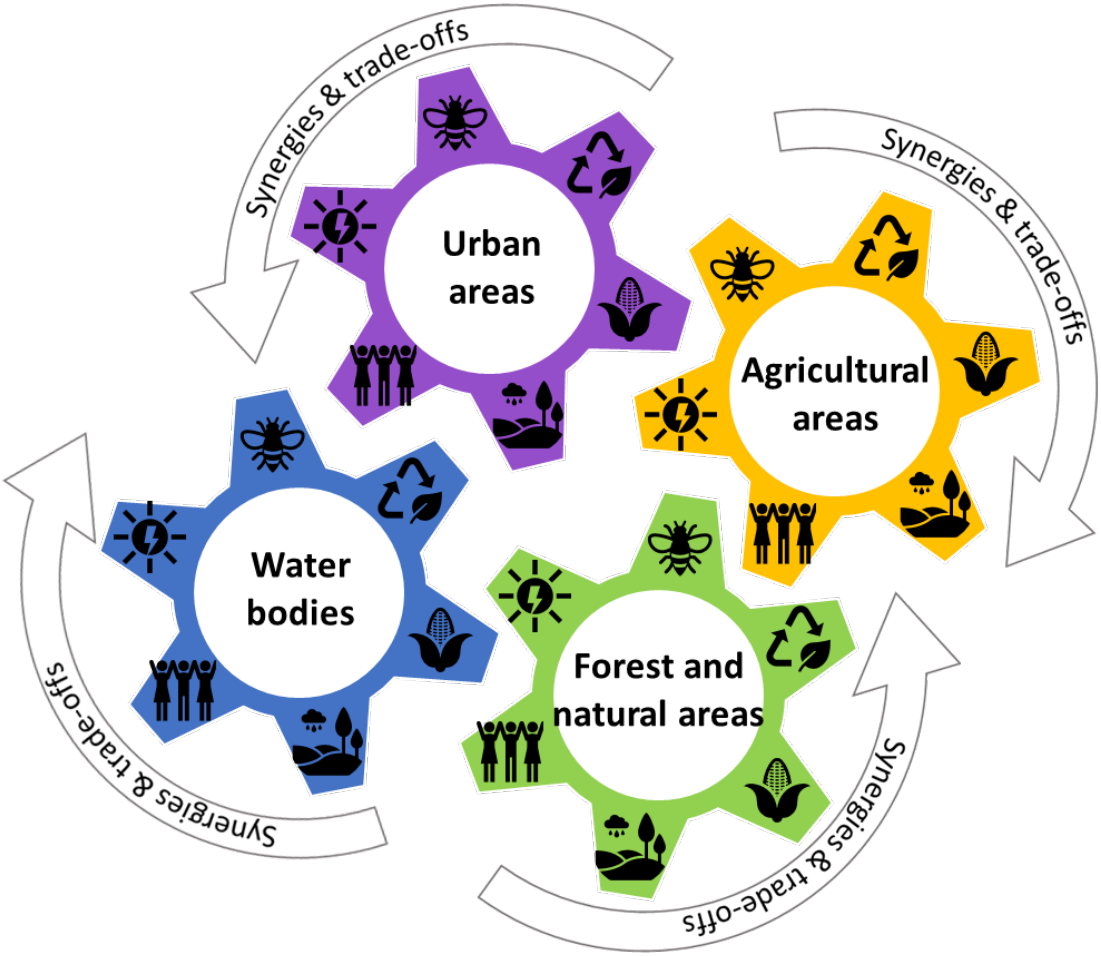
Climate knowledge agenda

Knowledge agenda on climate research for a climate neutral and resilient Europe by Wageningen University and Research



KB 34 - Circular and climate neutral

WAGENINGEN
UNIVERSITY & RESEARCH

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This climate knowledge agenda is initiated and funded by the KB programme Circular and Climate neutral. In 2020, this programme started as one of the five One Wageningen research programmes. Establishing a One Wageningen Climate Research programme was one of the advices from the One Wageningen Climate strategy to stimulate internal cooperation and to improve the visibility of our climate research. The climate knowledge agenda also contributes to the goals of the One Wageningen Climate strategy. The results of this project will be used to draft the future of the KB programme.

The main deliverable of climate knowledge agenda project is a PowerPoint presentation. This report supports and explains the results summarized in the PowerPoint (annex 3).

Contents

Introduction

Population growth, over-extraction of natural resources and climate change are only a few of the immense challenges our world is currently facing. The world needs large transitions to tackle these challenges and to sustain our future and the future of our planet. In 2015, the United Nations (UN) Global Agenda 2030 (United Nations, 2015a) identified the 17 sustainable development goals. Climate action (SDG13) highlights one of the main transitions; We need to take action now, to reverse the climate crisis and to get back and stay within sustainable boundaries of the earth.

The European Union (EU) aims to be climate neutral by 2050 (European Commission, 2020a). For this purpose, the European Green Deal provides an action plan in order to improve the resource use efficiency by transitioning to clean and circular economies, and by restoring biodiversity and cutting pollution (European Commission, 2019). European Commission (2020b) also has a vision on climate resilient Europe where by 2030 the aims are to: "i) prepare Europe to deal with climate disruptions; ii) accelerate the transformation to a climate resilient future; and iii) build deep resilience by scaling up actionable solutions triggering societal transformations".

Wageningen University and Research (WUR) is a leading institute when it comes to climate research and thus WUR can play an important role in the transition to a climate neutral and climate resilient Europe. WUR's strategic plan 2019-2022 highlights that *"Our research is driven by our desire to understand and to contribute to the world's challenges and the transitions that lie before us."* The climate knowledge and drive are an excellent base, but does not tell us what are the research questions we should ask ourselves to contribute to these transitions. Finding the research questions together was the goal of this project. Input, ideas and visions were collected from all institutes of WUR through interactive tools and dialogues. A detailed explanation of the project, its phases and how we tried to make it a true One Wageningen project can be found in annex 1. The results of all gathered input are summarized in a PPT (annex 3) and explained in this document; **Wageningen UR's knowledge agenda on climate research for a climate neutral and resilient Europe**.

The agenda includes the vision, attractive stories how the future of Europe could look like, and the research questions to work on to contribute to a climate neutral and resilient Europe. The future stories and the research questions are divided in four areas: urban areas, agricultural areas, forest and natural areas and water bodies. This area approach as starting point was chosen to stimulate interdisciplinary thinking involving multiple expertises and to improve understanding of the impacts of future problems and solutions. The definition of the areas is explained in Box 1.

Box 1: Definition and European land coverage of the four areas (based on the Corine Land Cover Classes)

- **Urban areas** – areas occupied by dwellings and building including their connected areas (road network, urban blue green, parking lots etc). In Europe, 3.0 % of the land is covered by urban areas
- **Agricultural areas** - areas consisting of arable land, permanent crops, pastures, heterogeneous agricultural areas (e.g. agro-forestry areas). In total, 48.9 % of the European land is covered by agricultural areas
- **Forest and natural areas** – Areas occupied by forests (Land coverage: 28.7 %) and shrub and/or herbaceous vegetations associations (Land coverage 14,1 %)
- **Water bodies** – 2.6 % of the European land is covered by water bodies. In this report, we also include the offshore water bodies.

Many national and international organizations drafted their climate research document with climate goals, strategies, agendas and action plans to reverse the climate crisis (figure 1). Box 2 shows the key messages that we have found when looking in these documents. A detailed analysis is provided in annex 2.

Box 2: Key message from climate research agendas from national and international organizations (e.g. FAO of the UN, EU, Dutch government):

- Business as usual is no longer sustainable; cut emissions; move to clean and circular economies
- Innovate together; connect people, problems and solutions; co-design, co-implement and co-evaluate to increase societal ownership and long-term sustainability of objectives
- Increase spending of governments on climate; promote investment in climate adaptation and mitigation
- Indicate where new knowledge and innovation are needed; invest in knowledge development and innovation
- Develop and use modelling and tools to quantify and monitor impacts; develop climate change projections; Understand trade-offs and synergies
- Identify mitigation and adaptation measures; develop smart solutions to future problems; design efficient interventions; Develop and implement immediate actions to reduce emissions; focus on concrete solutions
- Develop alternative pathways; develop integrated approaches that can consider more than one layer or component; assess mitigation and adaptation initiatives in an integrative way; develop an implementation plan

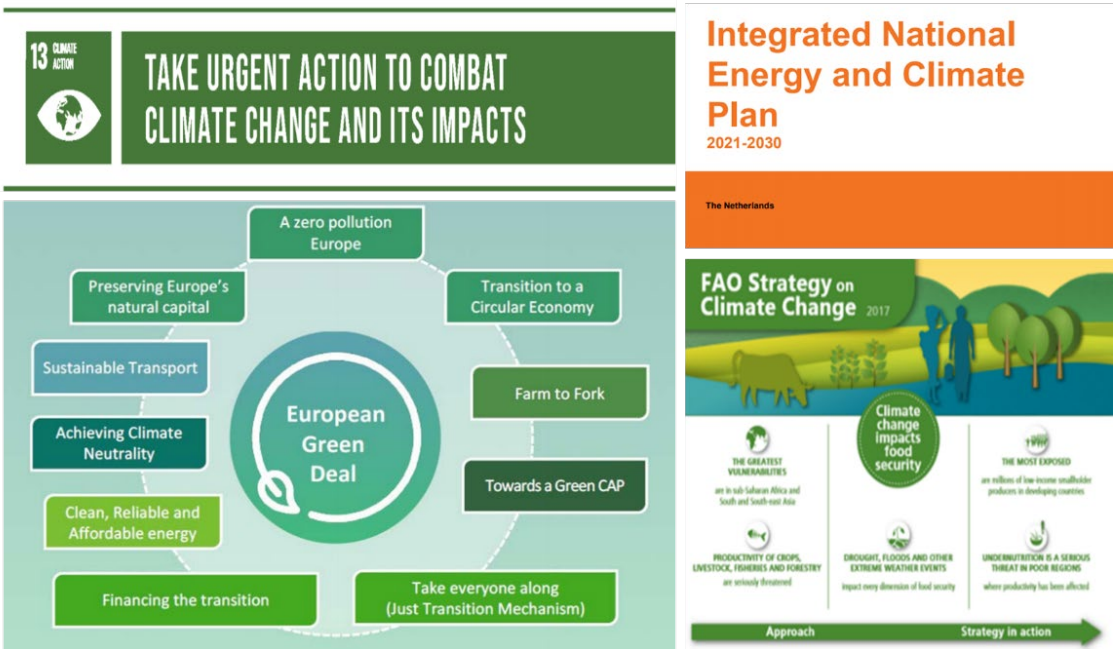


Figure 1: Overview of some of the knowledge agenda that were included in the study. (Left top: UN sustainable development goal 13. Left bottom: EU green deal. Right top: Integrated national energy and climate plan from the Dutch Government. Right bottom: FAO Strategy on climate change)

Vision

The WUR dialogues (explained in annex 1) highlighted that it is unclear which solutions we need in order to reach the EU goals to be climate neutral and resilient by 2050. Some possible solutions are clear, but opinions differ on what solutions are the best or most urgent, or the solutions lack full support. Society does not have the time to figure out what is the best solution nor to understand the synergies and trade-offs of every potential solution. However, we do know where we have to work towards. Therefore, the vision is to start implementing solutions to return and stay within planetary boundaries as soon as possible. We can make it happen by working on exploring the solutions and understanding synergies and trade-offs simultaneously (figure 2).

To find the best and most urgent solutions with full support, we should explore options and not just focus on THE solution we see at the moment. Successful and efficient exploration of options is only possible when we are flexible and allow for quick failure and refocus. This requires interdisciplinary feedback loops to be able to fail fast and to celebrate the small wins.

To understand synergies and trade-offs, we must look outside the boundaries of a specific research field and integrate knowledge across the different areas (urban, agriculture, forest and natural areas, water bodies) and climatic themes, but also geographically (e.g. what is the impact elsewhere in the world)

Solutions, synergies and trade-offs should be combined to create integrated approaches. This requires social engagement, connection to (external and international) stakeholders and analyzing and defining the roles and responsibilities of these stakeholders towards a climate neutral and resilient Europe.

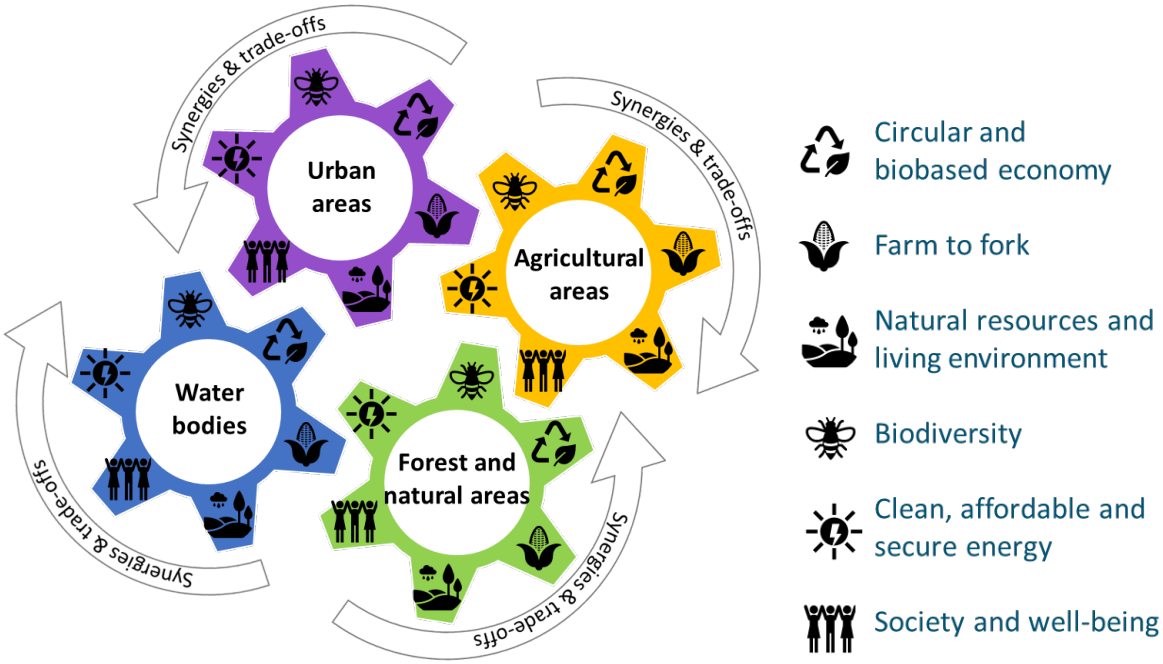


Figure 2: Left: Each area visualized in a gear. Applying a climate solution in one area will have synergies and trade-offs on the area itself and on the other areas. Right: WUR climate solutions are mainly related to these six themes

Overaching research questions

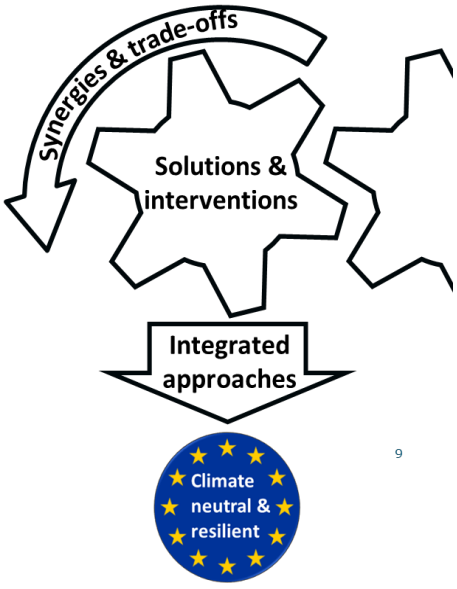
After summarizing all the input from the dialogues, five overarching research questions were formulated. These five questions are overarching and thus not specific to one area:

- Which knowledge and solutions do we need on our way to 2050?
- What should we do where to achieve a climate neutral and resilient Europe?
- What are the connections, synergies and trade-offs for agri-forest-urban-water challenges and what kind of frameworks, models and tools do we have to develop to quantify them?
- How to organize an active transition of agriculture, urban areas and other functions to find solutions for climate change affected nature, biodiversity and water (excess, quality and drought) problems?
- How to design a European nature and water infrastructure that contributes to an active transition of agriculture, urban areas and other functions to a climate neutral and resilient Europe?

