KARBONMAT: Designing sustainable business model (SBM) concepts for carbon sequestration in soils to transform the Norwegian food system

0. Relevance to the call

Transformation of food systems is a crucial requirement if Norway is going to effectively respond to, and address, the challenges of climate change and biodiversity loss whilst delivering sufficient quantities of safe and healthy food. However, one key dimension of transforming food systems has been largely neglected. Soil. The basis of **all land-based food production.** A fundamental requirement for an economically, socially, and environmentally sustainable terrestrial food systems is therefore healthy soil.

KARBONMAT directly addresses this need by developing **Sustainable Business Model (SBM)** concepts for Norwegian agriculture that **enable farmers to improve soil health, to store more carbon in their soils** and Norwegian companies to invest in these **to contribute to local sustainable food production and to reduce their climate footprint.** A well-designed SBM concept for Norwegian agriculture can make carbon sequestration in soils economically viable for farmers whilst transforming the sustainability performance of the Norwegian food system by reducing net emissions, enhancing soil health, and sustaining future agricultural productivity.

KARBONMAT addresses 3 of 6 thematic areas in the call: 1) **new approaches to primary production**, by developing SBMs for soil management solutions that improve the carbon capture, microbial biodiversity and thus productivity of soils as a foundational element of a more sustainable primary production system. 2) **new business model value creation**, by developing SBM concepts for valorising carbon in soils. By targeting carbon sequestration in soils the project also addresses the need for the development of 3) **new tools for sustainable food systems** by examining innovative technological tools (e.g. novel soil amendment products), new business models for carbon valorisation and policy tools to support sustainable soil management practices.

Hence, applying SBM concepts to sequestering carbon in Norwegian agriculture is **highly novel** for Norway and has the potential to **restructure the Norwegian food system** by establishing a new revenue stream for carbon valorisation including climate and environment. KARBONMAT relies on a close **co-production** of knowledge by including stakeholders representing different parts of the SBM value chain with specific tasks and deliverables. Furthermore, the project involves a **multi-actor panel (MAP)** with a mix of researchers and external stakeholders relevant for the validation of developed SBM concepts. In addition, the project establishes a **Responsible Research and Innovation (RRI)** committee led by an RRI expert to ensure good RRI practices. We involve 6 Norwegian and 2 international researchers, with a background in social sciences, economics, soil sciences and biology, ensuring **high interdisciplinarity**.

KARBONMAT contributes to the achievement of SDG2 (End hunger, achieve food security and improved nutrition and promote sustainable agriculture), SDG12 (Ensure sustainable consumption and production patterns), SDG13 (take urgent agent action to combat climate change and its impacts), and SDG15 (Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss).

1. Excellence

1.1 State of the art, knowledge needs and project objectives

Food system transformation is key to addressing multiple interlocking challenges, including climate change, biodiversity loss, soil erosion, and groundwater depletion whilst continuing to provide safe food and economic opportunities for rural areas (Daum, 2023). However, at present, food systems contribute to exacerbating these problems (Herrero et al., 2020). To meet these challenges there is a crucial need for innovation in the food system to enable transition towards more sustainable practices. However, one key dimension in the green transition in agriculture, which has largely been neglected, is soil (Tahat et al., 2020).

The basis of all terrestrial food production is soil. “Soil and the multitude of organisms that live in it provide us with food, biomass and fibres, raw materials, regulate the water, carbon and nutrient cycles and make life on land possible” (European Commission, 2021: 1). These material qualities, the ecosystem services they provide, and food production systems they sustain mean that soil must be at the centre of transformations towards more sustainable food systems.

Consequently, soil health has recently gained increasing global awareness (Lal et al., 2021). Soil health is increasingly recognised as critical to achieving the United Nations Sustainable Development Goals (Lal et al.,

2021). The recent EU 2030 Soil Strategy (European Commission, 2021) asserts that healthy soil is an integral element in meeting climate, water quality, biodiversity, and long-term economic objectives.

Yet, soils are under threat. The majority of soils in Europe are estimated as being not healthy (European Commission, 2021). In Norway only 3% of the country is categorised as arable land (Worldbank, 2023), which means that a comprehensive soil protection strategy is needed to ensure local food production (Government.no, 2023). There is therefore a need to adopt soil management solutions that improve the carbon capture, microbial biodiversity and thus productivity of soils as a foundational element of a more sustainable **primary production** system. Sequestering more carbon in soils appears to be a highly promising management practice to address these challenges. Carbon sequestering in soil has been shown to have multiple 'win-win' benefits on soil productivity leading to increased crop yields combined with a high potential of GHG emission reduction (Carliste, 2016). Furthermore, well-covered, carbon-rich soils can reduce disease outbreaks, provide pest control, and exposure to soil microbes can reduce allergies (Lal et al., 2021:3).

