Non-paper: Contents proposal for Horizon Europe Cluster 6 - Food, Bioeconomy, Natural Resources, Agriculture and Environment, Finland
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Cluster 6 aims to find answers and solutions to the challenges of overexploitation of natural resources, pressure on soil and water, biodiversity loss and climate change and its impacts. In addition, this cluster aims to foster sustainable use of natural resources and support and the development of solutions for an innovative bio and circular economy.

The purpose of this paper is to bring inspiration regarding the themes and calls of the work programme, as well as to describe the Finnish position within the cluster. The paper is based on wide stakeholder discussions conducted during February-May 2020 and November 2021.

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The Finnish position

Regions in the EU are different and need different solutions to tackle such issues as demographical development, urbanization, sparsely populated areas, and logistical challenges. As a large, sparsely populated country with a northern location, Finland has its own special features. A large part of Europe's **boreal area**, especially forests, is located in Finland, and research focusing on the **arctic** and **boreal** terrestrial and aquatic ecosystems can also shed light on the state of alpine ecosystems. **Cross-disciplinary forest research, including impacts of forestry on aquatic ecosystems (e.g. hydrological cycles, nutrient management and humic substances) and biodiversity, sustainable forest related value chains and wood-based material technologies** in general are crucial topics for Finland.

The Baltic Sea is the main European brackish water body directly connected to the North Sea and North Atlantic. It is naturally low in biodiversity and particularly vulnerable. Because of its naturally restricted circulation it is also one of the most polluted seas in the world, although advances in the management and governance of the sea have improved the situation, ye a lot of work remains to be done to reach a good environmental status. Climate change poses specific pressure on the sensitive **northern nature, arctic areas** and animal and plant species. These changes need to be understood and monitored. Setting up mitigation measures will require multi-disciplinary research efforts.

Nordic and Baltic collaboration can offer a lot for EU: effective and close cooperation among administration, research institutes, industry and other stakeholders, a long tradition in collecting data on natural resources, continuous dialogue, and openness are necessary to ensure a consistent and balanced approach to abrupt threats in boreal conditions, as well as to ensure resilient societies. However, Finland and the other Nordic countries need new ways in collaborating with other Baltic Sea countries, as well as other EU13 Member States.

We fully support the continuation of **Multi Actor Approach (MAA**), which has proved an effective method in bringing research communities into closer cooperation with stakeholders and thus increased co-creation in certain themes and topics. In addition, we support deeper **collaboration among funding instruments** like European partnerships to increase the impact of research and innovation chains**.** We need better identification of where such monetary cooperation can contribute to increasing impact in value chains. This should be realized in mapping possible topics for future funding collaborations already when drafting the work programme.

Nature-based solutions are one tool when contemplating interconnected environmental and human health issues through their contribution to multiple goals: climate and water regulation, pollution absorption, providing habitats for a variety of species, mitigating extreme climatic events, decreasing urban heat effects and noise pollution, protecting natural capital, improving human health and well-being. However, we need information about their sustainable boundary conditions or safeguards. For instance, fast growing Eucalypt trees may be the quickest way to increase the carbon sink in afforestation, but they do not improve the biodiversity or resilience of the forest. Municipal and private planners need reliable guidelines and design standards for the entire lifecycle of NBS: how to construct them for given and predicted climatic conditions? How to cater for progressing urbanization and its effect on catchment scale hydrologic processes and climate? How to maintain them and assess them? How to quantify and monetarize their added values? There is a global need for such guidance, and it is the key to make NBS a true managing and business alternative to conventional systems. This is reflected by a myriad of global initiatives.

Cross-cutting themes in Cluster 6

- ✓ Valorisation of ecosystem services in value chains. Ecosystem services are easily overlooked in the economic analysis of production and consumption processes.
- ✓ Health, well-being and societal impacts of ecosystem services, including nutrition and water safety
- ✓ Social acceptability of environmental and climate action taking into account their lifestyle and employment impacts on different populations such as indigenous people and youth
- ✓ Coordinating Cluster 6 strategic orientations with SDGs and Green Deal, as well as the EU Biodiversity Strategy for 2030, Farm to Fork Strategy etc.
- ✓ The principle of no loss to the integrity of ecosystems
- ✓ Nexus thinking: inter-disciplinary analysis of the inter-connected economic, societal, climatic and biodiversity impacts (positive and negative feedbacks; distinguish environmental from social sustainability, and from biodiversity impacts and inter-related to SDGs) effects on employment, innovation, lifestyle, equity, and water safety and management, and address eco-system resilience Nature-based solutions with their multiple benefits in water safety and regulation, climate change mitigation and adaptation and their support to biodiversity, culture, and human and environmental health and well-being.
- ✓ Social innovations and drivers for behavior change. Steering mechanisms should make environmentally friendly choices easier.
- ✓ Innovation in the domain of bio-based material technologies will drive the transition towards a green, bio-based circular economy, and necessitates cutting-edge research in both the technological and social dimensions for accelerated adoption of solutions in society.

Finnish Comments on Key Research Foci

Environmental observations and monitoring

As a large, sparsely populated country, Finland experiences a variety of climate change -related effects. Global change includes changes in nature but also in **human-nature interactions, urban infrastructure, and livelihoods**. We also need to observe what happens when human interaction appears in or disappears from an ecosystem. Long-term observations and monitoring, including analysis of legacy records, provide the possibility to assess these changes and analyse their drivers and their consequences over decades. It is important to bring together existing records including Copernicus and GEO services and to build new ones on these where necessary. Monitoring of biodiversity, climate, land-use, and pollution can all benefit from new remote sensing technologies. *In situ* -components are increasingly important sources of data, and innovative integration of EO and *in situ* data can support sustainability issues in many fields of science.