The main and specific questions for each area (urban areas, agricultural areas, forest and natural areas and water bodies) are explained in the next chapters. The reading guide for the area related questions is shown in box 3.

Box 3: Reading guide for the areas

- Each area is discussed in 3 parts: the first part is the 2050 future story. The goal of the stories was to tell an inspiring story at the start of the dialogues to trigger the participants to think about 2050. The second part introduces and explains the main research questions. And finally, an overview is given of all the collected research questions. The research questions are from phase 1 of the project and the area specific dialogue (annex 1)
- Research questions are structured in three categories per area: (1) Solutions and interventions, (2) Synergies and trade-offs, (3) Integrated approaches (see figure in this box)
- New and updated questions can/should arise in the future through interdisciplinary feedback loops



Urban areas

Future story: European urban areas in 2050

I am living in a green city. When I look out of the window of my house, I see abundant trees and waterbodies everywhere. Green is also abundant on the walls and roofs of buildings, where it contributes to energy efficiency and biodiversity.

The roof of my house is connected to a raingarden, just like the other houses in the city. These raingardens are connected to a large, green infrastructure that permeates the entire city and connects it with its environment. The green infrastructure helps in the treatment of rain- and stormwater, municipal and industrial wastewater. This way we can use it as a source again.

Water bodies also play a key role now in the energy network of the city. It is used as a thermal source to cool the buildings nearby and to irrigate the city green. The district combined heating and cooling network has become the key temperature regulation system in our city. I enjoy living in the new energy neutral housing. It has both cooling and heating options to make life comfortable now the climate has more extremes.

When I leave my house, it's always nice to take a deep breath as soon as I step outside. Thanks to the green infrastructure and reliance on clean energy, I breathe healthy air. Smog has become something from the past.

When I walk down the street, I pass playgrounds and sports fields. They are also part of the green infrastructure of our city. To buffer times of extreme rainfall and drought – our new reality - storage facilities for water have become very common in our city. Storage facilities are integrated not only in playgrounds and below sports fields, but also in basements of apartment buildings and in groundwater. The green in my city is also a key element for temporary water storage, and thus helps avoiding flooding and peak discharges during extreme rainfall events. This happens quite frequent nowadays. These days the streets are made of permeable pavements. This way the water can infiltrate in the subsurface below.

Our streets look different than before, because private car-ownership has decreased considerably. All the space that was once in use for parking places, has been transformed into green space and pleasurable walking and cycling infrastructure.

Above these newly developed cycling and walking paths are PV surfaces. They are important for our electricity supply, but they are also used as shading devices. These are quite necessary: in summer, we experience frequent heat waves, but thanks to these devices, it's still nice to go for a walk. The PV surfaces are also placed above waterways. This has resulted in an improved water quality. It is quite normal to take a dive in one of our city's waters; something you wouldn't dream about in 2020.

In the park near my house, I like to meet with my 92 year old mother - even on a warm summer day. She lives in the countryside, about an hour away. Thanks to new, hands-free forms of transportation, she can come over for a visit by herself! Normally, she stays over for dinner. We order our food simply online and locally and regionally produced food arrives within the hour. I still remember lots of white vans driving through my street every day in 2020 for e-commerce deliveries. Glad we do that so much more efficient now!

Freshly cut lettuce, herbs and fruits are produced in our city's vertical farms. Other produce comes from regions with optimal soil and growing conditions. Animal products have become rare in my diet, we eat mostly plant-based now and we control how to create fabulous tastes and textures. The animal in the production chain has been replaced by high-tech production processes that produce meat and cheese directly from the raw products (such as grasses).

Talking about efficiency: did you know that we have virtually no waste? Waste is outdated. Instead, thinking in sources prevails. The green waste and human waste that is generated in our city is used after treatment as nutrient source for the local farms and those in the larger region.

We have an economy where the "priceless or voiceless" planet values are also considered in economic pricing, in an economy based on regeneration rather than depletion. I still remember the shock and protests

when depletion tax was introduced, but it forced so much new sustainable developments I cannot look back without thinking: why didn't we do this earlier?

Research questions urban areas

Solutions and Interventions: Climate-adaptive, circular and healthy urban environments

Solutions are needed that can be implemented to develop our urban areas towards climate-adaptive, circular and healthy living environments. A key challenge is to develop these interventions in such a way that they are scalable and that they are developed with the local context - in terms of climate issues, governance structures -, costs of transition and embedding in society in mind.

"How to develop effective strategies and Nature Based Solutions and integrate them as site-specific, green solutions for climate adaptation, water management and other societal challenges in different types of cities?"

Different cities require different solutions to become climate-adaptive, circular and healthy living environments, including for example technologies and nature-based solutions for sustainable urban water management, smart mobility, and biobased materials. It is key to research tailor-made solutions and strategies for different types of cities across Europe - experiencing different (climate) issues and societal challenges, having a different spatial set-up and landscape context.

"How to enable these effective strategies, with stakeholder support and with what kind of policies, institutional frameworks, and financial instruments?"

The effective implementation of solutions and strategies requires research into enabling governance structures and new (urban) economic models to finance these solutions. Moreover, knowledge is needed on how to make the transition inclusive for all urban actors, including minorities and the urban poor, for example with appropriate forms of democratic governance.

Synergies and trade-offs: Multi-functional solutions

There is a multitude of challenges that need to be addressed to ensure cities will be resilient and pleasurable living environments in the future. Solutions for these challenges, including for example the energy transition, circularity, climate change adaptation, healthy living, social segregation, which all have their costs and spatial claims. It is a challenge to find integrated, multi-functional solutions that result in win-win situations.

"Which economic wins and spatial synergies can be achieved when formulating solutions and strategies for the various challenges that cities face?

Further insight is needed into potential synergies and trade-offs between the solutions for the various challenges that cities face. Research needs to shed light on the compatibility of demand for space and resources for the provision of different urban functions, such as demands for water for domestic use, industrial use and urban green. What kind of solutions and strategies can minimize trade-offs but tackle several challenges simultaneously, thus resulting in economic wins and spatial synergies?

"What kind of assessment frameworks can be developed to weigh (the costs and benefits of) various sorts of urban interventions? "

Assessment frameworks need to be developed that can be used to (quantitatively) weigh and prioritize diverse types of interventions, including technological and nature-based ones. It is imperative that these frameworks consider various urban users and beneficiaries, externalities, long-term costs and benefits, as well as both the (ecosystem) services and disservices that solutions provide.

Integrated approaches: Co-creating the urban transition

Urban space is scarce, with many interests and actors to accommodate. Making the transition happen thus requires multi-stakeholder, multi-disciplinary collaboration. The challenge is to set up effective co-creation processes to implement, test and monitor multi-functional, integrated solutions. It is furthermore key to get the support of citizens and get them engaged to realize (behavioral) change.

"What are the potential conflicting and linking interests of urban actors and how to accommodate these diverging environmental, economic, societal stakes in the transition?"

It is key to get an improved understanding of the different stakes and roles of a variety of urban actors and to see where there are potential conflicting and linking interests. Research should thus involve a variety of actors, such as health institutes, governmental bodies, investors, project developers, sewage companies, and utilities, but also citizens have to be actively involved in this transition.

"What are the barriers, opportunities and enablers to mainstreaming integrative, multi-stakeholder approaches to climate-resilient urban development?"

Mainstreaming integrative, multi-stakeholder approaches to climate-resilient urban development requires insight into the factors that are currently acting as barriers and those that can be enablers of such processes. What are the systemic bottlenecks to implementation and upscaling and where are the obstacles and opportunities to get all stakeholders on board in making climate-adaptive, circular and healthy European cities a reality? Dialogues, building (European) collaborations for knowledge exchange, and pilot-research to learn by doing and lead by example, can be instrumental to research this.

Overview of all research questions and topics collected for urban areas

Solutions and intervention research questions
• Different solutions for different situations/cities. • How can people support the required changes? • What is the role of individuals in this story? • The thematic scope and importance will depend on the issues that are being experienced in different (types of) cities • Land in the cities is very expensive, how to get the future financed • Small solutions like greening the garden. How to make that happen? • What do we have to do to achieve behavior change? • Financing these solutions – new (urban) economic models (e.g. include asset managements) • How to limit urban sprawl while at the same time creating liveable cities, or is that the new city? • When is nature the best solution and when technology? • How to set up governance which transcends political cycles? • Economic inequality; how to organize green cities for poor and dense cities? • Which social, economic, and technical measures help us move from trickle-down climate innovation (starting with and mostly benefiting economically powerful groups) to bottom-of-the-pyramid innovation (targeting larger groups of middle and low income citizens) in establishing climate-neutral cities? • Which social, economic, and technical measures help us to create 'smart cities' that are not merely 'cities for the smart'? • Which forms of democratic governance help to effectively engage low and middle income citizens in meaningful participation in the climate transition? • How to reuse water using the capacity of nature to clean? • How can we selectively capture useful components from sewage water? • Climate adaptation and efficient resource usage are part of all financial transactions • How to start now to have in the future greener cities and retrofitted grey infrastructure supported by blue-green infrastructure? • Cities that grow vertically instead of expanding horizontally • Implementation remains the biggest question; what are the economic and social ramifications how do we overcome them? • Which plants and trees are most effective in capturing heat and carbon dioxide in densely populated areas?

- How can urban soils contribute to climate adaptation, mitigation and enhancing the quality of urban life?
- How to combine sustainable tourism and climate proof cities?
- What is the impact of droughts on cities in EU and worldwide?
- What is the potential of water sensitive urban design/water smart city/sponge city approach?
- What is the potential of urban forestry?
- Can we built with wood from European forests in a sustainable way?
- How can NBS contribute to climate neutral cities?
- How to involve and mobilize citizens?
- What are the land use instruments and planning processes to make urban agriculture possible in big and mid-sized cities in the coming years?
- How to reach now technology readiness levels for the future urban development?

Synergies and trade-offs research questions

- Economics (cost effective, cost and long-term benefits?)
- Try to understand complexities.
- Effects of measures of water management on biodiversity?
- How are materials valued and how do we avoid producing materials for which we don't know future impacts or don't have recycle possibilities?
- Mechanisms to include ecological impacts in pricing - the doughnut model, Kate Raworth?
- International collaborations between countries – which synergies are possible between countries?
- Tipping points for transitions and dynamic systems - and how does it link with the rest of the world?
- PV panels vs biodiversity etc. Different benefits and usages of water and the players that have a (different) stake
- What is the health profit of a green city?
- Trade-off between water and green. If water is scarce, what kind of green?
- Trade-off economics and 'green cities' -> internalize Externalities, costs of greening
- Trade-off between environmental externalities and food.
- Urban- rural connection
- Biodiversity vs Water for human use
- Recreation vs Biodiversity – how do we give 'space' to nature and space for recreation, are they combined or separated?
- How to incorporate spatial trade-offs in our measures for circularity?
- Concentration (density and urban green-blue structures) versus strategic 'sprawl' (interwoven new urban systems)
- Which transport infrastructure innovations are performing well in terms environmental and social benefits, and why, related to the specific problems of the area regarded?
- What is the potential health impact as result of increased mobility, reduced stress, and number of people exposed for area concerned?
- What risks in water needs exist in different cities around Europe?
- Evidence base (cost/benefits) of nature based solutions for cities

Integrative approaches research questions

- Process how to get there
- Transition processes, how to get it connected/integrated, multi stakeholder – multi discipline process (human interactions)?
- How do we arrive at this circular system?
- How far in this story can we come for 10 billion people?
- How to set up this transformation process?
- How to force this story into ALL levels of ALL institutions?
- To what extent is stability needed for this transition?
- Which are no regret policies?
- The EU and municipalities want to start with it. Why are goals and realisation not matching?
- Different types of cities – which ones have similar issues and/or governance structures / local context?
- What are the steps needed to go from dream to reality?
- What is the role of Europe on the global stage? How can knowledge be effectively shared?

- Connect with financial/ investment streams (there is a lot of money being invested in cities, connect with this opportunity for renewal and innovation)
- Connect with other/new actors (developing, investing actors) - those who have incentive for change
- Prioritizing; what is most important to achieve in the city?
- Who are the main actors and stakeholders that have the power, influence and motivation to change the old system/regime to a transitional and more sustainable pathway?
- The big HOW TO change? What are enabling factors to really change?!
- What are the systemic bottlenecks to implementation, deployment (upscaling) and policies for upscaling within and beyond the area?

Agricultural areas

Future story: European agricultural areas in 2050

I am a farmer. In 2020, I took over the business from my parents. The following years I decided that business-as-usual was no longer the case. Mono-cultivation and high input systems were not suitable to adapt to climate change and to reduce the greenhouse gas emissions. We were confronted with the reality that earth surface was warming, and I had to do my share.

I first started with re-designing the practices on the farm. I intended to become more climate smart. So instead of only cultivating grains and potatoes, I started operating a diverse farming system with a mixed crop-livestock. So, I now have cows and chickens on the farm as well. The advantage of such a diverse system lies in its ability in adapting to climate change. And you know what I mean by climate change, right? We have frequent heat waves, droughts and extreme rainfall events(!).I have integrated agroforestry on my land, allocating part of it for nut and fruit trees for us and our customers, and fodder trees for the cows to nibble. The chickens scavenge freely underneath the trees and utilise the unavoidable household waste (which we have very little by the way). Agroforestry helped me find alternative sources of protein for my livestock. These practices were also more in line with my aim to improve animal health and welfare.