There are a wide range of possible soil management practices that can increase carbon in soils. The most common ones are diverse crop rotations, cover crops. agroforestry, reduction of soil tillage, fertilisers rich in organic carbon, and permanent grassland (Paulsen ed., 2020). Some of them require just small adjustments on the farm (e.g., planting cover crops) while others require changes in the entire farming system (e.g., enriched crop rotations, agroforestry) (Demeyer et al., 2021). Several of these practices include multiple benefits for soils and food production overall (Carliste, 2016).

However, these promising soil health management practices have proven costly for famers within the current regulatory, market and business frameworks. These barriers include, 1) the opportunity cost for farmers interfering with cash crops, 2) the need for initial investment in equipment or infrastructure, and 3) the need for ongoing investment in seed, labour and management. Common policy approaches for overcoming these financial barriers are subsidies, grants, and tax incentives. However, these have experienced limited success. As a result, adoption of sustainable soil health management practices remains low in Norway and elsewhere (Carlisle, 2016). Hence, there is a pressing need for **new regulatory frameworks**, **social entrepreneurship** amongst key stakeholders and **innovative SBMs** that work in tandem to ensure that farmers are paid and supported for their effort to store carbon in soil (Van Colen & Lambrecht, 2020). SBMs comprise a "model of the firm" that focus on integrating economic, social and environmental factors into the value proposition, value creation, and value capture activities of the business (Boons & Lüdeke-Freund, 2013).

One attempt to address this problem has been the implementation of carbon credit systems for agriculture. A carbon credit system allows companies to offset some of their GHG emissions by paying farmers to store carbon in their soils. Unfortunately, international carbon credit schemes have been criticised as poorly tailored to local conditions. In some instances, carbon offsets have incentivized practices that are detrimental to real climate ambition as a result (Castagné et al., 2020:4). Furthermore, carbon credit programs have experienced limited acceptance by farmers due to restrictive policies, insufficient knowledge, landowner structures, and complicated complex monitoring and reporting requirements for accreditation (e.g., complicated soil samples must be taken from multiple locations, at specified depths, at regular intervals, and by certified researchers) (Castagné et al., 2020; Verschuuren, 2017).

A domestic carbon credit system for agriculture seems to be a good approach to address these problems with global schemes by improving *local* relevance and giving rise to new revenue models supporting tailored action (Demeyer et al., 2021:5). There are already notable initiatives in neighbouring countries Sweden (Svensk Kolinlagring), Finland (CarbonAction) and Denmark (Agreena) but Norway lags significantly behind. The only available program is run by Norsk Karbonlagring AS, which enables companies to purcahse carbon credits in the form of biochar that will be stored in soils on farms. The farmers participating in this program receive the biochar for free, but they are not paid for carbon credits as is the case in international examples.

However, there is a growing interest among companies in producing local carbon credits (Van Colen & Lambrecht, 2020; Demeyer et al., 2021). Recent research on crowdfunding of climate measures in Norwegian agriculture showed that the private sector is increasingly concerned about local food production and that investors are willing to support their local farmers financially (Stoknes et al., 2021). Hence, there seems to be an opportunity for developing a **regulatory framework**, tailored to the Norwegian context, that can support the development of innovative BMs that emphasize soil health, biodiversity, food production and support for local agriculture whilst being financed by the private sector. Identifying ways to exploit and maximise the potential of this opportunity, to foster healthy soils, capture GHG emissions, improve biodiversity and transform the sustainability of primary production is at the heart of the KARBONMAT project.

In KARBONMAT we argue that this can be done through the development of **SBMs** for carbon sequestering soil management practices that are **co-designed with relevant stakeholders**. The project explores how SBM concepts for carbon sequestering management practices can be designed by applying a

highly interdisciplinary approach encompassing both social and natural sciences. The name KARBONMAT (Norwegian for 'carbon food') refers to the possibility of making Norwegian food production more sustainable and productive by storing more carbon in soils to improve the health of agricultural soils while simultaneously addressing climate change, biodiversity loss and productivity objectives (European Commission, 2021). This project will, in co-production with relevant stakeholders, design SBM concepts for healthy/carbon sequestering soils in Norwegian agriculture as a novel socio-technical practice that promotes the transition towards more sustainable food systems.

1.2 Research questions and hypotheses, theoretical approach and methodology

The overall objective of KARBONMAT is to develop SBM concepts for carbon sequestering soils in Norwegian agriculture that enable farmers to adopt healthy soil management practices, and companies to invest in these to contribute to local sustainable food systems, new practices in primary production, improve biodiversity and reduce their climate footprint.

