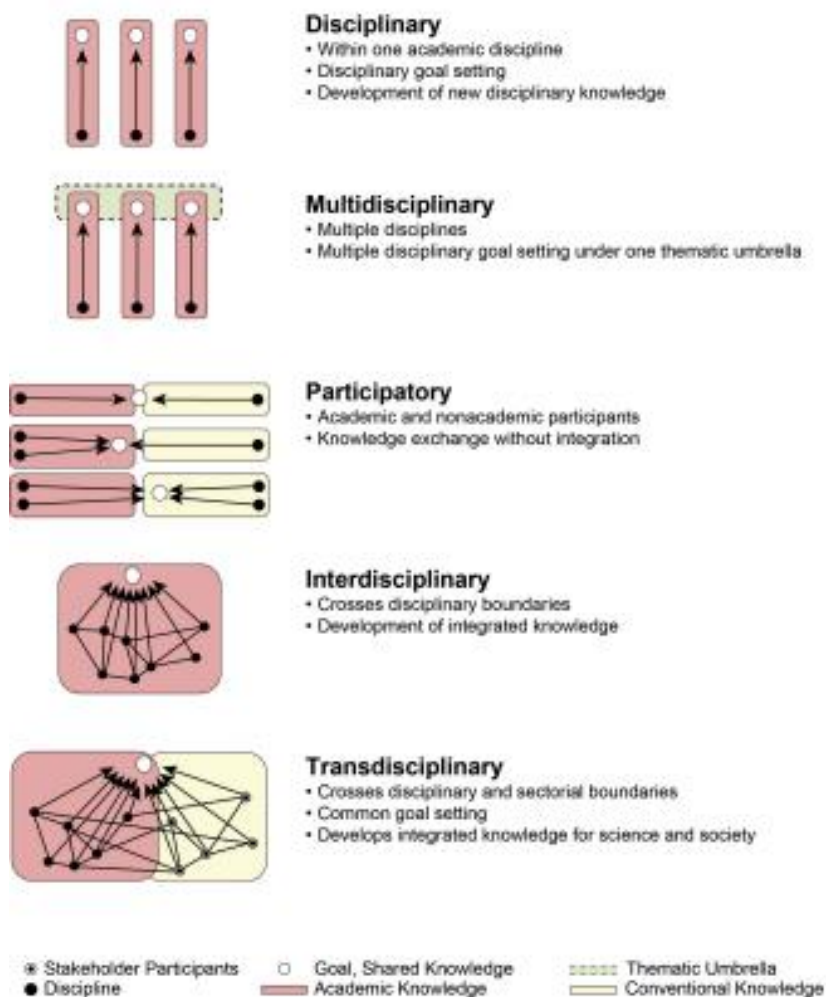


Figure 4. Graphical representation of the concepts of disciplinary, multidisciplinary, participatory, interdisciplinary, and transdisciplinary research (from Morton et al. 2015)

Figure 4 depicts the core concepts of integrative research as a set of relations between academic disciplines, knowledge, stakeholders, and goals. Having this in mind, the CoE Forest 4.0 research platform needs to understand the changing nature of natural and technological systems therefore it needs constantly to develop new projects with diverse stakeholders. Knowledge generated through these projects needs to be synthesized and be able to be applied in diverse settings within the forestry value chain.

### 2.3 State of the Practice

As CoE Forest 4.0 will have a strong focus on innovation and its impact, there is a need to develop a unique organizational culture that nurtures creativity. Based on this, for the purpose of this delivery, we have also researched the different models used within highly innovative tech companies today. One such company is undoubtedly Spotify, which is A Swedish company and presently the largest and