In **urban and semi-urban environments,** we need remote sensing observations of, for instance, urban heat island effects, of water retention and reuse potential, and of green networks and corridors. Remote sensing can also support sustainable urban planning that supports urban biodiversity, liveability, and climate resilience.

Destruction of wetlands is widespread in Finland, and we need observations and modelling about how peatlands and their utilization are influencing GHG emissions and how socioeconomic activities are related to this. There is also a need for more data on the marine environment, including both coastal and Open Ocean. Remote sensing and high-frequency automated monitoring would provide opportunities for both increasing spatial and temporal coverage. In addition, standardization of eDNA practices in conjunction with automated sampling may provide new cost-effective solutions for monitoring of marine and terrestrial biodiversity in the future. Currently the resilience of marine ecosystem against multiple stressors, for example, climate change and various pollutants, is not well understood.

In northern Europe, climate change adaptation in forests, peatlands, and inland waters requires more information about **natural hazards** especially from satellite observations. For fast response to emergencies we need very reliable observations that are connected to modern forecasting methods. Remote sensing has great potential and can be more cost-effective than traditional observation methods. **Remote sensing covers a wide range of technologies**, including not only earth observation satellites, but also airborne and drone-based imaging and LIDAR technologies, as well as mobile terrestrial sensor platforms. **Each of these technologies offer tools for monitoring environmental changes in different spatial and temporal resolutions**. Pushing the capabilities of these technologies towards real-time monitoring and forecasting at high resolution will greatly advance the possibilities of predictive (vs. reactive) ecosystem management. Furthermore, solutions for wide-scale integration of data across technologies will allow for the holistic modelling of ecosystems and the trajectories. **Thorough testing and piloting are necessary for optimal usage of such emerging technologies.**

Developing integration of observations at various scales (*in situ*, drone, airborne, satellite) is necessary to shed light on environmental change and preconditions on, for instance, agriculture and carbon modelling on catchment level to understand the interactions of soil, water, forest, and sea. Of particular interest are **the changing winter conditions**, for instance, **water content in snow and in soil**. Harvesting requires frozen ground and the change in winter conditions has effects on livelihoods and socioeconomy. We also need to monitor the impact of the green transition: can we quantify the climate and environmental effects of transitioning to circular economy and renewable energy? What is the effect of the **increased demand for metals and other natural resources to supply increasing digitalization and new solar and wind power sources?** How can RI and environmental monitoring support Shared Socioeconomic Pathways?

An ongoing challenge is to find out ways to use observational information across disciplinary and national boundaries. The **interoperability of information** is a key factor in **producing environmentally significant SDG indicators.** This is important for biodiversity monitoring and biodiversity indicator development, modelling and scenarios as well. As pointed out by EU MAES and INCA initiatives, **comprehensive biodiversity data** is becoming more and more indispensable for estimating the state of ecosystems and ecosystem services and of the sustainability of different industries such as agriculture, forestry, and other land-use-related sectors.

The interoperability of data is also crucial in enabling **the digital transformation necessary for evidence-based decision making**. It allows administrative and research entities to electronically exchange, amongst themselves and with citizens and businesses, meaningful information in ways that are understood by all parties. Information in standardized form is usable through interfaces for various applications and services. We need services and databases that are accessible and understandable, not only within their national borders, but also across disciplines, countries, and policy areas. Connectivity between observation networks in national and European level is crucial. Developments in the European and global level interoperability (e.g. GEO(SS), Copernicus programme, Destination Earth, EUROGOOS, EOSC, and cross-disciplinary activities between ESFRI infrastructures such as ICOS, eLTER, ACTRIS etc) should be bought to national level observational information systems, helping to build locally and regionally relevant knowledge services and high societal impact. This requires **high-quality IT systems to support research infrastructures and biodiversity, land, climate, and marine observations and their analysis through AI and cloud computing.**

Biodiversity and Natural Capital

Under the pressure for achieving carbon-neutral societies, there is an urgent need for mapping optimal strategies to maintain biodiversity in all human activities, including forest management and agriculture under the changing climate. The **Do No Significant Harm (DNSH) principle** should act as a cross-cutting theme in this destination. Research is necessary on the **effects of different forest management and farming practices on biodiversity,** taking into account the specificities of the respective local ecosystems. Furthermore, we need better understanding on **the functional diversity** of nature. Under changing (climate) conditions, proper management methods, site selection for nature conservation sites, etc. should take into account how natural processes (and species) evolve and become locally adapted. Now, many species are probably (at least partly) maladapted to current conditions.

Increasingly, we need to find ways to tackle conflicts between biodiversity protection and the use of land and terrestrial and marine natural resources. In addition, we urgently need novel, scalable solutions and strategies to **rewild/restore terrestrial and aquatic ecosystems, including restoration of constructed rivers, wetlands and drained peatlands.** Similarly, **urban environments** require research on restoration and rewilding. Research in this field requires an interdisciplinary approach when integrating ecological, socioeconomic as well as behavioral aspects. Finally, the effectiveness of **marine protected areas** in safeguarding marine biodiversity requires further study, as do the ambitions to increase their extent.