Circular options followed. Circularity was not just a concept, but ithas become a way of living for us. How? Less raw materials, valorizing the biomass, and paying more attention to the quality of soil, water and air. For example, I use manure and human excreta for fertilising my crops, which improved the nutrient use efficiency and reduced the nitrous oxide emissions. The composition of the animal feed, with easy-to produce alternative protein sources and with the optimum use of land and crop residues, also reduced methane emissions from my cows. How do I know this? Since my farm is part of a central monitoring system that uses data from all farms in the network in Europe, I can monitor the greenhouse gas emissions of my farm. My neighbour farmer Nick and his wife Chloe organise workshops to keep us up-to-date with all the new information and knowledge emerging on farming systems.

Speaking of Nick and Chloe, I also work together with other neighbouring farms. We check and align production based on the demand in our region. This network of farmers crosses the borders of all European countries. Cross-border coordination ensures that livestock and crops remain healthy and that we never exceed carrying capacity of land and water for the production of food. We have a system by which we exchange raw materials and biomass such as manure to improve efficiency. It is like second-hand shopping.

To optimize the use of manure, the areas for arable crops, livestock and horticulture are positioned strategically. This does not only happen in the Netherlands! Grasslands and marginal lands are restored and used to feed animals throughout Europe. New grazing methods and forage systems developed. They contribute to carbon sequestration, biodiversity and landscape restoration, and are therefore mitigation and adaptation too.

Soil and water are essential components for us farmers in this erratic climate, so we ensure that they are and remain of excellent quality. To do that, we use the principles of precision agriculture (for example fertiliser management). Precision farming is evolving throughout Europe and the rest of the world, often with Dutch know-how.

My tractors and other farming machinery use hydrogen produced from wind or solar energy. This way I reduced my carbon dioxide emissions from fossil fuel use. Thanks to the solar panels on the roofs of my stables, I have even become an energy supplier. There is also a biogas plant on my site. Would you have imagined in 2020 that the production, processing and transport of products would use only renewable energy in the future? Yes, it is happening! Since we did not add further carbon dioxide from fossil fuel use in the atmosphere, we were able keep the global temperature rise below 1.5 °. This happened because we acted together!

You may wonder all this required investment. You bet it did! I had some reserves because farmers all over Europe have had a healthy, predictable and consistent income with long term contracts to ensure stability. It has to be like this, because it is not easy to get good harvests in such an unpredictable climate. Of

course, we have multiple sources of income and a well-functioning climate policy. Penalties and rewards are part of the finance mechanism.

Our consumers pay a fair price for our products. Just like me, they wanted to change their dietary preferences. There was no one right approach or one right practice to get there. We had to approach all possibilities with a curious mind. Dialogues are in place in the entire supply chain to make transparent and informed decisions on how to cope with climate change. Citizens respect farmers because of their efforts and the way we are connected to produce food within the planetary boundaries. Social farming is a thing! For example, students, people with disabilities and even office workers from the cities regularly come to work on my farm.

These systems are the result of co-design, co-build, co-implement and co-evaluating among farmers, citizens and policy makers. Circular, climate resilient and nature-based solutions were the best decisions of early 2020s, we are still harvesting the fruits of it now.

Research questions agricultural areas

Solutions and interventions: Food production and climate change

Arable agriculture and livestock are the backbone for European food supply and livelihoods. The changing climate is however posing challenges for the use of resources and land, and thus for food production. Strategies for climate adaptation and mitigation often need tailor made solutions and interventions in different regions and societies, considering the great variety of interests and motivations of those involved. Understanding the role of arable agriculture and livestock in different settings and contexts is, therefore, of pivotal importance for enabling those involved to shift towards more resilient and climate neutral agricultural production.

How can the European agricultural production systems adapt to climate change and reduce the GHG emissions by designing and implementing alternative and diversified farming systems?

In order to reach a climate neutral and resilient agricultural production, it is of key importance to identify adaptation and mitigation possibilities in food production. This will require the optimization of current systems, but also the design of alternative and more diversified systems.

Which strategies and interventions are relevant and how can farmers, value chain actors, researchers, governments and consumers contribute to achieve effective, efficient and legitimate solutions?

Collaboration is key in designing and implementing the alternative solutions. For lasting solutions all relevant stakeholders in the agricultural sector must be engaged in both the design and the implementation. Identifying, demonstrating and implementing novel ways of joint, coherent and fair modes of working towards a future proof agriculture becomes of paramount concern.

Synergies and Trade-offs: Interactions between environmental, social and economic aspects of agriculture.

Efforts to implement solutions for a climate neutral and climate resilient agricultural production in Europe will have synergies but will also have trade-offs on other areas and sectors. Food production might come at the expense of water availability, water quality, circularity, biodiversity loss, soil quality and socio-economic vulnerability. None of these concepts can be seen in isolation since they are inherently linked. For effective, efficient and legitimate solutions, we need to identify and understand how the different components of the food systems interact and to what extent this interaction affects the outcomes (e.g. social, economic, environmental, consumer preferences).

What are the trade-offs and synergies at different dimensions while transitioning towards climate neutral and resilient agricultural production systems?

While the solutions may create win-wins on some of the dimensions, it is likely that there will be trade-offs on some others. The priorities for selecting one or multiple solutions and their consequences at different levels, therefore, need to be analyzed carefully.

How to minimize trade-offs and enhance synergies of future farming systems?

Integrated approaches: Tools for multiple stakeholders

Agriculture faces issues of developing solutions in settings of scarce resources, many and diverging interests and multi-faceted complex challenges. Solutions must reflect these concerns and create common ground for support of integrated approaches based on a level playing field for the stakeholders in the agricultural sector.

How to develop new or adapt the existing integrative approaches and tools that address the multitude of often conflicting interests among the many stakeholders engaged in agriculture?

Tools and methods are of great importance to structure the challenges and solutions and identify synergies and trade-offs. Within integrative approaches such tools and methods can help bringing together stakeholders for developing joint solutions for different spatial scales, zones, sectors and issues, including conflict resolutions and new mechanisms for the design and implementation of a resilient and climate neutral agriculture.

What are suitable locations for different farming systems across Europe to optimize agricultural land use and lower the climate related impacts?

Overview of all research questions and topics collected for agricultural areas

Solutions and interventions research questions
• What do you need to keep farming running? • Crop-livestock balance? • Study climate regions that shift towards the north (Spain/France to NL) • Change in behaviour. Study more. How will farmers, but also consumers and industry act (risk preferences)? • How to achieve change; governance (support), what is effective, what's not? Timelines important. • Energy: only solar and wind is NOT enough to get to circularity • Enabling policy environment? How do we create that? • How to make true pricing possible? • How to avoid the leakage effect in other parts of the world? • Which crops should we grow in 2050? • How can agriculture contribute to climate neutrality? • How can agriculture be part of the solution? • How to lower emissions with for example other diets? • New plant varieties that can be grown without pesticides/herbicides and under water stress conditions • EU spatial planning • Diversifying on income • Role of government to stimulate change is required. • Crop and livestock species that fit better to future conditions • What will you put where? (Agriculture etc). • Choices for certain areas better adapted to certain changes (spatial choices) . • Reducing / moderating consumption (especially animal based products) • What should a farmer be? Specialization vs generalist. • Do we want to produce everything local? World trade aspects • Do we have to make choices now? Keep options open? • How can you use Nature Based solutions for improving agriculture?

- Which innovations are now needed to make the big changes in the future?
- Is the consuming willing to pay?
- Can we feed Europe?
- How to generate energy local? Using good agriculture land for PV panels is not the solution
- How to produce with limited emissions and pesticides?
- How to best arrive at mitigation and adaptation in the European land sector?
- Improve postharvest behaviour of crops (breeding) and to make the postharvest chain more energy efficient
- How can we achieve food security through circular agricultural production systems supported by effective policy instruments?
- How can we stimulate consumers to change their life style towards healthy and environmentally-friendly ones? What incentives do we need to use for making this change?
- How can we make products that are more flexible toward adverse conditions in the chain. This means crops that can be stored at higher temperatures without quality loss, crops that are resistant to common postharvest pathogens, crops that do not loose water postharvest
- What will be the consequences of new production and distribution systems for the postharvest? Are the current technologies still suitable or do new technologies need to be developed?
- Can we develop climate neutral refrigeration technologies making food cold chains more sustainable?
- How can sensory technologies and information technology improve our understanding of quality management of fresh produce and therewith improve supply chain decision?
- What storage solution has to be created for consumers to optimally store fresh produce to maintain the fresh produce to optimal condition for consumption and reducing food waste?
- How to reduce the need for food refrigeration?
- What can Wageningen do for the marginal areas?
- How we can shape our (food) production economy into a cascade/network in which enough is produced for everyone while respecting the finiteness of resources and value of life?
- What strip cropping combinations increases the resilience of the production systems?
- Can we close the nutrient, carbon and water cycles and at what level?
- Sustainable food production requires healthy soils in terms of soil structure, soil chemistry and soil biodiversity: how can we achieve these healthy soils?
- What are effective water harvesting techniques for all different sub-climates in Europe?
- What animal products would we produce when only small numbers of livestock are available?
- How can we produce animal products without animals?
- To what extent can we implement the production of animal products from animals that yield more, e.g. insects?
- Which plant-based food products can replace animal products?
- How can sustainable animal products and plant-based alternatives be produced to deliver the healthiest possible product?
- What are the suitable protein source in Europe?
- How make this production and circulation to be sustainable?
- How to reach behavioural change in diets?
- How to reduce food waste?
- What is the potential of food production at sea? seaweed, oysters, mussels
- What is the genomic potential in biodiverse soils and water systems?
- Can we enrich those systems with the microbial/host/environment gene functions we need?

Synergies and trade-offs research questions

- What is the impact of new systems on greenhouse gas reduction?
- With more crop diversity and climate resilient crops, what is the effect on financial profit?
- Check if farm innovations have effect on climate adaptation and mitigation
- Food system approach (wider than only agriculture) and assess also equity, food security, biodiversity; next to food production)
- Better understanding of impact of CC on agricultural production and food system/ chain.
- The impact on labour market due to high-tech production systems;
- The impact on land use under various production scenarios
- Do we have enough water for future food system (including adaptation)?
- Spatial impact of climate neutral (spatial planning)

- Alternative uses of energy and the implications on agriculture
- Modelling studies that can capture trade-offs and forecasting
- Modelling of interventions and measuring impacts
- Dutch perspective- International perspective
- Possible trade-off with animal welfare if we focus on reducing land use
- More nature-inclusiveness could result in a lower production
- Nature based solutions for agriculture will require a lot of land; scarcity of land
- Profitable business models: Economics vs natural resource efficiency.
- Collaboration vs polarisation. Cooperation is hard to achieve
- Not only agriculture, means more divers landscape; positive for recreation and so
- Biodiversity and automate - when compatible and when not
- Dropping in productivity due to changing production systems
- Horizontal expansion (areas) (and agricultural resources) due to lower yield values
- What is the impact of new production systems towards the future on the sourcing countries as whole?
- Land use & planning -> mobility, energy transition, food & biodiversity, carbon capturing in soils
- Impacts of using different energy vs biomass production (biomass for economy vs biomass for food)
- What are the bottlenecks of introducing the circular and climate-neutral production systems in society?
- What is the good balance between economic growth and environmental quality (e.g. air, water quality and ecosystem services) by 2050?
- How to mitigate food safety risks and food fraud with the new protein sources and technologies in an early stage in order not to hamper the transition?
- How to define climate resilient and sustainable land use related to responsible food production systems?
- What is the effect of a higher soil organic matter content on water holding capacity and production on multiple soil types?
- What is the impact of climate change on food production in EU and how to adapt?
- Unsustainably produced food and products from outside of Europe, e.g. palm oil that causes deforestation in Indonesia or soy and beef that cause Amazon deforestation

Integrative approaches research questions

- How to get to more sustainable futures (Theory of Change)
- What is the role of different stakeholders? Societal and experiential Learning
- Connecting different types of production systems (link to food processing and marine environment)
- Studies on land management (multifunctional land use)
- Need for big change – baby steps now. Need system changes.
- Political trade-off (conservative vs progressive farmers)
- In 2050 climate will/have changed; rules of the game will be different
- Different legislation in different countries
- How to avoid exporting our problems outside the EU?
- Emissions per ha or kg product?
- Transition to avoid leaving some people behind integrated research agendas (beyond production of food and resource use)
- Integrated approaches – hard to manage multi-disciplinary work
- Students should go to the field. (bridge gap between practice and theory)
- Investigate how government can imply big changes hand in hand with bottom-up approach. Link to level plain field (within EU/world scale)
- We should be able to work together in always changing teams
- Exchange knowledge across different food systems in the world
- Are we going to collaborate or compete within Europe?
- Can we raise awareness by involving all relevant disciplines, ranging from governance to hydrology and from economy to ecology etc.?
- How to develop systems, tools and models that can quantify effects of techniques, policies or measures that can envisage future effects of current decisions?
- How to facilitate farmers to implement climate adaptation measures?

- What does optimal land use in Europe mean?
- Focus on showing how an integrated approach to food production that takes into consideration soil ecosystem health and quality, human health and well-being and food quality is the only way forward
- Development of adaptation pathways
- Fair prices for farmers
- Economic trade-offs with nature. Bigger companies vs single farmers. Smaller farmers take decisions that are better for nature

Forest and natural areas

Future story: European forest and natural areas in 2050

As a little kid, my father often took me out for a stroll in nature. During those walks, he told me a lot about the birds and the plants and about the beauty of nature. Thanks to my father, I became a big nature lover. I say this also on behalf of Nico. Now, in 2050, I still often go for a hike, as do many others who travel along the extensive new trails that cross European nature. Many of these trails are now as famous as the trail to Santiago de Compostela. But since our parents' childhood, climate has changed undeniably and has changed the natural environment as well.

The kind of forest I used to walk in with my father, I can now only see in outdoor museums, as we call the small remnants of nature reserves. Here nature is intensively managed, conserved and restored. This micro-management enables rare species to survive, especially in the most valuable and vulnerable nature areas.

Nature outside these outdoor-nature-museums is completely different. This nature consists of large units in the landscape where spontaneous processes are the shaping forces, creating highly dynamic landscapes with a large diversity in habitats and species. However, habitats and species composition changed substantially, driven by the changing climate, integration of land use in natural areas and intensive but sustainable utilisation of ecosystem services. These ecosystem services are still delivered by nature, like in the old days, but by different species and are key to a sustainable economy and human well-being.