Secondary objectives that are in support of the overall objective include to:

I. identify and revise existing carbon sequestering soil management practices relevant for the Norwegian context and document their relevance for the Norwegian context by a practical field trial (WP1)
II. measure environmental sustainability effects of carbon sequestering soil management practices in Norwegian agriculture (WP1)
III. explore legal and policy frameworks that may facilitate or inhibit the application of SBM concepts for carbon sequestering soils in Norwegian agriculture (WP2)
IV. review existing BMs for valorising carbon in soils and analyse how these might be applied in a Norwegian context (WP3)
V. investigate the interest towards existing BMs for valorising carbon among Norwegian farmers and co-design optimal BMs from the farmers' perspective (WP4)
VI. explore the interest of Norwegian companies in investing in carbon sequestering soil management practices (WP5)
VII. develop and recommend measures for the implementation of SBM concepts for carbon rich soils in Norwegian agriculture with relevant stakeholders (WP6)
VIII. integrate responsible research and innovation principles and practices in the project (WP7)

Theoretical approach

KARBONMAT is an interdisciplinary project that draws together different disciplinary, theoretical, and practical perspectives to develop **innovative and robust SBM**s that facilitate carbon sequestering soil management practices. SBMs embed sustainability into the BM, so that a company can improve its sustainability performance and outcomes. SBMs have three distinctive characteristics making them different from traditional BMs: 1) creating value for multiple stakeholders, 2) including society and the environment; 3) delivering non-financial value, e.g., social and environmental values; considering not only value creation, but also value destroyed as a result of company's negative effects on society and environment and value uncaptured (Goni et al., 2021). KARBONMAT applies the adapted SBM canvas framework developed by Bocken 2015 (in Bocken et al., 2018) and based on the well-established Business Model Canvas (BMC) developed by Osterwalder and Pigneur (2010). The BMC consists of nine basic BM components visualized through a canvas. The main purpose is to help mapping, designing, and inventing new BMs. To adjust to the growing focus on sustainability, the adapted SBM canvas encompasses environmental and social values in addition to the economic one (Bocken et al., 2014) (See **Figure 1** for a detailed description of SBM canvas). To design SBM concepts the project is divided into different work packages (WP) where each WP addresses different dimensions of the adapted SBM canvas. We have highlighted each SBM element by underlining the relevant key words in the WP descriptions.

To demonstrate and verify SBM concepts we apply a design science approach, which "focuses on developing design principles that provide the main guidelines to develop targeted solutions for a problem in a specific context (Van Aken & Romme, 2009 in Van Burg et al., 2012:458). Design principles "involve a coherent set of normative ideas and propositions, grounded in research, which serve to design and construct detailed solutions" (Van Burg et al., 2012:458). In our study, the design principles present BM elements that shape the different dimensions of the SBM canvas. To obtain information for each dimension of the SBM canvas and hence identify the design principles, KARBONMAT applies a **mixed method approach** consisting of a mix of qualitative and quantitative methods for the BM design.

The project has a **strong stakeholder engagement** and ensures **co-production** of knowledge by 1) including stakeholders (representing different parts of the SBM value chain) with specific tasks and

deliverables across work packages and 2) establishing a MAP relevant for the validation of developed SBM concepts.

To ensure collective stewardship of science and innovation, KARBONMAT will follow a thorough **RRI approach**. The concept of RRI is a means of ensuring that innovation policy delivers acceptable material solutions to key societal challenges. Stilgoe et al., (2013) have developed 4 criteria for good RRI practice i.e. **Anticipation, Inclusion, Reflexivity** and **Responsiveness.** Anticipation "prompts researchers and organisations to ask 'what if...?' questions," employing "systematic thinking aimed at increasing resilience, while revealing new opportunities for innovation" (p. 1570). Reflexivity implies "holding a mirror up to one's own activities, commitments and assumptions, being aware of the limits of knowledge" (p. 1571). Inclusion is characterized in opposition to a top-down policy approach, stressing the importance of involving "new voices in the governance of science and innovation as part of a search for legitimacy" (p. 1571). Finally, responsiveness means a built-in "capacity to change shape or direction in response to stakeholder and public values and changing circumstances" (p. 1572). KARBONMAT will establish a RRI committee consisting of representatives of all project partners to account effects and potential impacts of the developed SBM concepts on the environment and society (see WP7).

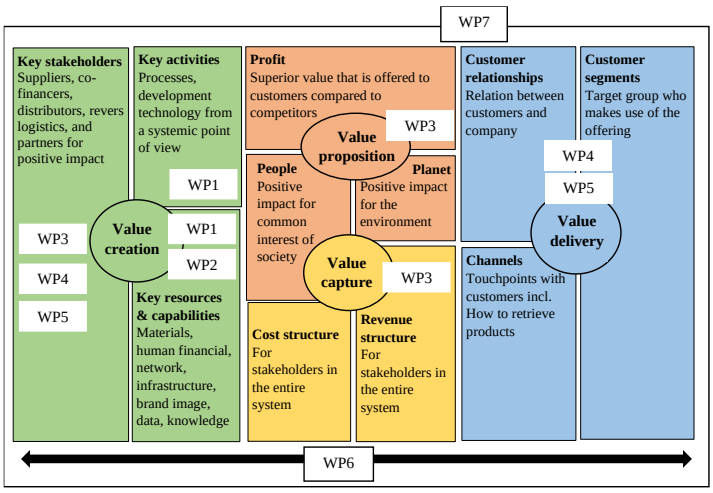

Figure 1 Adapted Sustainable Business Model Canvas including WP distribution

<u>Work package structure:</u>

KARBONMAT will build on 8 interrelated WPs that are described in the following:

WP1: Identification and measurement of effects of carbon sequestering soil management practices relevant for Norwegian food production and their multiple sustainability effects

Background: International research suggests that the use of organic fertilisers and soil amendment products have a positive impact on soils across a range of dimensions (i.e. carbon sequestration, beneficial effects on soil erosion, water holding capacity, reduction of crop loss due to pathogens) (Wittwer et al., 2021). We know that compost likely has a positive impact on carbon sequestration because of the key role of communities of microorganisms (microbiota) on accumulation of stabile soil organic matter. However, application of compost-based soil amendments has so far not been tested systematically and verified in a practical context among farmers in Norway. There is a need for documentation of the effect with carbon measurements and DNA-based methods for surveys of microbial biodiversity.

There is no "one size fits all" solution for carbon sequestering soil management since every farm is different with diverse needs, agricultural practices, and varying soil quality. It is therefore necessary to identify specific soil management practices by applying soil amendment products that are relevant in Norwegian contexts. This requires practical testing, measurement and verification among farmers in Norway. **WP Tasks:** WP1 will prepare an overview of internationally approved carbon sequestering soil management practices using compost and which are most feasible for Norwegian agriculture (<u>key activities</u>). **T1.1 –** These practices will then be validated with farmers (WP4) and companies (WP5) to identify their preferences for adopting and investing in these. In addition, the WP will, throughout the project, validate sustainability effects of these practices by applying compost in field experiments among 19 farms that are partners in a Norwegian initiative led by Grønt Fagsenter Buskerud. **T1.2 –** We will generate data from soils where the compost has been applied, to measure exact impacts and co-benefits of these practices on Norwegian soils. The effects of these management practices on soils (environmental validation) will be studied in parallel with the social validation of the SBM concept. The collected data will cover microbial biodiversity, chemical/mineral content of the soils and soil structure. **T1.3. –** In a last step these data will be analysed together to document the effect of the carbon sequestration methods and correlation of these effects with microbial biodiversity and chemical composition and the farmers' practices. The experimental results will be included as part of the environmental validation in the final project report (<u>key resources</u>). **WP leader:** Eirik Kolsrud with scientist Anders Næss (Grønt Fagsenter Buskerud). **Deliverables:**1 newsletter to project website (**D1.1**), 1 podcast (**D.1.2**), 1 chronicle

(**D1.3**), 1 internal report to WP2-6 (**D1.4**), inputs for final project report (**D1.5**), presentation at final project conference (**D1.6**).

WP2: Exploring appropriate legal and policy frameworks for carbon sequestering soils

Background: Previous research has shown that policy uncertainty and regulations can lead to lower acceptance of carbon sequestering soil management practices (Dumbrell et al., 2016) and that long-term policies with a more holistic focus than just emission reduction are necessary (Verschuuren, 2018). However, governments often follow different environmental targets and design environmental policies in isolation which can be contradictory. Hence, there is a need for a more holistic approach to policy design that takes into account various environmental targets and conflicting impacts (Demeyer et al., 2021) and can support the development of local carbon sequestration schemes. **WP Tasks: T2.1** – To identify and analyse Norwegian environmental policies relevant to carbon sequestration in soils. The aim is to identify potential contradicting environmental goals that can limit farmers' adoption of carbon sequestering soil management practices and provide policy recommendations on how these can be improved to enable carbon sequestering farm practices. **T2.2 –** To conduct a desk study of international carbon farming policy/legislative documents to investigate their relevance for Norway. The focus of KARBONMAT is on voluntary carbon markets and quite a few initiatives have developed over the last years to provide locally certified emissions reductions projects. Based on Cevallos et al., (2019) we can identify 11 main domestic carbon certification schemes across Europe. The list will be updated as part of the desk study in WP2. **T2.3 –** Following T2.2 we will carry out interviews with representatives of existing national carbon certification schemes for sequestration projects in Europe. Through the desk study and interviews with representatives of the identified schemes, WP2 will identify key principles for a prospective policy and legislative framework, which serves as part of the SBM infrastructure for the value creation. **T2.4 –** will include a research visit of Prof. Maehle and Dr. Otte to Tilburg University to work with Prof. Verschuuren on the academic paper. **WP leader:** Dr. Pia Otte (Ruralis), partners: HVL, Tilburg University. **Deliverables:** 1 newsletter (**D2.1**), 1 podcast (**D2.2**), 1 chronicle (**D2.3**), 1 conference presentation (**D2.4**). 1 internal report with policy recommendations to WP3-6 (**D2.5**), 1 journal article (**D2.6**).