most popular audio streaming subscription service in the world, with an estimated 286 million users<sup>2</sup>. To achieve this level of scale, Spotify invested in increasing the innovation and productivity of their developer teams. As such, the so-called “Spotify model” is a people-driven, autonomous approach for scaling with a central focus on the importance of culture and network<sup>3</sup>. The so-called “Spotify model” for establishing teams is based on the concepts of chapters, squads, tribes, and guilds. The core organizational unit of the “Spotify model” is based on Chapters that are organized by the area of expertise (i.e., skill sets). Squads then collect clusters of people from different Chapters and have them all work towards delivering a product or service. For promoting the work across Chapters and Squads in this model, there is also the concept of Guilds. In this regard, Guilds are looser collectives of people who are organized around a shared interest or goal, (they remain in their Chapter and Squad while being part of a Guild). To put all these structures together, they have organized the Tribes that represent a whole cluster of Chapters and Squads (with Guilds running through them). In Figure 5, these structures are depicted accordingly.

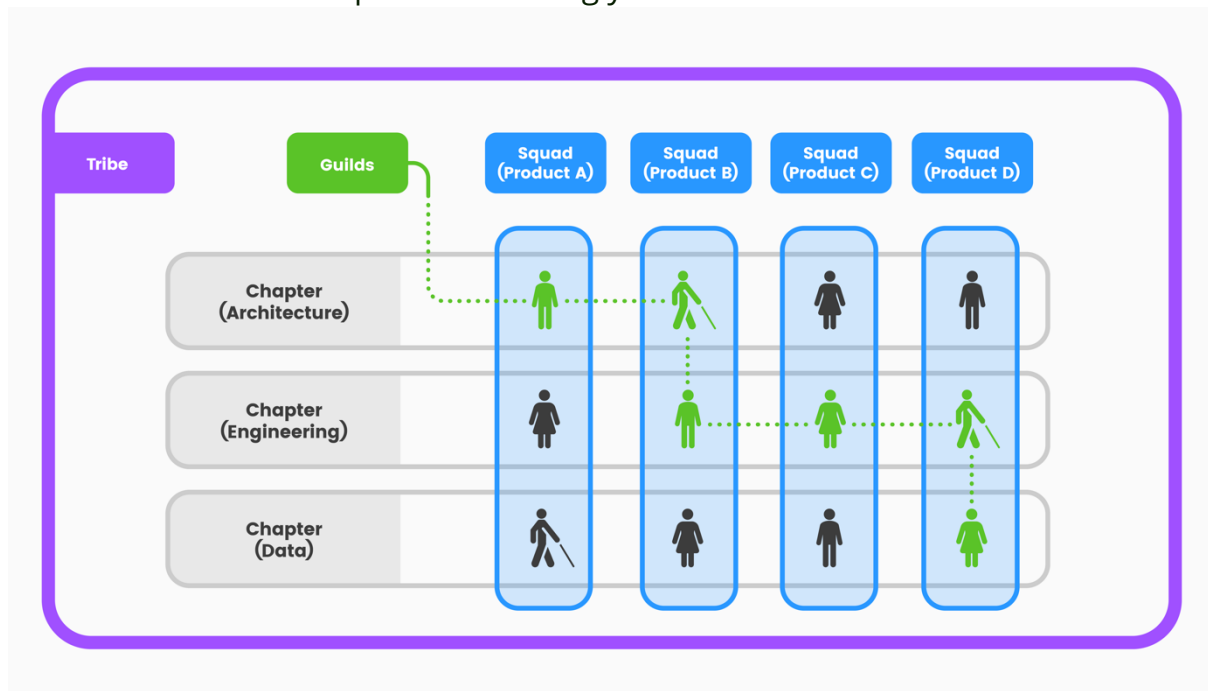


Figure 5. Spotify Model<sup>4</sup>

The Spotify Model for the team organization has undoubtedly contributed to the company's success, fostering innovation, and empowering its workforce. The high degree of autonomy and cross-functional collaboration has led to the rapid development and delivery of quality products. Regardless, the model is not without problems that are typically attributed to its scalability challenges for

<sup>2</sup> <https://www.atlassian.com/agile/agile-at-scale/spotify>

<sup>3</sup> <https://www.and.digital/spotlight/blog/agile-tribes-guilds-squads-chapters>

<sup>4</sup> <https://www.and.digital/spotlight/blog/agile-tribes-guilds-squads-chapters>

smaller organizations<sup>5</sup>. In practice despite having a plethora of organizational models to support innovation, in a recent McKinsey<sup>6</sup> report, a survey suggests that there is a need to combine multiple structural models to drive innovation efforts.