So now, when I go hiking, I visit forests areas that have arisen in marginal rural areas and they are well adapted to the new climate. The forests are throughout Europe and well connected through corridors and steppingstones in the rural area like hedge rows, tree rows, small forests, agroforestry, forest gardens and natural strips. This way, deer, wild boar, wolves and other animals can freely migrate from one place to another, safe of road-kills. Also plants can easily disperse through these corridors. This way they can migrate with the shifting climate zones.

I am not the only one enjoying these areas. The amenity of the landscape attracts many people and the nature and forest areas are intensively used for outdoor recreation, sports, safari tours and spiritual experiences. These areas have been developed with a system of carbon credits, because trees and forests soils store large amounts of carbon. Polluting businesses use this system to compensate their carbon footprint.

The forest is essential in the circular bioeconomy. All forests are managed sustainably and large-scale clearing areas have been replaced by small-scale cut-out systems. Forest products are cascaded optimal and used only in long living products such as constructions. This way, carbon is stored for long periods of time. Furthermore, forests retain and filter water contributing to high quality drinking water and flood protection.

Not only forests have changed drastically. In the marine environment, new extended salt marshes and seagrass meadows safeguard shores to sea level rise. They are sequestering large amounts of blue carbon and create habitat for benthos on which large flogs of water birds forage.

Although there are strict marine nature reserves, that are delivery rooms and safe havens for many fish species like cod fish, rays, sharks, bluefin tuna and common bottlenose dolphins, many areas are multifunctional. Wind turbine parks are combined with oyster cultures and recreation, like diving and hotels on sea. Sand needed for infrastructure, construction and coastal protection, is extracted in a limited way, using aquatic life friendly techniques.

River areas cover extended areas with shallow meandering streams, swamps, reed beds and open waters. Large populations of water birds, beavers, otters, water insects and plants are making this a very attractive landscape for recreation. Hikers can walk all along the river from the source to the sea all through natural landscape.

This landscape is very dynamic with frequent water peaks but no high dikes are needed because of the expansion of the area. High water peaks can easily be stored in the area, supporting the biodiversity of the area. The area produces clear drinking water for large parts of the population.

Besides nature, also society and human culture have changed. We have said farewell to a culture that combats nature to reduce risks and increase welfare at the cost of nature and natural resources. We have grown to a culture that is in balance with nature and uses nature for societal well-being and prosperity. Cultural and spiritual values of nature are the basis of nature conservation and intertwined in society, economy and policy.

Natural areas are more and more integrated with other types of land-use like urban and agriculture. For example, in the cities green roofs, nature-inclusive buildings, tiny forests and forest gardens are common. Future urban expansion is fitted in existing and new nature areas in such a way that they have zero or a positive impact on the environment.

European policy safeguards that natural processes can take place undisturbed. This way, natural patterns and structures will develop that are important for climate resilient and biodiverse nature areas. Enhancing nature and biodiversity is the starting point of all actions that impact nature, simply just because biodiversity is the base of our existence. We can only adapt to effects of climate change and find mitigation strategies if we make use of natural processes and nature based solutions.

If, in a few decades, I tell my grandchildren about the discussions we had on climate change and protection of biodiversity and sustainable forestry, they hardly believe me because these values are then fully integrated in the economy and culture of society.

Research questions Forest and natural areas

Due to climate change, we expect that future nature areas will be different from the ones we currently know. There will be (1) strict reserves where nature is intensively managed, conserved and restored; (2) large units in the landscape where spontaneous processes are the shaping forces, creating highly dynamic landscapes with a large diversity in habitats and species and with recreational use; and (3) there will be areas where nature is highly integrated with the built-up environment and agriculture.

To create such a spatial design, (computer) models for land use optimization have to be developed together with GIS tools and frameworks to evaluate options for spatial design and governance, deliverance of ecosystem services and safeguarding biodiversity.

Besides development of tools to support technical solutions, tools must be developed for cultural and behavioral change that is needed to place nature in the heart of society and prominent on the policy agendas. For instance, science-policy interfaces and science-society interfaces and further operationalization of transformative change.

Solutions and Interventions: How can a small step for man make a big step for mankind?

The challenge is creating a nature-inclusive society at different levels and from different perspectives: from local to global; managed and unmanaged; and in the short and long run.

How to increase resilience of nature to protect biodiversity and contribute to climate challenges (e.g. droughts/floods, CO2)?

Improving resilience of nature is important to protect biodiversity and vital nature that contribute to human well-being. What nature-based solutions can we use to combat climate change (adaptation and mitigation)? Therefore, we should explore options and not just solutions to be sure we at the end find the best solution.

How to operationalize the Eco System Services framework for climate adaptive strategies and biodiversity?

Operationalization of the framework for Ecosystem Services is needed through which it can be explored how we strike balance between different functions at different scales and time. Working across sectors is easy to say, but how to organize and operationalize it (without greenwashing or eco-terror), e.g., how to operationalize transformative change? Establishing a common understanding of what we mean by "nature"

is important part of a common language connecting science to society and policy and guiding the cultural change that is needed to come to a nature-inclusive and circular society.

Synergies and Trade-offs: Finding the win-wins

The challenge is simultaneously preserving and using forest and natural areas (ecosystem services) and improving societal welfare.

How to design a European green infrastructure that contributes to climate adaptation and a sustainable footprint.

ESS delivery, nature conservation, management intensity, and governance for our marine and terrestrial nature areas? Where and when can we integrate functions and when do we have to separate them? The speed of those changes will depend on the extend of changes, commitment of everyone and the resources involved.

Multiple land use: what will we gain or lose?

Footprint, carbon accounting, fairness values, ESS can help to illustrate what we will gain or lose and help to deal with trade-offs. Ecological and socioeconomic change is part of the transformational pathways.

How can climate change help to conserve biodiversity?

But cultural and behavioral changes might be key for a sustainable and climate proof future nature areas. Drafting an European or global vision on how economy could be organized and how nature can be included will help to achieve such cultural and behavioral change.

Integrated approaches: Shaping the future forest and natural areas

The challenge of integrated approaches for forest and natural areas is to the development of science policy interface and the integration of biodiversity and ESS in society (transformative change)

How to support strategic policy objectives, shape research programs and knowledge dissemination?

Supporting policy makers timely with the right information is essential for integrated approaches. An important question is on how to shape a future integrated biodiversity and bio-inclusive society in the context of climate change. To create knowledge needed in requires a solid Policy Science interface. A science-policy interface encompasses a network of scientists and other actors in the policy process. This network will allow for exchanging knowledge, co-evolution and joint creation of knowledge. The aim of such an interface will be to enrich policy-processes and decision-making.

How to shape a future Biodiversity-and Bio-inclusive society?

An important element will be to establish dialogue with actors and key stakeholders (about 'nature inclusive' - and what we mean by that). The question is how to support strategic policy objectives, shape research programs and knowledge dissemination. Answers will allow to integrate biodiversity and ESS in society in a more effective way needed for transformative changes.

Overview of all research questions and topics collected for forests and natural areas

Solutions and interventions research questions
• Explore options not just solutions • How can short term actions catalyse structural change? • What are drivers to develop natural resources (in the Ocean)? • How to organise economy – cultural changes can lead to solutions?

- How can you make changes that are feasible now but that also catalyse these changes in paradigms?
- Changing the way in which we do things. Providing information to do things different. We often have solutions and nobody knows about it
- Where are good conditions to realise large green corridors between nature areas of comparable ecosystems?
- How can we monitor the shift of distribution area of species, or detect the lack of shift?
- Where in Europe is best potential for large, resilient and well managed forests with large biodiversity values on the one hand, and a new style of buildings with European wood these forests?
- How do the forests look like (tree species and management) in different parts of Europe. And how can the supply of wood be used for building? Is there a spatial match between supply and demand, or how to overcome that?
- How to combine the forest restoration as envisaged in the EU Green deal with climate mitigation and adaptation?
- How can the restored forests play a role in the bioeconomy?
- Which financial incentives are needed to stimulate the forest restoration and which locations are optimal, also with the bioeconomy point of view as well as the required biodiversity protection?
- What are the most efficient and effective measures for restoration of carbon storage ecosystems, such as forests, peatlands, grasslands, salt marshes, seagrass meadows and kelp?
- What management strategies can be deployed to counteract the risk on soil biodiversity under climate change and intensified forest management in EU forest?
- Sustainable biomass usage based on care for nature
- How can water infiltration and delayed discharge prevent flooding, mitigate consequences of droughts, and promote soil carbon sequestration?

Synergies and trade-offs research questions

- Analyse how shifts in values occur?
- Link nitrogen to the broader picture (do not isolate one topic from others)
- Ecosystems services at larger scale than the nature can generate: what are the main drivers?
- Contribution of Dutch agriculture to degradation forest/nature?
- Bio-economy and the influence on nature/biodiversity and justice/equity
- Displacements effects. To evaluate European policies at global levels
- Greenwashing
- Will nature develop itself as consequence of climate change?
- Footprint – we benefit from a nice environment by buying cheap products (grain and timber, etc) from outside EU
- Strike balance between uses – balance delivery of ecosystem services
- Also need to strike a balance/integrate between areas not just uses
- Conserving nature & using nature, ecosystem services, improving economic growth
- How do we balance the trade-offs and synergies (carbon, biodiversity...)?
- Where in Europe are what ecosystems most sustainable under conditions of climate change? What does this mean for our N2000 goals? e.g. high moors in the Netherlands will be not sustainable because of a lack of water in the future.
- Provision of wood based biofuels without harming biodiversity
- Trade-offs between biodiversity, mitigation strategies and sustainable provision of renewable materials
- How will European forest soils be affected by a growing EU wood based bioeconomy?

Integrative approaches research questions

- Optimization of different functions (within forests) but also between countries-globally
- More integration across sectors
- Working with policy makers on the means of delivering the vision (social sciences 'how' in relation to process, plant/animal/ environment 'how' in practice)
- Europe in relation to the rest of world
- Analyse problem definitions and how they influence the attribution of power, blame and responsibility
- How will values change? What is the policy behind this? How can this be accomplished?

- What is the governance in Europe?
- What is the way in which we do our education and research?
- How do we engage with opportunities and challenges?
- How we are going to make choices?
- What are the real triggers/true drivers to work on a European basis?
- How global is our footprint? Is there still a global aspect in the future?
- Use different views in different topics to think about solutions
- Establishing a common understanding of what we mean by "nature" and "nature inclusive"
- Finding our role in politics/ political decisions – as scientists
- What role can the EU forest based industry play in a circular bioeconomy , and how to stimulate this with EU regulations
- Necessity for sustainable investments in agriculture and forestry
- What role do European forest soils play in climate mitigation and are they resilient enough to withstand climate change?

Water bodies

Future story: European water bodies in 2050

It's July 2050. I just returned from a boat trip through Europe, as a member of the EU future water team. This team was established after the droughts of 2030, which were followed by unusual rainfall events, causing severe floods. In 20 years, we have achieved quite a lot in the transition towards more integrated water management, combining urban and city development, agriculture and nature.

The reason for our trip was to study the measures Europe has taken to have climate neutral and climate resilient water bodies. We are currently preparing the successor of the water framework directive on water quality. This will be an action plan for integrated water management: addressing water storage, water quality and water availability. Water management in urban and agricultural areas are an integral part of this action plan.

We started in Hungary and made our way over the Danube river. We travelled over land to Belgium, and then by boat over the Scheldt river and delta. We ended on the Dutch coast of the North Sea. In every country I saw how policymakers, stakeholders and scientists tried to find a balance to cope with the effects of climate change: do we adapt or do we intervene?

All through Europe I saw the struggle between water scarcity and water availability. Water-intensive land use functions, like agriculture, were shifted to areas where water can still be made available throughout the year. Climate change and biodiversity considerations are an integral part of such shifts. The water management of selected forests, nature areas and farm fields is focusing on increasing the water holding capacity and biodiversity.. At the same time this paves the way to get rid of excess water caused by the more intensive rains we are facing. For example: farm fields are no longer monocultured areas, all areas I saw were polyculture crops, resulting in improved ground water storage and a more biodiverse animal and plant life. Structural planning of ground water levels is a key point and requires a maximum of multi-stakeholder flexibility to adapt.

We did our trip mainly by boat, since the waterways are significantly more used for transport of people and goods. I saw the Room for the Rivers programs applied all over Europe. In these programs, rivers are given space for floods in excessive water periods. These flood plains combined with extra water storage in urban areas and man-made lakes upstream, makes the Space for the Rivers program very successful. Furthermore, smart agricultural production systems have been developed, making a more balanced use of the flood plains. Of course, it was quite a challenge, as these processes affected many people. Many of them had to leave their house or agricultural business, to make room for the water. Design sessions and smart investment plans for rural and urban development helped to provide engagement in joint solutions for water bodies. Inhabitants and farmers were provided with suitable alternatives to prolongate their livelihood and business, although at different locations and in different business setting, They are now situated in urban and rural areas and re-designed their business making maximum benefit of the new water management strategy. The research on parallel groins provided new design solutions, new solutions for dry periods have been developed and the upstream downstream linkages have been improved.

As we approached the coastal zones, we experienced a wide variety of ongoing adaptation measures. I saw various nature based solutions along the saline brackish gradient. For instance, I saw oyster reefs, nature restoration to support marine nursery grounds, double dikes for protection and nature development, and grazing on salt marshes. Overall, in the delta area, there is no constant fight against the water, but production has been adapted to saline conditions and combined with sediment and carbon capture. The Delta institute in Zeeland, established in the 2020-s, is now a world-famous knowledge partner on saline agriculture.

Then we came to the seaside. A lot has changed here over the past years. Climate change caused the sea temperature to rise. Because the rate of change in temperature is extremely high, species have difficulties to adapt and migrate fast enough. In the past 30 years, we've tried to align the natural adaptation of fish with anthropological interventions to support changes in the ecosystem to maintain the may ecological functions. Reef structures originally designed for cod, are now occupied by other warmer-water species, such as sea bass. Fisheries programs are focusing on the harvest of the surplus of the ecosystem. Natural and semi-natural reefs are planned in such a way that the ecosystem is readapting, considering a maximization of ecological functions, improving nutrient turn over and long-term carbon storage.

Many shipping companies and ports are sustainable, coastal ports have adapted to provide an excellent service for electric, hydrogen and wind driven logistics, making use of the clean energy provided by wind parks at sea. Although investments in wind farms are done, the transition to alternative energy sources and energy carriers such as hydrogen are currently taking place. The infrastructure of wind farms installed in the last decade already adapted to these changes. Aquaculture has been moved further offshore, out of the coastal region, and is low-carbon and equitable. The production systems are designed in climate smart and adaptable ways, making it possible to redirect production to climate change effects, both technically as well as biologically. These production systems provide biomass, and are fully implemented in the food system, and are used to return nutrients to land, fix carbon, and provide a basis for ecological developments at sea. The beauty is: all these developments were planned and implemented in ways that effectively engaged all stakeholders affected. European countries decided together what the best spots were to develop energy parks and aquaculture, to really preserve ecological systems.