Extensive long-term monitoring and collection of data on biodiversity are a prerequisite to paint a more comprehensive and accurate picture of the state of biodiversity, and Cluster 6 should work closely together with European efforts to improve monitoring (EEA, European Biodiversity Partnership (Biodiversa+), EuropaBON, ESFRI LTER). We need to i) fill in the gaps in the current monitoring schemes, ii) increase understanding of genetic and functional diversity in relation with ecosystem processes such as biogeochemical cycles, iii) develop novel methods e.g., eDNA, Earth Observations, modelling, AI to get better understanding on biodiversity change and its impact on ecosystem services.

The evaluation of biodiversity and ecosystem services needs a wider perspective. The role of natural environments in promoting **health and well-being** need more emphasis in the Cluster’s research themes, and collaboration with Cluster 1 (Health) is important. The need to better understand the interconnections of health and biodiversity has become evident during the COVID-19 pandemic. We should start to focus on the solving of the root causes for such pandemic diseases - causes such as destruction of wildlife habitats, environmental pollution and overexploitation of nature, the same causes that are behind the global biodiversity loss and climate crisis. Here, approaches such as **Planetary Health or One Health** can be of assistance.

We need to strengthen the links between biodiversity and economy and to develop further methods for measuring the biodiversity impacts of economic activities such as the development of sustainable financing. The integration of biodiversity indicators across all economies is urgent for transformative change. There should be both sectoral integration of BD to economy (e.g., with models), but also at wider scale of national economies (beyond GDP, e.g., with ecosystem accounting). Policy instruments are crucial part of regulation of environment-economic systems. Valuing natural capital and biodiversity also requires their incorporation into **national accounting systems** and the development of water and marine ecosystem accounting and their use to support the Water and Marine Strategy Framework Directives. Telecoupling effects of global trade to biodiversity across the regions must also be part of the accounting.

Research, innovation, and piloting of **steering mechanisms** in policy is key in halting biodiversity loss. We need more research on estimating the potential and the impacts of different policy options and steering and follow-up mechanisms; the role of different subsidies, incentives, taxation, and information/guidance. For example, the deployment of **Nature-based Solutions** as part of the EU sustainable finance taxonomy requires strong knowledge base to ensure the positive biodiversity effects.

Research requires interdisciplinary approach when integrating ecological, socioeconomic as well as behavioural aspects. Here, bringing in the perspective of social sciences and the humanities, as well as collaborative methods and co-creation (RRI) in research should become mainstream. This is essential to find ways to tackle conflicts between biodiversity protection and e.g., the use of terrestrial and marine natural resources and land use. The effectiveness of marine protected areas in safeguarding marine biodiversity requires further study, as do the ambitions to increase their extent.

Special focus should be put on **biodiversity in the Arctic**, which is an area especially vulnerable to the changes caused by climate change as well as on biodiversity of **aquatic environments**, such as the Baltic Sea. Furthermore, the role of **urban biodiversity**, green infrastructures and protected areas need to be separately highlighted.

Agriculture and forestry

Forests are important for biodiversity, and climate and water regulation, but they also represent a major source of sustainable and renewable non-food and non-feed resources for transitioning towards a fossil-free, circular bioeconomy. All these functions should be ensured and strengthened in the light of EU climate targets as well as the EU Biodiversity Strategy 2030 and the New EU Forest Strategy for 2030.

In this context, sustainable forest use and management are more important than ever. In particular, when considering the more frequent and **extreme climate change related events, such as droughts, storms, floods and forest fires**. There is an urgent need to improve our knowledge and understanding on the adequate measures for increasing (restoration and afforestation) and adopting (resilience) forest resources and sustainably securing their multiple functions in the context of climate change. Maintaining of the carbon sink of forests and forest products in long term e.g., by minimizing GHG gas production from harvested wood and wood products is also essential.

Thus, investigating **the effects of individual forest management practices**, is crucial for developing both improved and novel approaches to sustainable forest management. In terms of functional traits in forest ecosystems, research is needed on the cause-effect relationship between two spheres: on the one hand, genetic and tree species diversity, structures at landscape and stand level, and soil diversity; and on the other hand, silvicultural and harvesting regimes. Relevant traits and thresholds should be identified to allow better selection of genetic material and species combinations, with the goal of maximizing sustainable ecosystem functions. All sustainability aspects, as well as the impact of climate change, need to be considered when analysing the consequences for biomass production, carbon sequestration, biodiversity conservation and the provision of other ecosystem services.

Research is needed on using vigorous regeneration material, altered growth dynamics, species shift and silvicultural regimes to foster growth under changing climate conditions. Further insights into hazard interaction analysis, the role of forest structures and the efficiency of prevention measures are required to develop new strategies for risk management that increase resilience and support the design of insurance schemes.

When developing forest management practices (e.g., Closer-to-nature forest management) a stronger emphasis needs to be put regional and local specificities (ecological, social, and economic), as to a large extent they influence and determine the applicability of certain types of management measures and regimes. In the Finnish context, continuous growth models/options need special attention: what are such management choices' biodiversity effects as well as their socio-economic (incl. ecosystem service) impacts. There is room for multi- and interdisciplinary research on sustainable forest management and use of forests, which aim to promote diverse and healthy forests, e.g., more environmentally sustainable techniques in forest harvesting, regulation timing of forest harvesting and logistically sound transport solutions, especially considering the changes in ecosystems and field conditions brought on by climate change and biodiversity.

When considering the multiple functions of forests, it is essential to deepen the understanding on the role of forests for water purification and management (e.g., regulation of run-off and water retention). For this purpose, a catchment-based thinking needs to be adopted in relation to land use and water management. It is important to acquire new knowledge on the integration of land use and water management and how "climate proof" different management practices are.