WP3: Review of existing BMs for sequestering carbon in soils and analysis of application for Norway

Background: Existing BMs for sequestering carbon in soils have different levels of involvement from governments or other stakeholders. There are 4 common types of BMs that valorize carbon sequestration. These include (1) models within the agrifood chain, (2) models outside the agrifood chain, (3) models at farm level, (4) models including government institutions (Van Colen & Lambrecht, 2020). In KARBONMAT, we focus on BMs valorising carbon in soils, which are usually initiated by governments and larger companies outside the agri-food sector. **WP Tasks: T3.1** – WP3 will develop a final list of relevant cases with BMs valorising carbon in soils. We have identified a preliminary list of 7 international projects based on carbon credit BMs and 3 listed as "others" with a particular focus on improving soil quality and increasing biodiversity on farmland. In addition to the international projects, we will investigate 3 Norwegian cases offering carbon compensation to companies: Norsk Karbonlagring AS (providing biochar to farmers), CHOOOSE (offering compensation for travel emissions) and Trefadder (planting trees in Norway). Furthermore, we will investigate one company that offers unique compost-based soil amendment products, which represents a key point in the carbon credit value chain: (Smartsoil AS). **T3.2 –** Following identification of relevant BM cases we will collect and analyse secondary data for the identified cases(company records, websites, press reports etc.). This will help to identify relevant stakeholders and design principles for the value proposition and capture in the SBM concept. **T3.3 –** Finally, we will conduct in-depth interviews with representatives of the cases. Combined, this data will allow us to identify the building blocks for the SBM concepts that will be validated with farmers (WP4) and companies (WP5). **WP leader:** Prof. Natalia Mæhle (HVL), partners: Norges Vel, Green House AS. **Deliverables: D3.1** 2 conference presentation, **D3.2** 2 newsletters, **D3.3** an internal report to WP4-6**. D3.4** 1 podcast, **D3.5** 1 peer reviewed journal article.

WP4: Interest towards SBM concepts for sequestering carbon among Norwegian farmers

Background: Farmers are key stakeholders in the development of SBM concepts for carbon sequestering soil management practices since their level of interest ultimately determines adoption success. Previous research suggests that policies should focus on motivating farmers to undertake carbon farming by voluntary means, as farmers fear that obligations will limit thir ability to tailor soil management practices to their farms (Demeyer et al., 2021). WP4 will investigate the willingness of Norwegian farmers to adopt potential SBM concepts and their preferences. **WP Tasks: T4.1 –** Based on the identified carbon sequestering soil management practices (WP1), relevant policy frameworks (WP2), and BM building blocks (WP3), farmers will be presented with first scenarios of SBM concepts. This is relevant for the value creation of the SBM. We will validate preliminary BM scenarios with 3 focus groups (consisting of 6 farmers in each group) with the

19 farmers in WP1. These farmers are from 3 municipalities and include a mix of conventional, organic and regenerative farms, both with and without livestock (recruited through Grønt Fagsenter). These farms are very different (in types of farm management, soil types etc.) and were chosen to generate data that can be representative of differences in farm types at the national level **T4.2 –** To strengthen the results from T4.1, we will also carry out scenario testing with 2-4 focus groups with farmers who are not familiar with carbon sequestering soil management practices from the same municipalities (recruited through Green House AS). **T4.3 –** Based on the inputs from these two soruces the BM scenarios will be modified and then validated in the form of a choice experiment in a national survey with farmers. **WP leader:** Dr. Maja Farstad (Ruralis), partners: UWA (Dr. Marit Kragt – choice experiment expert), HVL, Grønt Fagsenter Buskerud, Green House AS, UWA. **Deliverables:** 2 newspaper articles in farming press (**D4.1**), 1 conference presentation (**D4.2**), 1 internal report to WP5 (**D4.3**), 1 podcast **(D4.4)**, 2 journal articles (**D4.5, D4.6**).

WP5: Investigating companies' requirements for SBM concepts sequestering carbon in agriculture

Background: WP5 will examine the value propositions relevant for companies' willingness to offset their GHG emissions via SBM concepts for carbon sequestration in agriculture. There has been an increased interest among companies to pay for locally produced carbon credits due to reliability issues with international compensation projects. Co-benefits to support local farmers financially and assist them in local ecosystem services might be a further motivation for companies (Demeyer et al., 2021). However, there is a need to investigate the willingness of Norwegian companies to pay a fair carbon credit price reflecting the additional efforts and costs necessary for long-term soil measures. **WP Tasks: T5.1 –** It will begin by exploring which types of carbon valorising systems Norwegian companies currently pay for. The WP will also explore whether certain carbon sequestering soil management practices identified in WP1 are more appealing than others. 3 to 6 focus groups will be conducted with Norwegian companies who are currently offsetting GHG emissions or contributing in other ways to reduce their environmental footprint. **T5.2. –** To provide a comparison, 3 to 6 focus groups will be carried out with companies who are not yet participating in any carbon valorising scheme. Green House AS will help to identify relevant cases. The focus group participants for T5.1 and 5.2 will be presented with different scenarios of a SBM for carbon valorisation in agriculture identified in WP4. **WP leader:** Prof. Natalia Mæhle, partners: Ruralis, UWA, Green House AS. **Deliverables: D5.1** 1 newspaper article, **D5.2** 1 podcast, **D5.3** 1 conference presentation, **D5.4** 1 internal report to WP6-7, **D5.5** 1 journal article.