Have I told you about the natural fish we ate during our European tour? As a result of the EU-agreements, the water system from coast to the hind land is not only designed to prevent salt water to enter, but also to open barriers for migration opportunities for fish. This created a network of migration routes, resulting in an increase of stocks of fish and an improved ecological function of rivers, and streams. Restoration programs are only functional because of the smart and integral choices for water infrastructure projects in the past.

What did I learn during my trip? I saw a lot of positive developments that we can build on for the successor of the water framework directive on water quality. It was inspiring to see that many countries already jointly organized an active transition of agriculture, city planning and other functions to find solutions for water excess and drought problems. Not only did I learn how the farmers dealt with the new water challenge, also the water management is completely changed from a mono-sectoral approach to an integrated water solutions approach. I saw tailor made solutions going from marine to riverine systems and integrated approaches to cover both inland, nearshore and marine.

The greatest challenge in the period 2020-2050 has been to create and utilize the ecosystem in our waters in a non-exploitive manner, balancing nature on the one hand and food provision on the other. There is a variety of strategies on this now, including more integrated ones. One cannot find answers in single issue solutions, but we should build upon integrated strategies to sustain the marine and land production and optimize use and resources. The decision to do this by intervening or by adapting will stay a tricky one.

Research questions Water bodies

Solutions and interventions: Balancing the water challenges

Integration of solutions for management, mitigation, and optimization for water use, functions and infrastructure is highly desired. However, the change of climatological pressures results in different local, regional, national and international adaptation requirements for water use and management. The challenges vary significantly depending on the functional use, geography and climate scenarios and are nested, which means that a solution at one level may not be a solution at another level. However, the main challenge remains to deal with water excess, scarcity and unsuitable quality water, with changing climatological pressures and adapting ecosystems. We expect challenges to increase.

Radical choices need to be made for transitions, and more often than not water is the linking element. Substantial sacrifices have to be made by users, regarding functions, geographical and demographical focus, when addressing water issues. Transitions as a result of climate adaptation for water use, changes in storage, release and adapted functions will lead to conflicts, barriers, opportunities, and other changes. To address these, there is a need to start the dialogue on water management and infrastructure options in future already now, and to involve various stakeholders early in the process.

"What are the key scenarios and solutions to address in water management and use, related to climate change adaptation?"

To obtain a level-playing field in information and insight on current and future water balance, adaptation, water use and management options: all key scenario's and solutions need further inventory, mapping and understanding of functions (regional and local) as a basis for integral planning, scoping and study.

"How to design European water infrastructure and related water management options, that contribute to an active transition of agriculture, city planning and other functions to a climate neutral and resilient Europe?"

Water is an integral part of agriculture, city planning, and other functions all over regions and countries in Europe, not taking administrative frontiers into account. Therefore, only an integral and coherent water infrastructure and management will allow to tackle future climate change challenges. The main challenge is how to create a water system in which demographic and geographic boundaries and challenges are considered, but not leading, and opportunities for water storage, addressing floods, drought and water quality for all development and functions are put forward in an integrated system. All geographical ad demographic, socio-economic developments and associated prioritization should incorporate water management as a pre-requisite for the current and future plans.

Synergies and trade-offs: Understanding the water complexities

In water management and infrastructure many options for adaptation, interventions, and resilience options are considered. Different strategies, scenarios and adaptation measures can be developed, implemented or accepted. From coastal waters to the inland water bodies, similar challenges arise, in which debate occurs on the negative drawbacks, lack of resilience, and lack of robustness in the system. Among the most intense challenges, the very fundamental question raises whether we want to guide the water or whether we agree that the water is guiding us, or whether we steer for combinations of these two directions?

Every choice in water management has an impact on supporting functions, as agriculture, city planning, rural development, natural capital, etc. On a broad scale from coast to inland water bodies, the main challenge is that water related decisions impose severe impacts on users and the socio-economic environment. Understanding the synergies and trade-offs supports the decisions, and enables broadly supported choices.

"Understand the synergies and trade-offs in long and intermediate term transition scenarios, accommodating the necessary balance between all water types."

Future water challenges and integral water use present themselves in a multi-dimensional context. The entire complex ranging from clean and freshwater to completely salty water with all kind of quality water in between where attention to water quality, biodiversity and valuing nature is required. Different policies apply for different types of water (the EU Water Framework Directive mainly addresses fresh water, but not brackish water environment). There is a different between enhancing storage (positive in case of water shortages) and enhancing run-off (positive in case of excess water). The transition to a future water system requires to understand the synergies and trade-offs in long and intermediate term transition scenarios, accommodating the balance between all water types.

"Understand the climate related processes in marine, delta and freshwater bodies on food web functions, expected regime shifts, adaptation potential, carbon storage, effects on ecosystems and drivers for water quality improvement."

In many of the choices and strategies which we will need to address, we encounter a lack of basic system understanding for marine systems, delta and inland fresh water bodies. Food webs are known, but behavior and functions of these in interaction with water are still not well understood, especially in climate change scenarios. Also carbon storage potential, mitigation, and basic ecosystem functioning (inland, fresh water, brackish and marine), are not known and changing considerably. Drivers to support, stimulate or invest in water quality improvement, or making use of sub-optimal circumstances are not yet well understood, like food production under marine and brackish conditions, taking ecosystem services and climate change into account. Therefore, significant research questions lay in understanding climate related processes in divers water systems in relation with use, functioning and functions. This key knowledge generates the basis for scientific informed decision making and provides important information for scenario studies in other fields.

Integrated approaches: Fluid decision making.

The challenge of integrated approaches for water systems is to use integrated strategies to sustain and manage production based on marine and inland water bodies, balancing biodiversity and climate change. A wide range of impacts, synergies and trade-offs are directly related to a complex set of choices, strategies, interests, treats and opportunities. Decision making therefore is not desirable to be done on a single-level or narrow stakeholder level. Decision making on water systems occurs in a tremendously complex, sensitive and dynamic play field and needs quality information. Given the complexity of the integrated water strategies a transformation process for strategy implementation is highly challenging and new tools need to be developed to guide and monitor these processes.

"How to organize an active transition of agriculture, city planning and other functions to find solutions for water excess, drought and quality problems?"

"What are effective pathways for knowledge integration to make decisions by multidisciplinary research and approaches to create multi stakeholder applicable solutions on water availability and use, spatially based scenarios for salinity, drought, different levels of waterbodies now and in the future, addressing salinity gradients; and governance regarding water use and water pollution and city planning?

Overview of all research questions and topics collected for water bodies

Solutions and interventions research questions
• Novel financing of sustainable water management • Where will/should we do what? • Storing water is difficult to combine with nature and fish migration. • What to do where? • Do we know how to manage various functions e.g. with off-shore wind (energy from sea, food from sea, sustainable use- do we know what that will look like?) • How do we produce sufficient food without harming the environment too much? • For the sea: CO2 fixation • Food production with high water use needs to stop in regions with water shortage • Stop high energy consuming fisheries • Rivers are used not only for transport but also for irrigation, water management during drought (or in general: waterbodies have multiple functions) • Do we safe the coastline or let it go? • Innovation and financing innovation; how to keep a level playing field? • Which social, economic and technological measures help us to create healthy and resilient coastal/marine socio-ecological systems? • Which forms of democratic governance help to effectively engage stakeholders, and especially marginalized groups, in meaningful participation in the climate transition in coastal/marine environments? • How smart land use planning can prevent water scarcity as much as possible? • How solidarity between areas can be promoted by cooperation and tuning of land use planning? • Link land and sea and link drought and flood/water security issues. International activities based on river basin approaches, but integrated • A healthy North Sea requires further development and valuation of the nature at sea. How to do that and what are the costs and revenues? • A EU-wide system of Payments for Ecosystem Services, which is integrated into all policy fields, such as CAP or the structural funds. • How to create / utilise the ecosystem in a non-exploitive manner, balancing nature and food provision? • What does happen if fresh water becomes scares, how do we optimise a system in which fresh water scarcity can be turned into a resource supplying infrastructure? • How to deliver sufficient water to maintain food production, healthy society and a vibrant biodiversity in the context of higher temperatures and less water availability?

- How much food can we sustainably take out of the systems, and how will that amount change with the change in puts as a results of the transition of the land based food productions?
- What are suitable designs to prevent flooding and stabilize river discharges throughout the year to secure fresh water delivery?
- How can we use nature to help us to cope with sea-level rise?
- How can we use off shore wind farms for other function as well? food, nature, recreation?
- What is the realizable and sustainable water system to apply in the drought area/season in Europe?
- Is that possible to use new technologies to create new drinking water e.q. new water as a side product of hydrogen burning?

Synergies and trade-offs research questions

- Field scale and regional and national scale to make trade-offs visible, and what kind of effect will happen where, for whom?
- Make it clear that not doing something will also create a cost
- Salinity – is part of integrated solutions – we like to understand better the impact, how will it react in the natural environment
- Impacts on land and impacts on sea to be brought together
- Off shore wind takes space – but space is limited. One quarter of North sea will be off-shore wind by 2050. Multi-use with aquaculture, but no fishing in those areas
- Who gets the benefits, who gets the costs? Needs balancing, in order to avoid conflict, or avoid nothing happening
- Land use /agriculture/water management have to adapt and deal with both droughts and floods: What are the consequences of water storage on land for other functions on land?
- Food production moved to the sea results in trade-offs with biodiversity. What happens with the land if many functions move to the sea?
- Climate will change trade-offs, other types and functions
- When do the investments pay off?
- Economic choices: which sectors do we keep supporting?
- Cumulative effects of human pressures; reduction of human pressures; more insight in processes and mechanisms rather than species level (Panda effect).
- What are the environmental impact and ecosystem risks of fish farming further off shore and new production systems with low impact?
- How do organisms respond to climate change, including temperature, pH and oxygen?
- How does climate change translate into life cycle connectivity?
- Can we understand and extrapolate effects at population and food web level?
- What are the consequences for food provisioning from marine waters?
- How do food webs change along with changes in the distribution of cold-blooded marine and aquatic animals due to rising temperatures?
- How do marine and aquatic harvest and production change along with changes in the distribution of cold-blooded marine and aquatic animals due to rising temperatures?

Integrative approaches research questions

- European approach both political and stakeholder driven
- Break down in steps, temporal and spatial steps (different scales)
- Same language/methods all over Europe, where do we talk about, how do we measure it?
- What are the interests?
- Integrated monitoring tools to be created (work together towards a solution). Different lines of evidence for different areas of knowledge.
- How do we get research to the public, and the other way around?
- We need to tools to monitor and create knowledge, make decisions and create solutions
- Translating knowledge to stakeholders and knowledge into Action
- Creating policies is one, but monitoring tools to control as a united Europe is different story
- The balance between national and European stakes
- The connection agriculture and mariculture: transition with stakeholders
- What is most cost-effective: is circularity achievable?
- Hard for disciplines to work together: work on tools and create incentives
- Change from 'know first, then implement' to 'we don't know many things, but we will need to act, and we are learning along the way'.

- Integrated approach to cover both inland, nearshore and marine; micronutrient and water scarcity. Research on optimal use of saline regions for production, carbon fixation as well as nature is needed.
- We should build upon integrated strategies to sustain the marine and land production and optimise use and resources. We need large scale test sights to ideally test and validated novel, system overarching principles. Decision makers need to make decisions based on overarching frameworks and visions.
- We need a program which targets on better forecasts (system wide) on what will happen due to climate change.
- Living labs at sea, natured based solutions, integrated transition agenda's (Transport, energy and food production) and flexible policy/ regulations

Overview of overarching and thematic research questions

In the first phase of the project (annex 1), also research questions were collected that didn't fit to one specific area, because the research questions were overarching or thematic. The following overarching and thematic research questions and topics were collected:

- Which regions in Europe are most suitable for: energy production, carbon storages in forest/nature, food production etc?
- How to organize a policy change from national land use planning to European land use allocation to be able to cope and reduce climate change.
- Increasing divide between North and South. Northern Europe will mostly benefit from Climate change or see more limited impacts while Southern Europe will suffer more from climate change. At the same time the Norther countries are much better prepared and have more opportunities for investment
- How does are a climate neutral and resilient future look like?
- what is the potential of NBS in Europe for adaptation and mitigation?
- How to accelerate large scale implementation?
- What are new business models for NBS?
- How to deal with increasing risk for droughts, heat waves and wild fires?
- The tiger mosquito has already come to some parts of Europe and will find an increasingly large habitat. This increases the risk of vector-borne disease (epidemics).
- Establish support for coherent assessments and transparent inclusive decision making. Coherency should be both a cross-sectoral matter as well as integrating soil, surface and air issues. under which conditions could the governance of 2 be improved? And what should be our priorities in policy, science and society at large?
- For which products do we need better recycling? How can we develop products with better recyclable parts? Which new materials can we produce from waste? How can we improve plastic recycling? How can we achieve separation of tens of different waste streams in the future?
- I see a population more conversant in the central concepts of complex adaptive systems (e.g. feedback loops, delays, etc.) so they are more receptive to long-term policy. This will require changes to curricula.
- Regionalise energy and resource production rather than expanding this in the (few) natural areas still available. Even if this could mean a slow or end of local economic growth
- Climate effect, societal issues and regional profiles for inclusive and adaptive development (comprehensive, but with clear regional profiling and landscape approach//building narratives
- Relations EU, region and global. Future dependencies and drivers, that relate to climate change, adaptation and related economic activities and perspectives
- How to demonstrate that nature based solutions represent a sustainable response to climate change adaptation?
- How to integrate NBS with technological solutions?
- Societal transformation can take place in order to achieve a more sustainable and integrated approach.
- Can we predict what type of (which) infectious diseases we will face in the future and develop solutions before 'the problem' starts to arise?
- How can healthcare systems in European societies prepare for a shifting burden of infectious diseases and demographic shifts?
- Need to develop a much improved connection between the water, food and energy sectors. Clean Energy production will use more water (hydro+ biofuels), more land (solar, wind, biofuels) and food (biofuels). To be able to provide sufficient water, food and energy for all in a changing climate a nexus approach is needed.
- What possible mechanisms can we use for acceleration to social- & nature inclusive energy landscapes, often combined with sustainable food production and to create major global impact?
- Can we create a knowledge alliance with frontrunner regions in the world, to share experiences, build on successes developed elsewhere, and with practical examples that promote optimism.
- How should we design policies to incentivize and facilitate the adoption of clean technologies? How should these policies facilitate pioneers? What can we learn from past and existing policies? What are the roles of government, business, NGOs, ...? How are sub-national, national and supra-national policies linked?