Besides a positive effect on biodiversity and the sustainability of forests, sustainable forest management, practices should also consider how they can offer more diversified and sustainable economic opportunities from forests. For example, marketing of non-wood forest products and ecosystem services offers a range of new opportunities for the development of new business and entire value chains. Research in this area needs to pay specific attention to the practical implementation of these novel opportunities, exploring their marketability (e.g., understanding market opportunities and demand), their sustainable use and governance. For example, Payment for Ecosystem Services (PES) schemes are well understood in theoretical terms, but more research and experiences are needed in relation to their practical application.

Diversification of income opportunities, needs to consider traditional and innovative uses of forest ecosystem services, extending also beyond the borders of forests (e.g., role of nature based solutions in urban areas, promoting sustainable and effective use of wood as raw material). It further requires strengthening research and interaction with forest owners and managers to get a good understanding of their needs and capacities for implementing novel business models.

To take informed decision on forest management, accurate and reliable data on forest resources, their dynamics, condition and multifunctionality are essential. However, there is a need for more research to utilize new technologies and solutions. **Practical solutions on geoinformation** technology e.g., in spatial analysis and visualization would offer promising alley to boost commercial solutions further, e.g., mapping, modelling, and predicting storm damage risks in forests or potential flood areas or greenhouse gas emission. This opens possibilities to give information about various impacts of climate change not just globally but also locally and regionally. These kind of solutions are essential when developing smart solutions for **risk management or anticipatory measures** in certain land based livelihoods, e.g. agriculture, and for urban areas too.

Sustainable agriculture, diversity in plant products, and various new ways of producing food are essential key for pushing ecological boundaries further. There is a need for more holistic inspection of whether food is produced sustainably from an economic, social, and environmental sustainability perspective, to make current food production practices efficient and productive. It must be noted that sustainability and its different aspects (economic, social, and ecological) vary between different geographical regions. In Finland, there are agricultural activities even in the northern parts of the country, which means that cultivation and as well as crop selection is distinctive among different geographical regions also within Finland. Thus, it must be noted that sustainability must be evaluated so that also regional aspects are taken into account.

There is still a need for better digital solutions and innovations on smart land use in agriculture, and for better information and data collection systems (see e.g. zoonoses) to fight unexpected crises. Healthy soils are a prerequisite for sustainable agriculture and other activities as well, and in the spirit of the Horizon Europe mission "Soil Deal for Europe", there is a need for research on how to develop circularity in nutrients or prevent nutrient leaching (e.g. use of soil improving fibres, gypsum or structural lime); how to better employ microbial biotechnology in crop fertilization and protection, and how to manage plant-microbe-insect interactions for better plant health. Research is needed also on how to improve biodiversity in soils and how to deploy nature-based solutions in water management, and restauration of biodiversity to create more resilient agricultural systems.

Agricultural systems are undergoing radical changes, faced with, and also enabled, by radical technologies, such as biotechnoloy. There are new ways of producing food, which need further consideration. Transition should be done in just way and equity considerations in mind. We need more information about **economic and social impacts of these new techniques**, which contradict with the "old" way, e.g., "traditional" farming. It is interesting to know how to combine these two; how do they interact with each other, or with the environment, consumer behaviour, nutrition and food safety etc.

There are potential cross-cutting synergies with Cluster 4 (Digitalisation and space) in such themes as data-based value chains of products in agroecological farming systems and data integration, transparency, (on-farm) traceability, data-based product information creation, i.e., identify novel sustainability indicators, and connect these to incentives and governance mechanisms for data sharing in value chains. Data space, fair data, and data ownership issues are important in agriculture and their importance is growing in farm business management. Additionally, nudging and supporting the uptake of digital practices are required at farm-level. To ensure efficient adoption of new technologies, it is vital to involve end-users i.e., farmers, teachers in agricultural colleges as well as advisor organisations closely to all these cross-cutting activities. Creating competencies and skills among farmers and agriculture related SMEs is crucial to build up know how in digitalization in farm business management.

There is also a need for further research on how to best optimize the production and use of circular **bio-based fertilizers from different side-streams**; ensuring their safety and building evidence-based trust in their use to reduce dependence upon mineral/fossil fertilizers. There is also a need to find environmentally safe, but also effective alternatives for different pesticides such as microbial biocontrol tools and bio-based pesticides, and to implement integrated pest management through careful consideration of all available alternative or conventional plant protection measures.

Ethical animal husbandry includes zero tolerance towards animal diseases (including zoonosis); animal welfare, and antibiotic free production. In food production and processing end, we need more information for better monitoring on antimicrobial resistance (AMR), and food chain traceability as well as in **prevention of food fraud** for example through the development and use of authenticity analyses. Here is also a link to One Health concept, and to biodiversity.

AKIS (Agricultural Knowledge and Innovation System) in Finland is renewing co-operation among various AKIS-actors such as research, education, advisory sector, and farmers themselves. Efficient AKIS-work is essential in supporting dissemination and uptake of research results on farm-level. Furthermore, well-functioning AKIS promotes digitalization in agriculture and its renewal towards more sustainable business models.

Seas, Oceans and Inland Waters

The ocean acts as a global climate control system and plays a central role in regulating the Earth's climate, though, for example, transporting heat and moisture, and absorbing carbon dioxide and locking carbon to its sediment. The importance of the oceans for Earth's and human wellbeing is acknowledged both by the Intergovernmental Panel on Climate Change (IPCC) as well as United Nations Decade of Ocean Science for Sustainable Development (2021-2030).