### 3. Toward a Forest 4.0 methodological framework for research projects

Based on the state-of-the-art and the state of the practice, and being inspired by the researcher's expertise, we organized a workshop with all affiliated researchers. In this workshop, we discussed different methodological frameworks. We analyzed the core concepts for integrative research and we see that the CoE Forest 4.0 will mainly focus on transdisciplinary research that involves diverse societal stakeholders. Having in mind the vision of CoE and the need for dissemination of innovation with broader society and industrial actors, we sought inspiration from the Spotify Model. With reference to this, we concluded that a good methodological framework for the projects as a part of CoE Forest 4.0 will be a hybrid approach that aims to build the good aspects for both state-of-the-art and state-of-practice.

In this regard, we see that teams of researchers will be organized in a thematic team that will mainly focus on the core of the research expertise. The project teams will be formed orthogonally with members from all thematic teams relevant to the nature and scope of the problem addressed. In this manner, we will be focused on securing transdisciplinary by working in an innovation structure focusing on the solutions for each project. We believe that this model is both sustainable and scalable and, therefore can be suitable for the upbringing operations of the CoE. With time, the expertise level will be increased therefore this might bring new thematic teams being introduced, and consequently new projects being established. We believe that a flexible and scalable structure combined with an organizational culture will be the key ingredients to nourish impactful innovation to be generated by CoE Forest 4.0.

Figure 6 below depicts the methodological framework for the development of the projects as a part of CoE Forest 4.0. In our proposed methodological framework, we see that thematic areas of researchers should represent one dimension while projects are the orthogonal dimension with them. In the project, as we will be working in a transdisciplinary way, we will need expertise from multiple thematic areas. In this way, we are able to have projects focusing on the solutions, while the

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<sup>5</sup> <https://achardypm.medium.com/analysing-the-spotify-model-unpacking-the-pros-and-cons-of-the-tribe-structure-b23231629840>

<sup>6</sup> <https://www.mckinsey.com/capabilities/strategy-and-corporate-finance/our-insights/making-innovation-structures-work-mckinsey-global-survey-results>

work done within thematic areas contributes to incremental knowledge creation and synergies.