- How should we organize taxes and subsidies to optimally support a switch to clean energy and transport? What are the limits to the use of biomass and biofuel as a transition means? How can we improve energy and transportation that is not yet emission free?
- How can environmental risks of individual off-grid energy systems (such as off-grid solar installations with batteries or even H2-installations) best be managed?
- What are the triggers for decision-makers to change their current behavior in order to ensure that measures for biodiversity are included within new developments and that existing developments are modified in order to reduce their impact?
- Can we develop e.g coatings for fresh produce that also can be printed on. Coatings will decrease water loss and will postpone senescence and inhibit fungal growth. Can we develop sufficiently cheap and effective packaging materials that are bio degradable?
- How can we adapt European knowledge and experience to other regions incorporating local knowledge and engaging local actors in a fair way?
- What potential synergies are possible in developing climate policies in Europe together with other regions of the world?
- How does climate policies in Europe relate with human rights principles of fairness, equality, etc. on a global level?
- How can Europe (and other western nations) stop exploiting Africa (see e.g. structural adjustment programs from IMF and World Bank)? What is the influence on global industrial development, climate change, and political stability (with associated migration of peoples) of different scenarios of international cooperation v exploitation?
- Can Africa supply Europe with energy?
- Will climate change increase migration?

Conclusions & final recommendations

In the process of developing the climate knowledge agenda, a huge amount of climate related scientific research questions were collected. Clearly, a lot of climate knowledge is present and there is a large interest in the topic of climate at WUR. However, the knowledge is fragmented and not well disseminated. The knowledge should be brought together and more emphasis on dissemination is needed. This project shows that it is challenging to talk the same language at the different institutes of WUR but that the climate knowledge can be brought together. As an outcome of the project, we can also conclude that WUR should use more of its resources and knowledge to play a pivotal role in climate mitigation and adaptation, by enhancing internal collaboration, improving strategic collaboration, increasing visibility of WUR through improved knowledge dissemination. The following three recommendations follow from the conclusion:

Enhance interdisciplinarity in projects and education by (1) allowing for learning time to speak the same language in projects, (2) creating interdisciplinary feedback loops to be flexible, fail fast and celebrate the wins, (3) making learning and reflection part of the projects. (4) creating exit strategies of projects to guarantee knowledge transfer and impact enhancement and (5) developing interdisciplinary education programmes on climate research, to interact with students & educations institutes.

Connect to the rest of the world, to be always up to date on what is happening outside WUR, to enhance impact and create partnerships and tailor-made solutions by (1) creating incentives to work with other people and organisation (governments, international organizations, NGOs, private sector and civil society organizations inside the Netherlands and within the EU), (2) by establishing joint smart co-creation processes– ensuring knowledge transfer with different types of stakeholders (partnerships) and (3) intensifying the WUR lobby towards the EU/green deal to show how WUR can contribute on climate solutions.

Translate our climate research to real life cases to speed up the transition towards a climate neutral and resilient Europe by (1) creating a visualization lab to share model results showing synergies and trade-offs and visualize the impact of change and (2) demonstrating solutions in pilots, case studies and living labs to learn how to implement, to inspire others, to monitor effectiveness, to encounter real life challenges and as a motor to accelerate changes.

Investing in these recommendations will also improve the visibility of WUR as a climate knowledge provider and shows to the EU, governments and the private sector that WUR can offer solutions to the climate crisis.

Annex 1: Process

The project consisted of three phases. In phase 1, we collected the climate visions and questions of the individual WUR researchers of all science groups. In phase 2, we clustered the input and had dialogues per cluster aiming at finding the European research questions of the future. This will be the base of the European knowledge agenda with the most important research questions which was developed and visualized in phase 3.

In **phase 1**, we asked the individual researchers the following: *"Imagine you are somewhere in Europe. It is 2050 and Europe is completely circular and climate neutral. What do you see around you?"* Then we asked to place a flag on the map of Europe and share:

- Your idea/vision/ambition
- What are the greatest opportunities or challenges to achieve this idea/vision/ambition?
- What bold research questions should we ask ourselves to exploit the opportunities or overcome the challenges?

This resulted in approximately 100 flags from 40 WUR researchers. An example of one of the maps of Europe with flags is shown in figure A1:

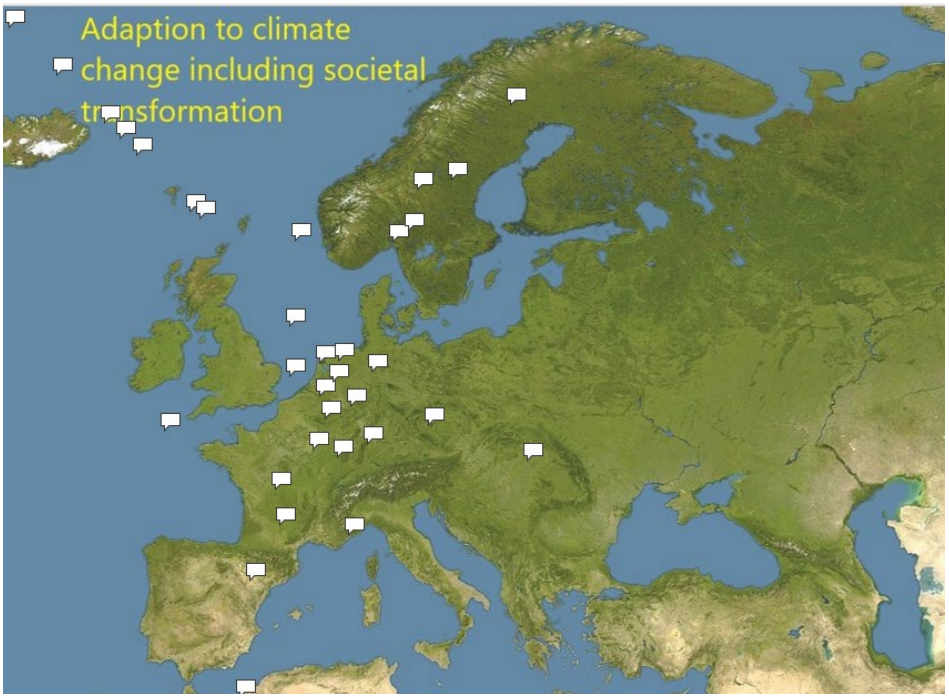


Figure A1: One of the European maps with flags from WUR researchers. Each flag was a collected future climate idea with a research questions

In **phase 2**, all input on the maps of Europe was clustered. The clustering resulted in the matrix below (Figure A2). The horizontal axis shows the 6 themes that WUR works on in relation to climate. These themes are based on the areas of WUR's domain (https://www.wur.nl/en/About-WUR/Mission-Domain.htm) and the areas of the EU green deal (https://ec.europa.eu/commission/presscorner/detail/en/ip_20_1669). The 6 climate themes are:

- Circular and biobased economy, which is based on
  - Green Deal Area 3: Industry for a clean and circular economy
  - WUR domain: Food, feed and biobased production
- Farm to Fork, which is based on
  - Green Deal Area 6: Farm to Fork
  - WUR domain: Food, feed and biobased production
- Natural resources and living environment, which is based on
  - GD Area 8: Zero-pollution, toxic-free environments

    - WUR domain: Natural resources and living environment.
- Biodiversity, which is based on
    - Green Deal Area 7: Restoring biodiversity and ecosystems
    - WUR domain: Natural resources and living environment.
- Clean, affordable and secure energy, which is based on
    - Green Deal Area 2: Clean, affordable and secure energy
- Society and well-being, which is based on
    - WUR domain: Society and well-being

The vertical axis shows the four main areas of WUR's research: urban areas, agricultural areas, forest and natural areas and water bodies. These four areas are based on CORINE land cover classes (https://www.eea.europa.eu/data-and-maps/dashboards/land-cover-and-change-statistics.

Per area, a future story for Europe in 2050 was written. The stores are from the perspective of an I person, who is living and/or experiencing the area in 2050 in Europe. The choice for an I person was made to show the perspective from one person and in that way present it as A future instead of THE future. The goal of the stories is thus not to present the perfect future, but to be inspiring and include the most important topics for the future based on the six themes of the matrix.

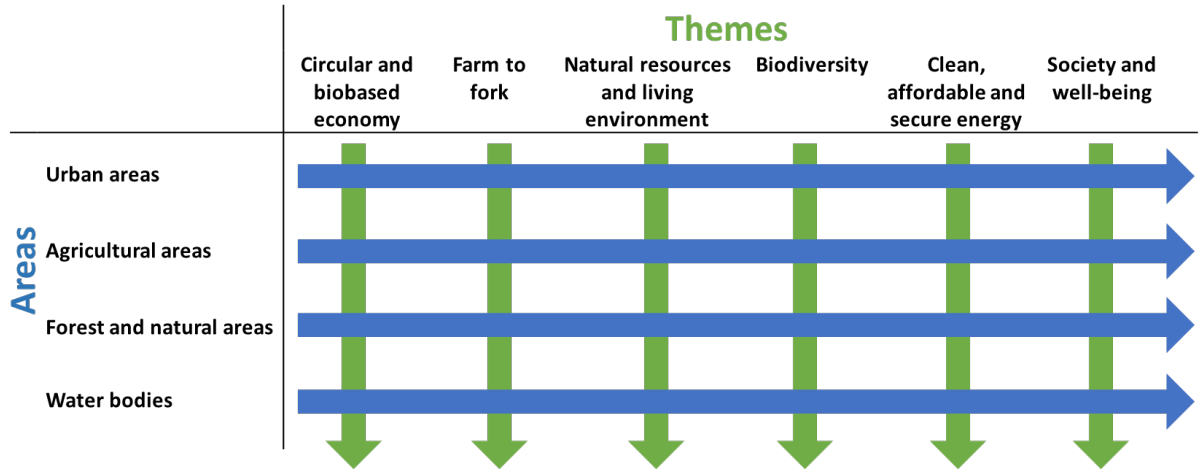


Figure A2: Climate domain of WUR

The last part of phase 2 were WUR dialogues. One dialogues was organized for each of the four areas. The dialogues started by telling the future stories and consisted of two break-out sessions. In the first session, we wanted to know what the participants think of this future, by asking:

- What appeals to you?
- What bothers you (as a citizen or researcher)?
- What is missing in this story?

In the second session we wanted to know what we encounter on our way to this climate-neutral and -resilient Europe and discuss:

- What trade-offs arise for Europe when we are heading towards this future?
- What research topics arise that should be further explored by WUR?
- What opportunities and challenges do you see for WUR?

In **phase 3**, we developed the knowledge agenda. The main research questions were structured in three categories: Solutions and interventions, synergies and trade-offs and integrated approaches as visualized in figure in box 3.

Annex 2: Existing agendas

Background

A synthesis of the existing climate agendas in and outside Wageningen University & Research (WUR) was conducted in order to identify complementarities and the gaps that could be filled in a future agenda. We did not intend to gather an exhaustive list of climate agendas that exist because the climate research in Europe is mainly driven by policy recommendations of the European Commission and the United Nations. Rather, we focused on the challenges and topics covered in the existing agendas. Below, we summarize the outputs of the search on existing agendas in relation to the organizations they originated from. This way, it was possible to identify the relationships among different agendas and the overarching purpose they served. They set the overarching agenda on climate research.

The United Nations

The United Nations (UN) Global Agenda 2030 (United Nations, 2015a) identified climate action as one of the 17 sustainable development goals (SDG13), however, note the intricate relationship among all SDGs (Figure A3). The Global Agenda 2030 refers to five Ps: people, planet, prosperity, peace, and partnership.

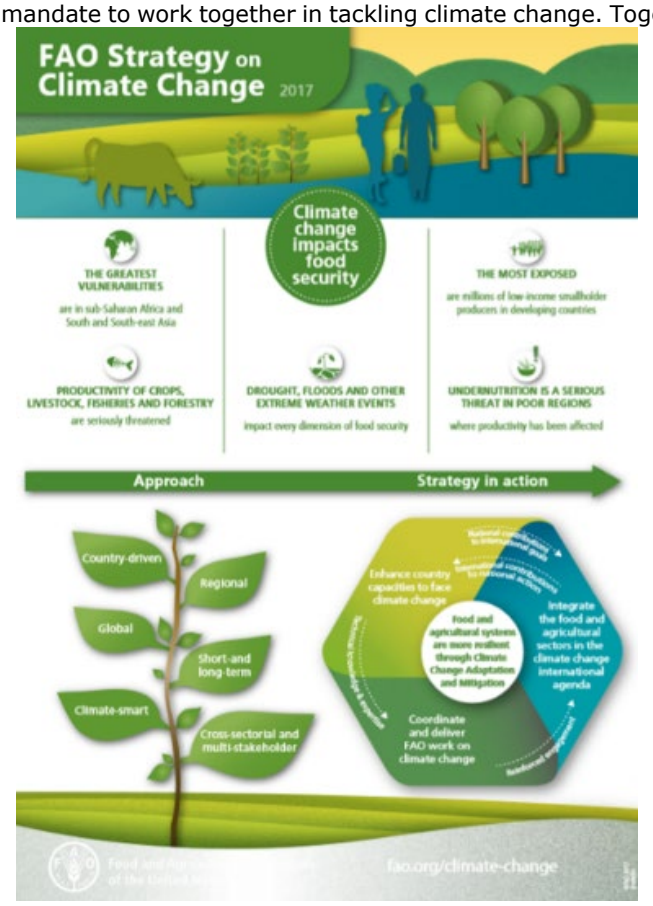
Figure A3: Sustainable development goals. Source: United Nations (2015a).

Global Agenda 2030 on climate action aims to "i) Strengthen resilience and adaptative capacity to climate related hazards and natural disasters in all countries; ii) Integrate climate change measures into national policies, strategies and planning; iii) Improve education, awareness raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning; iv) Implement the commitment undertaken by developed-country parties to the United Nations Framework Convention on Climate Change (UNFCCC) to a goal of mobilizing jointly $100 billion annually by 2020 from all sources to address the needs of developing countries in the context of meaningful mitigation actions and transparency on implementation and fully operationalize the Green Climate Fund through its capitalization as soon as possible".

A recent report by the Food and Agriculture Organisation (FAO) of the UN (2020) analyzing the progress on food and agriculture related SDG indicators (i.e. SDG2, SDG5, SDG6, SDG12, SDG14 and SDG15) stated that, the world was not on track to meeting the SDGs in its 10-year countdown. The major challenges identified were i) food insecurity rises worldwide; ii) the productivity and income of smallholder producers remain lower than those of large-scale producers; iii) high general food price volatility; iv) risk of extinction of local livestock breeds and reduced proportion of fish stocks within biologically sustainable levels; v) insufficient efforts to securing crop diversity; vi) gender inequality; v) water stress; vi) food waste and losses; vii) reduced forest area worldwide.