The ongoing global change, due to the impacts of climate change and societal change, is especially affecting the northern aquatic environments, which can have far reaching impacts. For example, the ongoing rapid change in the Arctic and adjacent boreal regions have wide, even global, effects on e.g., biodiversity, physical and chemical processes in the sea and the atmosphere, marine traffic, tourism and arctic societies and livelihoods, especially those of native peoples. Inter- and transdisciplinary research and innovation based on multi actor approach (MAA) is needed to solve these complex challenges. Indigenous communities and relevant stakeholders should be consulted from the very beginning of the process to contribute to formulating the questions that need to be solved. Therefore, developing transdisciplinary methodologies of co-creation, research on governance arrangements and practices to support the inclusion of local knowledge/diverse types of knowledge to manage complex challenges and support decision-making is also required.

Coordination of development and use of marine and freshwater research infrastructures in Europe is essential to conduct high quality research, improve monitoring, and foster innovation. The activities should utilize the existing European Strategy Forum on Research Infrastructures (ESFRI) where appropriate. For example, the Finnish Marine Research Infrastructure (FINMARI) combines all major components of the Finnish marine research community. The basis of this community also connects the national marine research infrastructure to international R&I networks. Similar, currently non-existing coordination on European level would benefit the whole marine sector and facilitate sustainable blue growth.

The field inventory data and observation networks like Finnish Ecosystem Observatory (FEO) can also be utilized to advance the monitoring of the state of the ecosystems. In addition, developing research infrastructures to manage multidisciplinary data (including non-numerical socio-economic-cultural data) is of great relevance. Here, also ICOS (Integrated Carbon Observation System) is worth mentioning.

The Baltic Sea has been described as a "time machine of climate change for the future coastal ocean", meaning that many processes caused by human pressures become accelerated or amplified in the Baltic Sea. Therefore, the Baltic Sea is especially vulnerable to climate change and biodiversity loss, invasive and alien species and pollution. Another unique feature of the sea is its salinity gradient, which is likely to be affected by the climate change leading to largely unknown changes in the marine ecosystem functioning throughout the basin. The gradient can also be exploited in the scientific studies, to model and estimate how the marine ecosystem and biodiversity may change with potential future changes in the seawater chemistry and to provide scenarios for future management measures.

A challenge is also to understand the resilience of the aquatic ecosystems and to create knowledge of the variation processes, interactions, and responses affecting to the ecosystem tipping points in an evolving world. Evidence is needed to understand the sustainable ecosystem thresholds to avoid possible irreversible shifts between alternative ecosystem states, potentially occurring at high societal costs. Another challenge is to understand the effects of multiple stressors and climate change on aquatic ecosystem functioning, for this both data and modelling approach are needed. Further, third challenge is to generate an understanding that the management actions preventing biodiversity loss are more cost-efficient than the ecosystem restoration to sustain healthy seas, coastal areas, and inland waters.

Alongside, it is important to emphasize the fact that most of the challenges faced by aquatic systems must be solved at catchment scale. In addition, changing seasonal conditions must be considered. For example, in the boreal region climate change is expected to increase precipitation and runoff, which in turn will increase erosion and leaching of nutrients and organic carbon into water bodies from the catchment. In addition, with warmer winters the soil remains unfrozen and in the absence of plant cover the retaining capacity of soil is diminished leading to accelerated leaching and runoff. Understanding and preventing these catchment scale effects, and to find adequate managements solutions, is important for maintaining good water status and the ecosystem services they provide.

We need to improve our understanding of **pathways and mechanisms of ecosystem recovery**. For example, external nutrient loading to the Baltic Sea has decreased since 1980s/1990s, but **eutrophication** status is still problematic and might be worsened due to warming climate increasing the nutrient export from land. Also, internal loading will continue to be a problem and could worsen in future due to climate change if stratification is enhanced due to increased freshwater runoff. The complex interrelation needs to be better understood and will require interdisciplinary efforts such as monitoring for restoration. In addition, development of restoration solutions integrated to the many uses of freshwater and marine ecosystems is much needed.

While there is much interest in the global blue ocean, most aquatic ecosystem services and their benefits (fishing, aquaculture, tourism, renewable energy etc.) originate in **the coastal seas,** riparian areas and lake shores being important locally. Also, most of the aquatic environmental issues we need to resolve are related to these areas – the primary recipients of the human-induced pressures. Here solutions should focus on the **nexus thinking**, and links to other destinations and topics within this cluster and other clusters must be made. One example of an issue that requires intersectoral cooperation is decreasing the nutrient and organic matter loading to marine and freshwaters from land-based activities and understanding **land-sea continuum** processes. Furthermore, a knowledge gap exists in estimates of carbon flow, especially in terms of linking the terrestrial carbon flow from rivers to marine realm, and within the marine ecosystem. Here **research-based innovation and piloting** especially through Nature Based Solutions to reduce nutrient loading needs to be supported. Nature Based Solutions for water protection in different land-based activities, such as forest management, need to be understood in a more comprehensive way.

Aquatic **impact studies** (not only studies on quantity and quality) of chemicals and hazardous material, such as, plastics, heavy metals e.g. mercury, and flame retardants are a critical topic for research. Especially, harmful effects of microliter according to **HELCOM's assessment "State of the Baltic Sea"**. The current regulation focuses on one chemical at a time but there is a critical gap in knowledge of the joint impact of mixtures of chemicals also in conjunction with climate change. Also, emerging and persistent pollutants and potential effect of advanced materials, including nanomaterials and their short- and long-term effects on ecosystems and organisms are important topics for research.