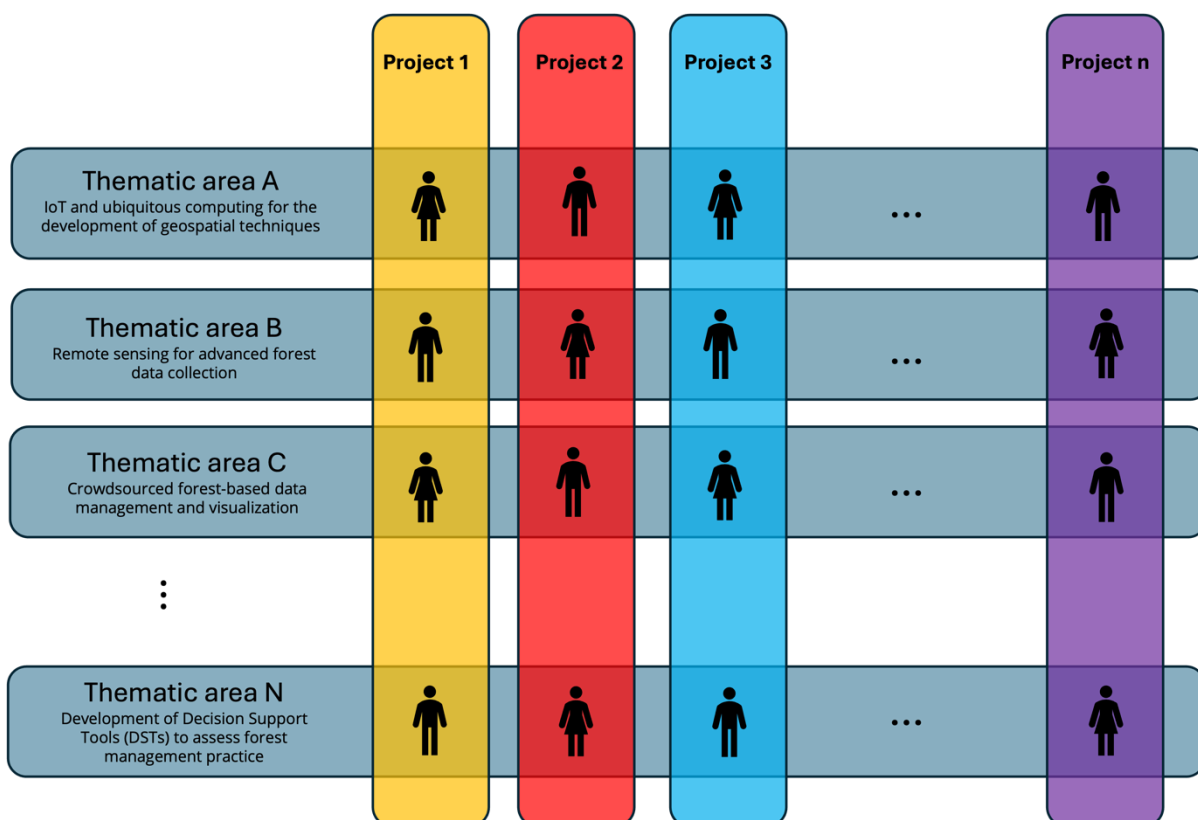


Figure 6. Methodological framework for research projects

We consider that this framework will provide sufficient flexibility and scalability that combined with a proper organizational culture at CoE Forest 4.0 will be the key success factor for sustainability.

As a part of the workshop with an affiliated researcher, we have done an initial test of the methodological framework. In this process, we discussed a couple of real-life examples of how Swedish and Lithuanian researchers from different thematic areas, will work together in projects. We see great potential in this methodological framework as it brings researchers from different disciplines together to work with complex societal problems. For illustration purposes, some of the projects that have been discussed included: 1) the Gaya project, 2) the Education project focusing on the development of educational activities as a part of the CoE 3) the Digital Product Passport project focusing on knowledge exchange between Swedish and Lithuanian researchers 4) Forest sound classification, etc. Throughout these projects, we have set up teams of researchers with diverse expertise that in a complementary manner support each other in these integrative research efforts.

## 4. Summarizing remarks

Developing a methodological framework for establishing processes required us to combine insights from multiple sources. Through this process of data collection from scientific publications, gray literature as well as active surveys and workshops with researchers, we believe that we have encompassed the full complexity of the framework. In this aspect, our aim with CoE Forest 4.0 is to work on a transdisciplinary project with both academic and other stakeholders. The framework developed with inspiration from the Spotify model seems to be appropriate for us to push more innovations in society and industry at large.

The Forest 4.0 framework, however, while drawing inspiration from the Spotify Model, distinguishes itself by:

1. **Prioritizing transdisciplinary research**, which actively involves non-academic stakeholders in the research process.
2. **Adopting a simpler, more scalable structure** better suited to a research-oriented organization.
3. **Focusing on innovation within the context of smart forestry**, to generate impactful solutions for society and the forestry industry.

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Fig 4. Graphical representation of the concepts of disciplinary, multidisciplinary, participatory, interdisciplinary, and transdisciplinary research (from Morton et al. 2015)

Fig. 5. Spotify Model

Fig. 6. Methodological framework for research projects