Relevance of the climate agenda: Increase spending of governments on agriculture, improving productivity of smallholder producers, increase efforts to securing crop diversity and improving local livestock breeds, prevent food waste and losses postharvest, continue with forest management. Note that these recommendations capture the entire world systems, and therefore the efforts in Europe may need to develop a more focused perspective than the general recommendations outlined above. There may have to be efforts directed to identifying/updating the European share of the above challenges (e.g. forest area, productivity at different scales and production systems), and the potential link to the rest of Europe.

The same year the Global Agenda 2030 was formed, the member countries of the UN signed the Paris Agreement (United Nations, 2015b) where each party committed to communicating a nationally determined contribution (NDC) every five years. Paris Agreement also pledged to keep the temperate rise under 2 degrees Celsius (°C). In 2017, the Koronivia Joint Work on Agriculture (KJWA) adopted during the Conference of Parties (COP13) marked the inclusion of crops, livestock, fisheries, aquaculture and forestry as a priority to the NDCs under the Paris Agreement (Drieux et al., 2019), emphasizing the significance of agriculture and food security in the climate change agenda. Therefore, UN member countries have a mandate to work together in tackling climate change. Together with the adoption of KJWA, FAO, supporting the UN member countries to adapt to and mitigate climate change emphasized that SDG2 and SDG13 were connected and had to be addressed simultaneously, and that the common challenges included access to technologies, markets, information and credit for investment (FAO, 2018).



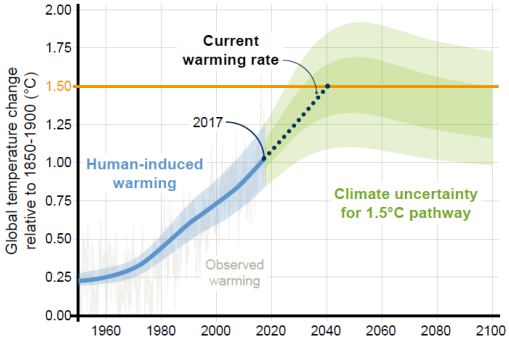
Relevance of the climate agenda: Consider the links between SDG13 and other SDGs, work together with other countries, promote investment in agriculture and livestock, improve access to technology, markets, information and finance, climate change projections.

Figure A4 FAO strategy on climate change. Source: (FAO, 2017).

The FAO strategy on climate change (FAO, 2017), formulated to serve its Member countries in achieving their targets as part of the Paris Agreement, indicated that "business as usual" was no longer the sustainable path to tackling climate change. This strategy and plan of action was framed by three outcomes: "i) enhanced capacity of Member Nations on climate change through provisioning of technical assistance; ii) improved integration of food security, agriculture, forestry and fisheries within the international agenda on climate change through reinforced FAO engagement; iii) Strengthen coordination and delivery of FAO work on climate change" (A4).

Relevance of the climate agenda: Develop alternative pathways, business as usual is no longer sustainable, support smallholders, develop knowledge and tools that can quantify the impacts, scale up climate finance, identify mitigation and adaptation measures, provide technical knowledge and expertise, develop integrated approaches that can consider more than one layer or component of the food system, develop an implementation plan, enhance partnerships.

Figure A5: Global temperature change over years. Source: (IPCC, 2018).



According to the Intergovernmental Panel on Climate Change (IPCC, 2018), the human-induced warming reached approximately 1 °C in 2017. If the current rate continues, global temperatures would reach 1.5 °C around 2040. Provided that the global temperature change can be kept under 1.5 °C with immediate reductions, CO_2 emissions may reach zero by 2055 (IPCC, 2018) (Figure A5). The IPCC provides the world with objective, science-based information (e.g. national GHG inventories).

Relevance of the climate agenda: Develop and implement immediate actions to reduce emissions, revise national inventories to reflect country-specific activity data.

European Commission

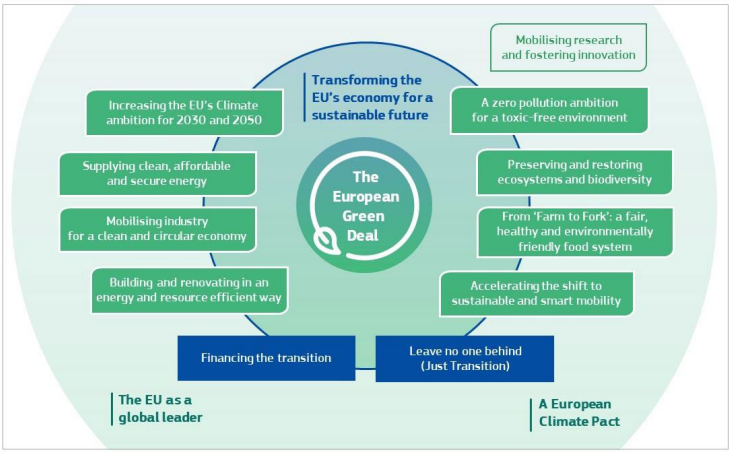


Figure A6 The European Green Deal

The European Union aims to be climate neutral by 2050 (European Commission, 2020a). For this purpose, the European Green Deal provides an action plan in order to improve the resource use efficiency by transitioning to clean and circular economies, and by restoring biodiversity and cutting pollution (European Commission, 2019). Policy areas in this section include EU climate action and the European Green Deal, climate strategies & targets, EU emissions trading scheme, effort sharing: member states' emission targets, land-based emissions, transport emissions, international action on climate change, innovation fund, protection of the ozone layer, fluorinated GHGs, adaptation to climate change, and funding for climate action (Figure A6).

European Commission (2020b) also has a vision on climate resilient Europe where by 2030 the aims are to: "i) prepare Europe to deal with climate disruptions; ii) accelerate the transformation to a climate resilient future; and iii) build deep resilience by scaling up actionable solutions triggering societal transformations". This document emphasizes the need to co-designing, co-implementing and co-evaluating adaptation pathways that are climate resilient or climate proof so that societal ownership is strengthened, and long-term sustainability of goals and objectives can be achieved. Carvallo et al. (2017) calling for a refocusing of research on citizens' political engagement in climate change further elaborated on the areas of remaining using the below questions:

- "To what extent do the citizens accept, question or contest the subject positions that the discourses construct for them?"
- "How do they (re)construct understandings of their political roles and opportunities?"
- "How do knowledges, organizational conditions, ideological and material aspects weigh in on communication practices that defy the political "common sense"?" What discursive space do they acquire? How do they play into political involvement on climate change?
- "To what extent and in what ways are citizens actually exposed to alternative discourses?"
- "How do debates and different interpretations have, or fail to have, significance for citizens' political engagement?"

- How does engagement depend on the nature of alternatives offered, the ways they are communicated and/or their positioning in public debate by media practitioners and other key actors?

Relevance of the climate agenda: Improve resource use efficiency, restore biodiversity, cut emissions, move to clean and circular economies, co-design, co-implement and co-evaluate climate-resilient adaptation pathways to increase societal ownership and long-term sustainability of objectives.

International research organizations and initiatives

Here we looked at a selected number of the research agendas of research organizations that collaborate with WUR.

Joint Programming Initiative (JPI) Climate Strategic Research and Innovation Agenda (SRIA) (**http://www.jpi-climate.eu/jpi-strategy/SRIA**) reports three overarching challenges and one mechanism:

The three overarching challenges are: i) Understanding the processes and consequences of climate change; ii) Improving knowledge on climate-related decision-making processes and measures; and iii) Researching sustainable societal transformation in the context of climate change. The strategic mechanism is connecting people, problems and solutions in a systemic approach.

The Consultative Group on International Agricultural Research (CGIAR) is a global partnership of organisations that are engaged in research to contribute to future food security. WUR has a collaboration with CGIAR on a number of areas one of which is the program on Climate Change, Agriculture and Food Security (CCAFS). The report by Wollenberg et al. (2012), setting the agenda on climate change adaptation and mitigation for food systems in the developing world, emphasized the need for new development pathways to mitigate the impacts of and adapt to climate change in low income countries by indicating where new knowledge and innovation may be needed. The priority actions were identified as: i) better modelling studies to identify the impacts of climate change on vulnerable farming systems; ii) better integrating and addressing the capacity of crop-livestock to adapt to climate change, including use of crop varieties and livestock breeds (e.g. resistance to heat, cold and extreme weather events) that are better suited for the future climates and uncertainty; iii) design and implement management practices to better utilize natural resources; iv) understand the role of agroecosystem and livelihood diversity, and create livelihood strategies; v) strengthen institutions that provide farmers coping mechanisms e.g. insurance linked to climate; iv) disseminate knowledge and learning related to adaptation.

Transforming Food Systems Under a Changing Climate is an initiative led by CGIAR CCAFS (https://www.transformingfoodsystems.com/about.html) and touches upon the following five areas to deliver key messages and expedite action:

- Adaptation and development pathways for different types of farmers
- Transforming food systems under climate change: Local to global policy as a catalyst for change
- Changing diets and transforming food systems
- Future technologies and food systems innovation for accelerating progress towards SDGs
- Financing the transformation of food systems under a changing climate

Global Research Alliance on Agricultural Greenhouse Gasses (GRA) (https://globalresearchalliance.org/) aims to bring countries together to identify solutions that enable growing more food without increasing GHG emissions. There are four research groups under GRA: livestock, paddy rice, croplands and integrative, all aiming to reduce the GHG emissions from their respective research areas.

Global Agenda for Sustainable Livestock (GASL) is a partnership of livestock sector stakeholders committed to improving food security while addressing the social-, environmental- and economic challenges. The main topics for the agenda include i) improving production efficiency; ii) restoring value to grasslands; and iii) managing manure (e.g. biogas).

Global Science Conference on Climate Smart Agriculture (2013) identified three themes – direct quote (Steenwerth et al., 2014):

1. Farm and food systems: Crop physiology and genetics, mitigation and adaptation for livestock and agriculture, barriers to adoption of CSA practices, climate risk management and energy and biofuels.
2. Landscape and regional issues: Modelling adaptation and uncertainty, achieving multifunctionality, food and fishery systems, forest biodiversity and ecosystem services, rural mitigation from climate change and metrics.
3. Institutional and policy aspects: Designing research that bridges disciplines, integrating stakeholder input to directly link science, action and governance.

Imperatives also included:

- Developing models that include adaptation and transformation at either farm or landscape level
- Developing capacity approaches to examine multifunctional solutions for agronomic, ecological and socio-economic challenges
- Developing scenarios that are validated by direct evidence and metrics to support behaviour that foster resilience and natural capital
- Reducing the risks that can present challenging barriers for farmers during adoption of new technology and practices
- Developing an understanding of how climate affects the rural labour force, land tenure and cultural integrity and therefore the stability of food production

Relevance of the climate agenda: Indicate where new knowledge and innovation are needed, design efficient interventions, incentivize large-scale shifts of adaptation and mitigation, assess mitigation and adaptation initiatives in an integrative way, understand trade-offs and synergies, look for hotspots in the systems, use modelling and tools to quantify and monitor impacts, look at systematically by connecting people, problems and solutions.

The Netherlands

The Dutch Government has defined the following long term climate goals for 2030 and 2050 in the climate law:

- The Netherlands has to reduce their greenhouse gas emissions by 95 % in 2050 compared to 1990
- In 2030, the aim is to reduce greenhouse gas emissions by 49 %
- In 2050, the aim is to have electricity production which is 100 % CO2 neutral

The ministry of economic affair and climate policy developed the integrated national energy and climate plan to reach these goals. Part of the plan is a knowledge and innovation agenda which has five missions: i) An electricity system that is completely CO2-free in 2050, ii) A CO2-free built-up environment in 2050, iii) In 2050, raw materials, products and processes in industry are net climate neutral and at least 80% circular, iv) Emission-free mobility for people and goods in 2050, v) In 2050, the agriculture and nature system is net climate neutral. Also the knowledge and innovation agenda agriculture, water and food from the top sectors has climate neutral and resilience as an integral part of the knowledge agenda. Their six missions are: i) Circular agriculture, ii) Climate-neutral agriculture and food production, iii) Climate-proof rural and urban areas, iv) Healthy, safe and appreciated food, v) Sustainable and safe North Sea, oceans and inland waters vi) The best protected and livable delta in the world.

Relevance of the climate agenda: Innovating together, Building and strengthening, investing in knowledge development and innovation, smart solutions to future problems; Support for the transition and acceptance of the solutions; system perspective; costs and benefits of climate policy; monitoring and evaluation

Climate knowledge agenda of Wageningen UR

What should be the questions we ask ourselves to get to a climate neutral and resilient Europe in 2050?

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Introduction – WUR - climate transition

Quote WUR strategic plan:

"Our research is driven by our desire to understand and to contribute to the world's challenges and the transitions that lie before us."

Quote WUR climate strategy:

"WUR has a large track record on climate and climate-change research by exploring the impacts of climate change on society, agriculture and ecosystems, and developing evidence-based solutions for mitigation and adaptation."

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Urgency: no time to lose - act now!

- We must return and stay within planetary boundaries
- EU policy to become climate neutral and resilient by 2050

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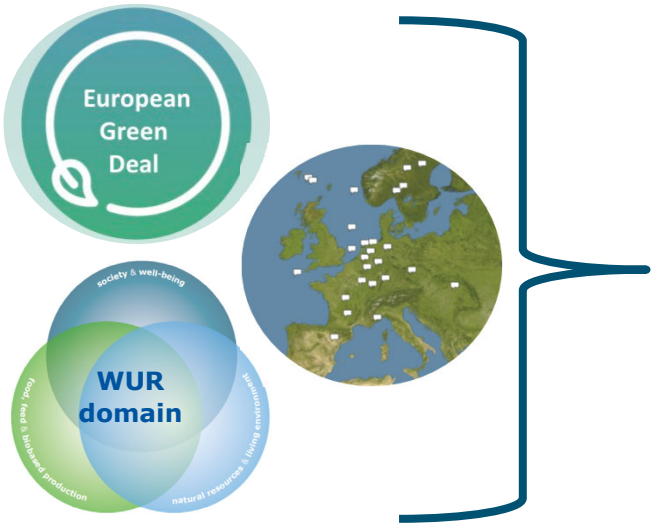
WUR climate themes



- Circular and biobased economy
- Farm to fork
- Natural resources and living environment
- Biodiversity
- Clean, affordable and secure energy
- Society and well-being

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An area approach as a starting point

Urban areas, agriculture areas, forests and natural areas, water bodies

Area specific approach:

- To focus on impacts from themes on the different areas
- To improve understanding of future problems and solutions
- To stimulate interdisciplinary thinking (outside own theme)

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Vision

- We don’t know exactly what to do and we don’t have the time to wait until we do, but we do know where to work towards. Make it happen, start!
- Explore options not just THE solution we see at the moment
- Be flexible, celebrate the wins and allow for quick failure and refocus of options. We need interdisciplinary feedback loops
- Integrate knowledge across the different areas (urban, agriculture and nature, water bodies) and climatic themes, but also geographically (e.g. what is the impact elsewhere in the world) to understand synergies and trade-offs of the solutions
- Social engagement, connection to (external and international) stakeholders to get support for the solutions and to analyse and define the roles and responsibilities of these stakeholders towards a climate neutral and resilient Europe.