WP6: Developing measures for implementing SBM concepts sequestering carbon in agriculture

Background: WP6 will draw together the experiences from all prior WPs into an integrative model to build concepts of SBMs for sequestering carbon in Norwegian agricultural soils that will suit farmers' and companies' needs, fit in with Norwegian policy frameworks and include soil health benefits. The SBMs will be presented to the MAP board for discussion on how to take the concepts further. Integration will take place throughout the project (see WP descriptions) and the results will be presented during a two-day conference at the end of the project (day 1 for researchers and day 2 for practitioners). Preliminarily identified members of the MAP and their roles in KARBONMAT are as follows:

- **Green House AS:** coordination of stakeholders in WP6, connect the research team to case studies in WP2 & WP3, and help to identify farmers for the focus group in WP4.
- **Grønt Fagsenter Buskerud:** WP1 leader, will contribute with relevant farm knowledge and prior findings of the "Jordhelse Karbonfangst" project, connect WP4 with 19 test farmers and identify 1 farmer for the MAP in WP6.
- **2 farmers:** 1 farmer from the research project "Jordhelse Karbonfangst" and 1 farmer who was not familiar with carbon sequestering soil practices prior to the project to ensure that developed SBM concepts align with farmers' priorities.
- **Norges Vel:** connect with potential companies for WP5. Norges Vel will also facilitate access to Norsk Karbonlagring AS, a case study in WP3.

WP Tasks: T.6.1 – The stakeholder list is preliminary. Thus, WP6 will carry out a stakeholder analysis (Reed, 2018) at the beginning of the project to ensure that all relevant stakeholders and their different perspectives are included. **T6.2 –** In addition, WP6 will includes 3 iterative MAP meetings to verify the SBM concepts identified and developed throughout the project. **T6.3 –** A research visit of Prof. Maehle and Dr. Otte to the University of Western Australia (UWA) to work with Dr. Marit Kragt on one academic paper. **T6.4–** WP6 will organize a two-day final conference. **WP leader:** Dr. Pia Otte (Ruralis) and Prof. Natalia Mæhle (HVL), partners: All. **Deliverables:** 1 Podcast (**D6.1**), 1 newsletter on website (**D6.2**), 1 conference presentation (**D6.3**), 1 presentation at the final project conference (**D6.4**), 1 final report (**D6.5**), 1 journal article (**D6.6**).

WP7: Ensuring Responsible Research and Innovation

Background: There is a growing emphasis on how the concept of responsible innovation can be implemented in broader organisational settings, particularly in the business context (Lubberink et al., 2017). RRI is understood as "what actors already do, in collective fora, in order to embed institutionalised interpretations of what it means to be responsible; into the practices, processes organisational structures and outcomes of research and innovation" (cited in Owen et al., 2021:2), WP7 will serve as such a collective forum, providing a meeting place for project participants to co-create good RRI practices that are essential in such a transdisciplinary project. To do this, the WP will involve a RRI expert as WP leader and establish a RRI committee consisting of 1 representative from each collaboration partner included in the MAP. The RRI committee will meet annually (and in addition after demand) to discuss project findings as they emerge, negotiate potential changes in the project and ensure close dialogue and a co-production process.

WP Tasks: T7.1 -7.3– Annual RRI committee meetings. The first task will be a kick off meeting where participants will discuss Stilgoe et al.'s (2013) 4 criteria for RRI (Anticipation, Inclusion, Reflexivity, Responsiveness) to develop a joined interpretation of these. This will lead to a list of 4 contextualized RRI guidelines that are circulated with all project members and provide the RRI background for all activities. During RRI committee meetings participants will report on the implementation of these principles in their tasks and discuss potential challenges in the project process to fulfil these. The RRI WP leader will facilitate these discussions toward joint solutions. The RRI expert will also attend the bi-annual project meetings to follow up and observe. **T7.4 –** The RRI expert will set up a digital reflection diary on a shared platform where committee members will contribute with their reflections. The diary will be the basis for a scientific publication on the application of RRI principles in transdisciplinary agricultural research projects. **T7.5 –** The WP will conclude with a final evaluation committee meeting to evaluate how far RRI criteria and outcomes could be met. **WP leader:** Prof. Arnt Fløysand (HVL), partners: All. **Deliverables:** Project specific RRI guidelines (**D7.1**), 1 collective research reflections dairy (**D7.2**), 1 journal article (**D7.3**).

WP8.1: Project management and administration

WP 8.1 will be a management WP that will ensure overall integration between all WPs. The WP leader will be supported in her management by the RRI committee and a project administrative advisor from Ruralis. The WP will also ensure the writing/signing of contracts between the consortium partners and the delivery of WP deliverables. WP8.1 will also manage the biannual project meetings (1 digital, 1 physical) (**T8.1**), the work plan for the academic publications (**T8.2**) and the annual and final reporting to the Research Council of Norway (**T8.3**). **WP leader:** Dr. Pia Otte **(**Ruralis), partners: All. **Deliverables:** signing/writing of contracts (**D8.1**).