Socioeconomic understanding of what can be considered a good status of the marine/freshwater environment is important, including better understanding of **alternative stable states of marine ecosystems, and their resilience and thresholds**, in particular. In addition, to determine what is good, we need environmental monitoring data and assessment information as well as useful indicators that are linked to social and environmental footprinting (e.g. EU's Product Environmental Footprint initiative), so that behavioural change and management potentials can be investigated and governance mechanisms improved. Investigating compensation mechanisms regarding biodiversity, footprinting and nutrient compensation as a tool to improve the status of the marine/freshwater environment. Investigating mechanisms for biodiversity and nutrient compensation as a tool to improve the status of the marine/freshwater environment are also seen beneficial.

The **EU Blue Growth strategy** focuses mainly on supporting sustainable growth in the marine and maritime sectors. We need to make sure that the blue growth also covers the European Union inland waters (82 000 km^2 of lakes and 1.2 million km of rivers). Increasing consumer awareness and acceptance, supporting creation of value chains for valorisation of side streams of aquatic biomass (fish, molluscs, crustacean, seaweeds, microalgae and microorganisms) as well as bycatch, underutilized and invasive fish species, support SMEs in this development, facilitate dialogue between research and stakeholders along the whole value chain and promoting open data platforms and digital solutions e.g. to enable precision fishing, RAS and aquaponics systems. These solutions are closely interconnected to the food system in supporting the transition to healthy, safe, and sustainable diets as well as recovery and resilience of the aquatic ecosystems.

Sustainability (environmental, economic, social) is the overarching discipline to be taken into account in all blue growth solutions.

Food Systems

The Finnish food research and innovation strategy supports sustainability, nutrition and economic growth targets set for the Finnish food system in recent national and EU-level strategies. The core interest in these strategies is in **environmental sustainability**. In line with the global sustainable development goals and current European Farm to Fork Strategy, Finland aims to be a pioneer in achieving a global standard for sustainability to protect nature, resources, and ecological diversity. Food catering services offer over 400 million meals annually in Finland e.g., free meals in pre-schools and comprehensive schools, lunches in work cantines, food services for elderly, in hospitals and prisons. Therefore, food services provide an important and efficient way to affect equally on diet sustainability from health, social, economic, and environmental points of view.

R&D&I mission defined by Finland emphasizes that 1) **healthy, safe, and sustainable diets** are viable for all, 2) **food and feed production, food processing and food retailing** is to become sustainable, competitive, and resilient, 3) **resource efficiency and zero waste** are key determinants in the food system, 4) **food system is a forerunner in research and innovations** to reach the sustainability targets in EU and globally.

The effects of climate change on agricultural production are currently highly uncertain; variable weather conditions with extreme events will challenge stable food production. Therefore, we must mitigate the negative environmental impacts on production and find resource-efficient and resilient solutions leading to secure, novel, competitive, and zero-emission food and feed system.

Regenerative agriculture capitalizing on water resources (including aquaculture and mariculture), advanced greenhouse technologies (e.g., vertical farming), biotechnical food production (i.e., cellular agriculture), in addition to innovations regarding traditional food production are needed. New organizational forms of cooperation and governance mechanisms in food value chains as solutions for sustainable food production are examples of opportunities for Finland.

Food safety, transparency, authenticity, and sustainability should form the basis for a competitive food system of the future that calls on all actors to act responsibly (primary producers, food processors, food retailers, consumers). Therefore, sustainable land and water use including increasing profitability and resilience of primary production, achieving significant reductions in the climate footprint of animal-based food production, assuring security of supply and delivery, reduction of import of required inputs, as well as increasing export potential of sustainable produced food in Nordic hemisphere are of high importance.. Furthermore, in the changing climate, shift to plant-based diets as well as to new food production technologies will have an impact on food related chemical and microbiological risks. shift to plant-based diets as well as to new food production technologies will have an impact on food related chemical and microbiological risks.

Prevention of food loss and ensuring material efficiency throughout the food system should be in focus, promoting also circular economy. To achieve this, Finland needs to intensify cross-sectorial public-private partnerships regarding new ideas, transfer of knowledge and exploitation of both existing and new technological solutions. Simultaneously, it is of importance to engage all key food system actors – producers, retailers, processors, foodservice, and consumers - as well as the political actors, to fully realize the environmental and societal impacts of the actions. This calls for the development of a digital platform of waste- and side-streams from the food value chains and new circular economy concepts, and investigations into the effectiveness of accompanying governance mechanisms supporting transparency and equity. This calls for development of a **digital platform of waste-/loss- and side-streams from the food value chains and**

new circular economy concepts based on cross-sectorial strengths that improve existing processes but also integrate **disruptive technologies** to develop sustainable solutions. For example, **agri-food and forest industry-based side streams** could be used as nutrient sources for cellular agriculture, as sustainable packaging materials, or for soil improvement thus enabling resource efficient food and feed value chain.

Food environment is currently in strong transition both at the system and consumer levels. This sets demands for the food system to provide feasible, palatable, healthy, safe, and sustainable food choices for the consumers to maintain and support their health and well-being from birth to old age. On the other hand, **consumers need to be motivated to make more sustainable and healthful choices**. Therefore, it is necessary to increase understanding of food and drink consumption, dietary patterns, and dietary intake in relation to nutritional security and health in vulnerable population groups, e.g., in children, adolescents, and the elderly. Focus should be on **gut microbiota and gut barrier function, the immune system, and inflammation in mediating the health impact of food**. **Digital technologies and machine learning** should be applied in promoting and enabling healthful eating.