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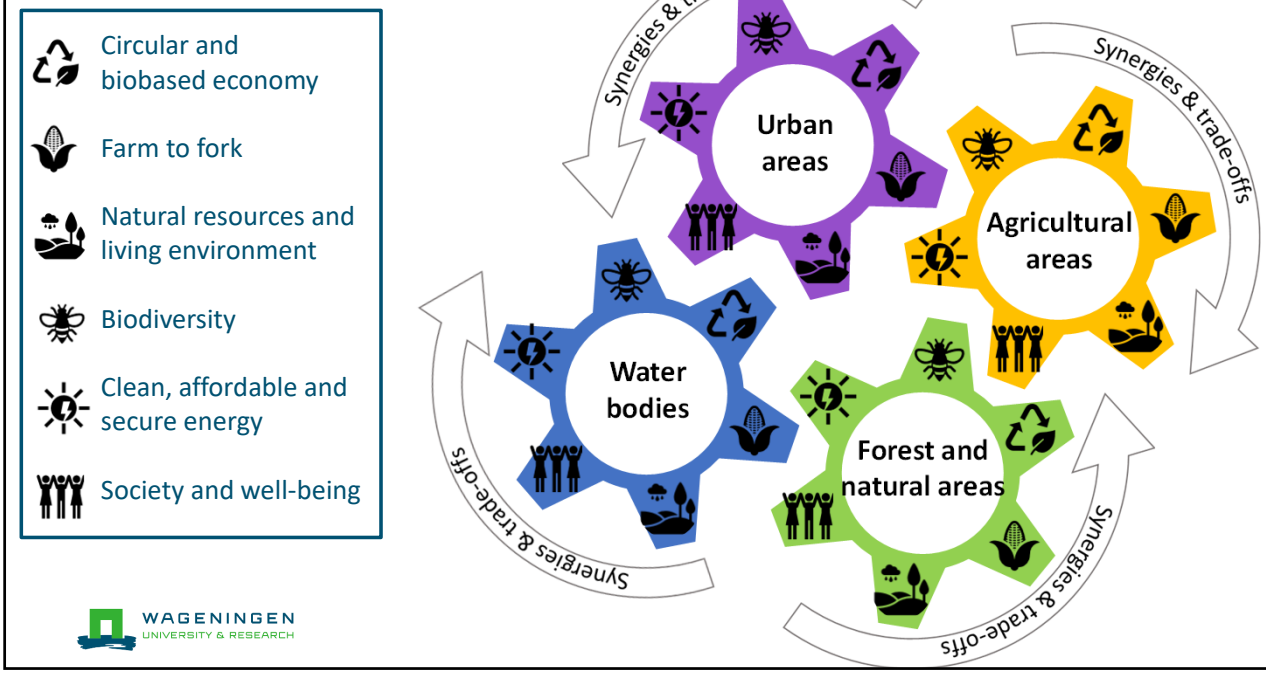

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Which knowledge and solutions do we need on our way to 2050? What should we do where?

- What are the connections, synergies and trade-offs for agri-forest-urban-water challenges and what kind of frameworks, models and tools do we have to develop to quantify them?
- How to organize an active transition of agriculture, urban areas and other functions to find solutions for climate change affected nature, biodiversity and water (excess, quality and drought) problems?
- How to design a European nature and water infrastructure that contributes to an active transition of agriculture, urban areas and other functions to a climate neutral and resilient Europe?

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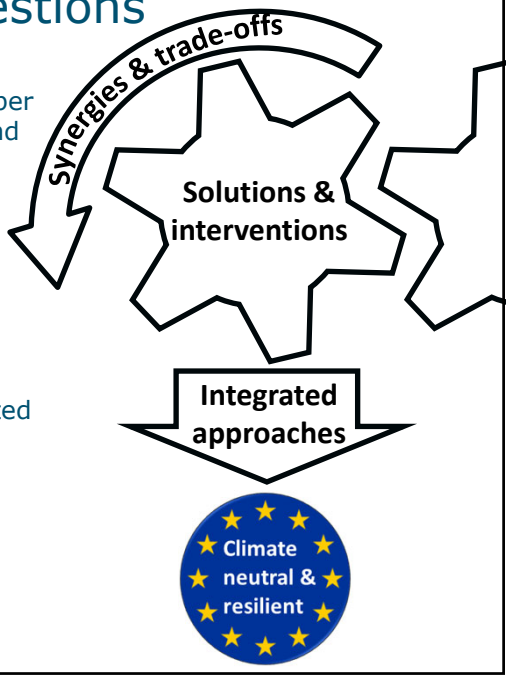
Reading guide – Research questions

- Research questions are structured in three categories per area: (1) Solutions and interventions, (2) Synergies and trade-offs, (3) Integrated approaches (see figure)
- Each area is discussed in 4 slides with the first slide introducing the 2050 future story. These stories where the starting point of the WUR dialogues. The following 3 slides deal with the research questions according to the 3 distinguished categories
- Questions are formulated in a comprehensive way and are based on more than 300 research questions collected
- Questions serve as stepping stones for discussions and for more specific questions
- New and updated questions can/should arise in the future through interdisciplinary feedback loops



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Me in my future city

I am living in a green city. When I look out of the window of my house, I see abundant trees and waterbodies everywhere. Green is also abundant on the walls and roofs of buildings, where it contributes to energy efficiency and biodiversity.

The roof of my house is connected to a raingarden, just like the other houses in the city. These raingardens are connected to a large, green infrastructure that permeates the entire city and connects it with its environment. The green infrastructure helps in the treatment of rain- and stormwater, municipal and industrial wastewater. This way we can use it as a source again.

Water bodies also play a key role now in the energy network of the city. It is used as a thermal source to cool the buildings nearby and to irrigate the city green. The district combined heating and cooling network has become the key temperature regulation system in our city. I enjoy living in the new.....

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Solutions and interventions

Urban areas

RQ

How to develop effective strategies and Nature based Solutions and integrate them as site-specific, green solutions for climate adaptation, water management and other societal challenges in different types of cities?

RQ

How to enable these effective strategies, with stakeholder support and with what kind of policies, institutional frameworks, and financial instruments ?

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Synergies and trade-offs

Urban areas

RQ

Which economic wins and spatial synergies can be achieved when formulating solutions and strategies for the various challenges that cities face?

RQ

What kind of assessment frameworks can be developed to weigh the costs and benefits of various sorts of urban interventions?

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Integrated approaches

Urban areas

RQ

What are the potential conflicting and linking interests of urban actors and how to accommodate the diverging environmental, economic, societal stakes in the transition?

RQ

What are the barriers, opportunities and enablers to mainstreaming integrative, multi-stakeholder approaches to climate-resilient urban development?

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Me on my circular, climate resilient farm

I am a farmer. In 2020, I took over the business from my parents. The following years I decided that business-as-usual was no longer the case. Mono-cultivation and high input systems were not suitable to adapt to climate change and to reduce the greenhouse gas emissions. We were confronted with the reality that earth surface was warming, and I had to do my share.

I first started with re-designing the practices on the farm. I intended to become more climate smart. So instead of only cultivating grains and potatoes, I started operating a diverse farming system with a mixed crop-livestock. So, I now have cows and chickens on the farm as well. The advantage of such a diverse system lies in its ability in adapting to climate change. And you know what I mean by climate change, right? We have frequent heat waves, droughts and extreme rainfall events(!).

I have integrated agroforestry on my land, allocating part of it for nut and fruit trees for us and our customers.....

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Solutions and interventions

Agricultural areas

RQ

How can agricultural production systems adapt to climate change and reduce the GHG emissions (design alternative and diversified farming systems)?

RQ

Which strategies and interventions are relevant and how can farmers, value chain actors, researchers, governments and consumers contribute to achieve effective, efficient and legitimate solutions?

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Synergies and trade-offs

Agricultural areas

RQ

What are the trade-offs and synergies while transitioning towards climate neutral and resilient agricultural production systems?

RQ

How to minimize trade-offs and enhance synergies of future farming systems?

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Integrated approaches

Agricultural areas

RQ How do we develop new or adapt the existing integrative approaches and tools that address (conflicting) interest of multiple stakeholders engaged in agriculture?

RQ What are suitable locations for different farming systems across Europe to optimize agricultural land use and lower the climate related impacts?

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Strolling around forest and natural areas

As a little kid, my father often took me out for a stroll in nature. During those walks, he told me a lot about the birds and the plants and about the beauty of nature. Thanks to my father, I became a big nature lover. Now, in 2050, I still often go for a hike, as do many others who travel along the extensive new trails that cross European nature. Many of these trails are now as famous as the trail to Santiago de Compostela. But since our parents' childhood, climate has changed undeniably and has changed the natural environment as well.

The kind of forest I used to walk in with my father, I can now only see in outdoor museums, as we call the small remnants of nature reserves. Here nature is intensively managed, conserved and restored. This micro-management enables rare species to survive, especially in the most valuable and vulnerable nature areas.

Nature outside these outdoor-nature-museums is completely different. This nature consists of large units in the landscape where.....

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Solutions and interventions

Forest and natural areas

RQ How to increase resilience of nature to protect biodiversity and contribute to climate challenges (droughts/floods, CO2,…)?

RQ How to operationalize the ESS framework for climate adaptive strategies and biodiversity?

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Synergies and trade-offs

Forest and natural areas

RQ How to design a European green infrastructure that contributes to climate adaptation and a sustainable footprint?

RQ Multiple land use: what will we gain or lose?

RQ How can climate change help to conserve biodiversity?

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Integrated approaches

Forest and natural areas

RQ How to support strategic policy objectives, shape research programmes and knowledge dissemination?

RQ How to shape a future Biodiversity-and Bio-inclusive society?

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Sailing on the European water bodies

It's July 2050. I just returned from a boat trip through Europe, as a member of the EU future water team. This team was established after the droughts of 2030, which were followed by unusual rainfall events, causing severe floods. In 20 years, we have achieved quite a lot in the transition towards more integrated water management, combining urban and city development, agriculture and nature.

We started in Hungary and made our way over the Danube river. We travelled over land to Belgium, and then by boat over the Scheldt river and delta. We ended on the Dutch coast of the North Sea. In every country I saw how policymakers, stakeholders and scientists tried to find a balance to cope with the effects of climate change: do we adapt or do we intervene?

All through Europe I saw the struggle between water scarcity and water availability. Water-intensive land use functions, like agriculture, were shifted to areas where water .....

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Solutions and interventions

Water bodies

RQ What are the key scenarios and solutions to address in water management, adaptation and usage?

RQ Is water guiding us, or are we guiding the water?

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Synergies and trade-offs

Water bodies

RQ What are the synergies and trade-offs in long and intermediate term transition scenarios, accommodating the balance between all water types?

RQ What are the climate related processes in marine, Delta and freshwater bodies on food web functions, expected regime shifts, adaptation potential, carbon storage, effects on ecosystems and drivers for water quality improvement?

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Integrated approaches

How to optimize water use and resources to sustain the marine and land food production, while not compromising biodiversity in a changing climate?

What are effective pathways for knowledge integration to make decisions by multidisciplinary research and approaches to create multi stakeholder applicable solutions?

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Conclusions

- Huge amount of climate related scientific research questions were collected in the process
- Lot of knowledge at WUR, but knowledge is fragmented and not well disseminated. The knowledge should be brought together and more emphasis on dissemination is needed
- WUR should use more of its resources and knowledge to play a pivotal role in climate mitigation and adaptation, by enhancing internal collaboration, improving strategic collaboration, increasing visibility of WUR through improved knowledge dissemination

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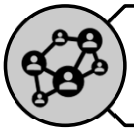
Final recommendations

Enhance interdisciplinarity (science)



Connect to the rest of the world (stakeholders)

Translate research to real life cases (impact)

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Enhance interdisciplinarity in projects and educations by

- allowing for learning time to speak the same language
- creating interdisciplinary feedback loops to be flexible, fail fast and celebrate the wins
- making learning and reflection part of the projects
- creating exit strategies of project to guarantee knowledge transfer & impact enhancement
- developing interdisciplinary education programme on climate research, interact with students & education institutes

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Connect to the rest of the world, to enhance impact and create partnerships and tailor-made solutions by

- creating incentives to work with other people and organisation (governments, international organizations, NGOs, private sector and civil society organizations inside the Netherlands and within the EU)
- establishing joint smart co-creation process– ensuring knowledge transfer with different types of stakeholders (partnerships)
- intensifying the WUR lobby towards the EU/green deal to show how WUR can contribute on climate solutions

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Translate our climate research to real life cases to speed up the transition towards a climate neutral and resilient Europe by

- creating a visualization lab to share model results showing synergies and trade-offs and visualize the impact of change
- demonstrating solutions in pilots, case studies and living labs to learn how to implement, to inspire others, to monitor effectiveness, to encounter real life challenges and as a motor to accelerate changes

This will also improve the visibility of WUR as a climate knowledge provider and shows that WUR can offer solutions to the climate crisis

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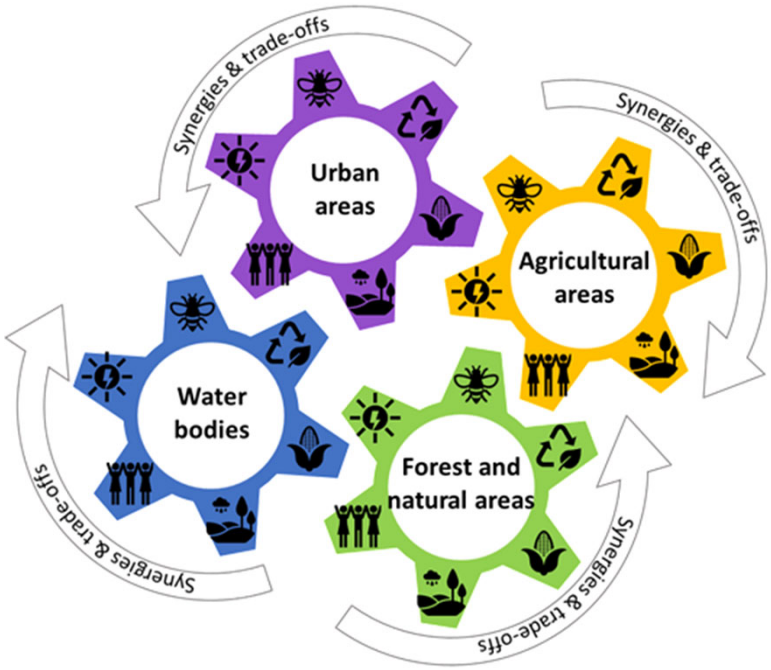
Thank you!

Make it happen, be flexible, fail fast and celebrate the wins



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