WP8.2 Communication and dissemination

Lack of knowledge of carbon sequestering practices was identified as one major barrier to adoption (Demeyer et al., 2021). To ensure societal relevance of the developed SBM concepts a wide dissemination of the results is needed among scientific and especially external stakeholders. Hence, WP8.2 will proceed continuously through the project period and will include a wide range of communication and dissemination activities. KARBONMAT will provide knowledge to farmers, other agricultural stakeholders and the general public through multiple communication channels including 2 short (2.5 min) videos that will be shared on the website and in social media, 6 podcasts, an interactive, dynamic project website, quarterly newsletters based on inputs from the science WPs, social media engagement on three different platforms to target a broad audience (Twitter, LinkedIn, Facebook) **(T8.4)**, 3 lay summaries in Norwegian of key academic papers. An external communication agency will assist KARBONMAT in its communication work (**T8.5**). The WP will also hire a professional photographer, who will take pictures of project activities that will be used for communication (**T8.6**). Stakeholders from the MAP will help in dissemination by communicating results through their own communication channels. All dissemination outputs will emerge from research findings and knowledge exchange with partners and we will remain reflexive, adaptable, and responsive to unexpected opportunities as the project evolves **WP leader:** Rita Moseng Sivertsvik (Ruralis), **partners:** All. **Deliverables:** 2 short videos (**D8.2**), 6 podcasts (**D8.3**), project website (**D8.4**), 3 lay summaries in Norwegian (**D8.5**).

Potential risks: We are aware of multiple **external** and **internal** risks in such a highly interdisciplinary project and have developed a contingency plan. Internal: Delay of paper submission. Mitigation strategy: A management WP will be responsible for follow up of the project progress. A research visit to UWA and Tilburg University will provide dedicated time for writing. Internal: High interdependency of WP deliverables. Mitigation strategy: Bi-annual project meetings between the researchers will ensure a close communication and timely solving of arising problems.

External: Global and national travel restrictions. Mitigation strategy: Replacement of physical meetings and data collection by video conferencing. External: Data collection challenges. Mitigation strategy:

Involvement of umbrella organisations that are well interlinked and can assist in finding new contacts (see MAP); using existing connections established through previous research projects. Agreena and Smart Soil AS have already confirmed their interest in being a case study of WP3 (see letter of intent).

Interdisciplinary approach: KARBONMAT consists of a highly interdisciplinary team combining rural sociology, sustainability research, entrepreneurship, agricultural and environmental economics, soil sciences and biology. The project includes external stakeholders from all parts of the value chain for SBM concepts. **Ethical issues:** KARBONMAT will comply with all regulations of NSD Norwegian Centre for Research Data and has dedicated a WP to ensure that the research conducted in KARBONMAT follows RRI principles and good practices (WP7). **Gender perspective:** The project leader is female and 4 out of 8 co-investigators are women, promoting the empowerment of women in academia. In addition, KARBONMAT will, wherever possible, try to recruit a gender balanced sample for the data collection. **Potential undesirable effects:** To reduce the climate footprint of the project, not all meetings will be physical. **Stakeholder involvement:** Stakeholders are involved throughout the project (see WP descriptions).

1.3 Novelty and ambition

KARBONMAT is an ambitious project engaging international experts and experienced Norwegian researchers with established track-records on the research in carbon sequestration and sustainable soil management practices, sustainable business models and co-design with stakeholders. There are a number of novel innovations in the project. **Firstly**, we will apply microbiota as compost-based soil amendment product that has been certified by DNA sequencing, and produced with controlled processes and ingredients. Hence, in contrast to previous research using organic fertilizers, we use soil amendment products with properties and contents that are reproduced across all the years of this project. This will lead to more reliable empirical data on carbon sequestration and soil health, and pave the way for a standardized approach to address these issues in future. **Secondly**, KARBONMAT is the first project to methodologically and theoretically integrate SBM canvas tool, user-centred design principles and choice experiments to develop proof of concepts of SBM focusing on the valorisation of carbon in soils. User-centred design itself is not a new approach as it emerged within computer sciences in the 1980s. However, within the field of business modelling it has just gained interest very recently (Tolkamp et al., 2018:756). By applying a user-centred approach to carbon sequestration in agriculture, the project presents a novel addition to this research and addresses the need for more studies on the design and management of SBMs in different industries (Boons & Lüdeke-Freund, 2013; Nosratabadi et al. 2019). **Thirdly**, the proposed research investigates a neglected element in supporting food system transformation. Notably, the role of the private sector in supporting the development of a new market niche in Norway for supporting carbon sequestering soil management practices. This suggested approach is new to the Norwegian agricultural system that mainly relies on the agricultural agreement based on annual negotiations between the state and the two farmers' organisations (jordbruksavtale). **Fourthly**, through the RRI approach taken in the project we will seek to embed RRI principles and practices within agricultural research. To date there has been limited engagement with RRI in agricultural innovation projects (Rose & Chilvers, 2018). This project therefore provides an novel opportunity to experiment with RRI principles in the agricultural context and the social science led-research context. **Finally**, the project will address the need for the development of new tools for sustainable food systems. This includes technological tools (soil amendment products), social entrepreneurship processes, policy and regulatory frameworks and new business models for carbon valorisation. This is connected to our most ambitious objective, to examine the ways in which carbon sequestration in soils can be supported so as to drive transformative change that ensures the future sustainability and productivity of the most important element of terrestrial agriculture.