The role of data-based and digital solutions will become increasingly important for the food system transition, and they should be developed throughout the value chains to create an equitable and **transparent food system**, where bottlenecks in data access and inequities in compliance costs with data requirements and regulations are avoided, to **generate new sustainable business opportunities for all agents**. Agile food production systems built also on circular economy -based solutions facilitate reaching both zero waste and wellbeing targets. Furthermore, it is important to emphasize **trustful research communication** and dialogue about the role of policies and legislation in renewal of the food system.

In addition to cross-sectorial PPP co-work, multidisciplinary research should facilitate the transition of the food system to reach the set sustainability targets. **Combining technology and natural sciences with social science and humanities** to empower food system research in Finland as well in Europe is needed more than ever for the generation of innovations and impact. It is necessary to develop **data-driven food systems** that are transparent, equitable in terms of data access, compatible with global sustainability-data needs and standards (e.g., to reduce imported displacements of environmental sustainability via inter-linked LCAs; to provide inputs into Carbon-border tax schemes), innovative in terms of cooperation models, and cost-effective to manage. Moreover, there is a need to engage citizens and other food system actors in research and innovation, by taking advantage of the common willingness of Finns to participate in research and to test new solutions. Boosting an interdisciplinary approach that connects the humanities and arts with technology and sciences, to fill the gap between consumer-oriented knowledge provision and the implementing and adoption of feasible, healthy as well as environmentally and socially sustainable food system solutions by all actors should be among the key focus points."

Bio-based innovation systems

Particularly important for both climate change mitigation and future business opportunities is the development and widespread use of **Carbon Capture and Storage (CCS)** and **Carbon Capture and Utilization (CCU)**. CCS and CCU can significantly reduce CO_2 (equivalents of GHG) emissions and increase their sequestration from the atmosphere. **Sustainable forest management** is necessary for high-value materials from wood biomass. **New uses of wood** to produce, recycle, and reuse textiles and chemicals, and to replace plastics from fossil origin with chemically modified cellulose, lignin, hemicellulose, and wood-based oil products in, for example, packaging batteries, healthcare applications, automotive and aviation, apparel, cosmetics and hygiene, furniture and construction are important new avenues for research to reach EU's circular economy and design principles as well as climate targets. Finnish universities, research organisations and companies are developing several innovative technologies and sustainable forerunner solutions based on high performance and functional wood-based raw materials. In parallel, industrial marine biology of the

Baltic Sea provides solutions for sustainable production of marine biomass both for energy production, food, pharmaceuticals, and feed.

Bio-based innovation extends to **consumer products & circularity** including smart and functional products in electronics, medical devices, wearables & packaging. One important aspect is to decrease the complexity and number of different materials in bio-based products that can use cellulose fibres, and cellulose polymers together. This will allow better recycling possibilities. We need innovations also for the reuse, repair, remanufacturing and recycling patterns as well as for related governance and financing models. Solutions for keeping the value of biological resources in the economy for longer through the optimization of product design, production processes, performance and end of life are crucial. Maintaining circularity and extending the life of bio-based products may challenge the traditional division between production and consumption systems, stimulating new citizen roles as peers, users and co-producers of services in reuse, repair and remanufacturing activities, similarly to energy prosumers.

Not only sustainable products but **smart logistics and distribution channels**, from **forest to mill** and especially **in the Arctic**, are an indispensable part of circular economy. We need safe and sustainable solutions for terrestrial and marine biomass processing to fertilizers, biogas, materials, food, feed, and biorefineries. Promising avenues exist in utilizing wood, wood-based side streams, wild berries, algae, and agrobased residues for pharmaceuticals, cosmetics, nutrients, enzymes, energy storage, and functional coatings and paints. This creates novel potential for forest owners to participate in new services related to well-being. Ecosystem services, further use of marine industry residues, and marine carbon sink opportunities are crucial topics for research, linking closely to the theme on seas, oceans and inland waters.

Bio-based building materials from wood, common reed, straw, hemp, bio waste and bio-based side streams are promising but require more research to take us towards built environment as a CO2 storage for the future. Products manufactured from solid wood, engineered wood (e.g., cross-laminated timber) or biobased composites, far outperform non-wood materials in terms of carbon-neutrality and in many physical properties, such as low weight and high insulating capabilities. These products are used in various wood-based building systems, but also in furniture, boats and cars (bio-based material solutions for the automotive sector, e.g., foams, biocomposites, nonwovens), as well as in many infrastructure solutions that need to be both highly durable and affordable, e.g., railway sleepers. Although the demands vary significantly depending on the use, common key performance criteria are durability, structural integrity, and fire performance. These need to be better understood, and at the same time, more competitive production methods need to be developed.

Related to the latter, wood-based building systems that use modular and prefabricated elements offer superior performance on many parameters when compared to non-renewable construction systems. However, due to the natural variations in wood quality and the multiple ways in which wood-based components can be assembled, dimensioning of wooden construction systems is far more complex than those using non-renewable materials. Therefore, wood-based building systems need to be further improved and better harmonized so that construction sectors in different countries increasingly opt to use them.

Carbon-neutral cities require increased deployment of circular and nature-based solutions and effective integration with the bioeconomy. Harmonization, standardization, and more intelligent digital design tools will help in the integration process.

Wood-based textile materials (e.g., Ioncell), textile recycling and other new uses of wood are important topics for research. Wood-based side streams are a promising basis for innovative value-added materials such as new composites and chemical products. Recycled materials have great potential as raw material for textiles, new performance fibres, packaging, and processing technologies. Wood-based nanofibrillar cellulose is a promising, biodegradable, non-toxic and environmentally friendly material for individual medicine and biomedical applications, membranes, optoelectronics, functional coatings, and sustainable packaging solutions. Furthermore, **lignin-based solutions** are finding their way into areas such as bio-carbon -based car batteries, tires and bitumen used in asphalt. Lignin shows promise as another versatile bio-based material that can substitute for a wide range of fossil applications. New material-forming methods are needed, to be able to create materials that have a high geometric complexity. Research is needed further, as the

constituents of biobased composites and fibres need to offer combined functions related to fire and moisture resistance, stability, and wear, while still being able to be recycled at the end of the product's lifetime.

Other biological raw materials such as **berries and plant bio-liquids** show great potential for innovation and Finland has world-leading competence in this field. Scaling up and piloting of production processes is a must for new bio-based products to enter the market, thus research should focus on broad TRL levels.

Beyond practical applications, this theme aims at discovering and harnessing nature's biological assets. Finland is developing breakthrough technologies in bioenergy based on microbes and photosynthesis, in synthetic biology, genome editing for material and added value products, and biotechnology for food.

Transformation to sustainability requires more than technological innovation. Maximizing the impact of bio-based innovation involves the elaboration and establishment of governance models enabling sustainable and inclusive bioeconomy patterns, including consumption patterns, market measures and financial models. Systemic transformation towards carbon-neutrality requires changing patterns not only in value chains but in governance and human behaviour as well. Digitalization and artificial intelligence in bio- and circular solutions, for instance in digital farming, is a key component of sustainable agriculture and bioeconomy and links this cluster to cluster 4 (Digitalisation and space).

Finally, this theme seeks to understand the **limits and multiple boundaries of bioeconomy with a healthy environment** and to develop international **sustainability criteria and certification schemes**. One of the key boundaries exists between biodiversity versus people well-being and industrial use of biomass. The Finnish approach to this theme and the whole cluster looks at the **whole value-chain from ecosystem to human.**

Circular systems

Being in multiple ways a forerunner in the economic and societal transformation towards promotion and adoption of circular economy principles, Finland has strong expertise particularly in bio-based circular systems. However, deeper understanding regarding creating and maintaining **sustainable and safe circular economy ecosystems** is needed. Drawing on this, as sustainable bioeconomy can be seen as the renewable segment of circular economy (European Commission 2018), it is necessary to increase understanding on **bio-based cycles** within and across the food system and bioeconomy, regarding safe **manure recycling** in particular, and to promote **safety and sustainability by design**. Holistic and safe circular economy approaches, technologies and processes for the **food industry and overall organic and inorganic nutrient cycles** need more emphasis. These are important contributors to the EU's carbon neutrality goals. Links between biodiversity and circular economy are essential to create **new, sustainable, and safe value chains and novel business models** as well as strengthen upcycling with the help of cascade use.

Plastics is another wider key focus area from the Finnish perspective. This links closely to the wider utilization of biocomposites and bio-based plastics. In particular, increasing recycling rates of plastic fractions and waste streams that are difficult to recycle (due to composing of multiple material types and hazardous chemicals) as well as effects of recycled plastics need further emphasis. For example, further understanding **waste electronics and electrical equipment as well as the chemicals and the separation and recycling of plastics** in this waste stream is highly important. This leads to better separation of metals and to the increase in value of their reuse. Overall, **chemical recycling** and technologies and processes that enable managing **impurities and material heterogeneity** in plastic recycling need more focus. From the Finnish perspective also the plastics use and streams in the **construction industry**, and increasing the recycling rates in this sector as a whole is an important R&I area. Standardization of recycled materials and more insight on perceptions of recycled materials among the actors of the construction industry are required to accelerate their uptake and use.

In addition to plastics, increasing understanding on **mechanical and chemical solutions in textile recycling** is highly important and very much needed. Development of processes for **renewable fuels and cellulose based raw materials and products** is also seen important. For Finland, developing knowhow and processes related to **circular water systems and technologies**, particularly in developing countries and emerging market economies is seen to be of interest.

Overall, **batteries and minerals and metals for batteries** are an important area of expertise and source of value creation for Finland. New technologies are currently developed in Finland and these need to be taken into practice. However, further developing circular economy processes over the entire battery and electronics lifecycles should be stressed in the upcoming calls. This should cover areas starting from **sustainable mining of raw materials**, developing recovery of minerals, decarbonization of industrial processes, and extending to further applications and recycling of battery and electronic wastes. These processes extend already over many different industries and sectors and this trajectory is further highlighted by all-inclusive digitalization. Therefore, holistic closed-loop approaches (covering e.g., mining tailings) are necessary as well as more research on **substitution of critical raw materials**. Developing means to measure the environmental impact of the battery lifecycle and digitalization is also necessary.

In particular, **education and training on circular economy for citizens, research professionals, and industries are highly needed**. Also, development of governance models guiding the transition from linear to circular economy are needed both in bio-based innovation systems as in circular economy systems. It is notable also that replacing and substituting fossil-based industries and businesses is highly challenging in the short run. Therefore, a period of overlap and co-existence of fossil-based and sustainable solutions is necessary. This calls for complementarity of novel solutions and business models for ’independent’ sustainable and circular economy solutions in addition to replacements and/or substitutes as well as policy innovations and coherence to support these developments. Developing disruptive technologies (e.g., synthetic biology) is imperative for circular economy and carbon neutrality to materialize. The complementarity of solutions from different paradigms (circular economy, bioeconomy, degrowth) may accelerate their acceptance.