2. Impact

2.1 Potential impact of the proposed research

Early academic impact: KARBONMAT will train early career researchers by involving an early career researcher as WP8.2 leader, and 2-3 master students at HVL. It will build additional research capacity in Norway and strengthen international cooperation in the university and institute sector by involving 4 research institutions, and including 2 research visits for two Norwegian researchers. **Medium-term academic impact:** The project will produce at least 7 peer reviewed open access publications in high-ranking international journals such as Journal of Rural Studies (5.157)*, Journal of Cleaner Production (11.072)*, Environmental Innovation and Societal Transitions (9.377)*, Land Use Policy (*6.189), Research Policy (9.473)*, Technological Forecasting and Social Change (10.884)*.[1]

[1] * impact factor of journals retrieved 20.01.2023.

The KARBONMAT team will present its work at least at 8 (inter)national conferences. **Long-term academic impact:** The project will contribute to the development of new theoretical approaches combining SBM theory, design principles and choice modelling. KARBONMAT will ensure reproducibility and the potential to reuse results by following the principles of Plan S. During the first project meeting, the project team will discuss the degree of openness of archived data and how the data can be aggregated and anonymized, so that it can be stored at the data repository service Dataverse Network Norway, which is aligned with the FAIR Guiding Principles for scientific data management and stewardship. The project team is planning to apply for a qualification or innovation project funded by RCN to carry out a pilot testing of the SBM concepts.

Early societal impact: The project will increase immediate awareness around carbon sequestering soil management practices among various stakeholders including farmers, policy makers, companies, by including 3 MAP meetings, publishing a monthly newsletter from different WPs on the project's website, pursuing a powerful social media presence, and carrying out 6 podcasts. **Medium-term societal impact:** KARBONMAT will increase knowledge on SBM concepts for financing carbon sequestering soil management practices nationally by creating 3 lay summaries in Norwegian of 3-4 key academic papers to make the findings understandable for stakeholders. The summaries will be shared on social media and the KARBONMAT website and reach approximately between 200-400 readers. The final SBM concepts will be open sourced published as part of the Ruralis report series. In addition, a final conference for stakeholders and researchers with approximately 100 participants attending physically and 200 digitally is planned. **Long-term societal impact:** KARBONMAT will contribute to enabling an alternative way of financing carbon sequestering soil management practices in agriculture nationally and internationally that can transform Norwegian food systems and accelerate the adoption of climate change mitigation measures on farms.

The project contributes first and foremost to the achievement of SDG 2 (end hunger, achieve food security and improved nutrition and promote sustainable agriculture), but also addresses SDG 12 (Ensure sustainable consumption and production patterns), SDG 13 (take urgent agent action to combat climate change and its impacts), and SDG 15 (Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss). Furthermore, KARBONMAT contributes to fostering local food systems that can contribute to rural development by creating more jobs and a sense of community. Furthermore, it develops a new market for financing carbon sequestering soil management practices that has not existed in Norway before and that is highly needed to enable farmers to adopt these practices.

2.2 Measures for communication and exploitation

The full scope and plan for communication and dissemination is described in WP8.2.

3. Implementation

3.1 Project manager and project group

The KARBONMAT team consists of a mix of leading senior and junior scholars and stakeholders based in Norway, the Netherlands and Australia. Project leader **Dr. Pia Piroschka Otte** is senior researcher at Ruralis – Institute for Rural and Regional Research with a strong expertise in alternative finance systems for agriculture and project management. She has successfully led the Coolcrowd project, a large international research project financed by the Research Council of Norway, and managed several WPs in other international research projects relevant to KARBONMAT (Capture+ on biochar development; ClimateCropping soil health). She has published widely in leading international journals. Otte will lead WP2, WP8.1, and co-lead WP6. **Dr. Maja Farstad** is a senior researcher at Ruralis. Her research focuses on development toward a more sustainable future, encompassing both barriers and enablers – contextual and behavioural conditions. She has led an international research project (Climplement) that identifies barriers and enablers of implementing climate solutions in Norwegian agriculture. She will lead WP4. **Rita Moseng Sivertsvik** is a researcher at Ruralis. She has a master's degree in political science from the Norwegian University of Science and Technology (NTNU). Moseng Sivertsvik is very engaged in communication with external stakeholders, and popular science dissemination. She has been responsible for Ruralis' involvement in communication activities in different research projects. In KARBOMAT she will lead WP8.2 and serve as a project administrative advisor in WP8.1.

Prof. Natalia Mæhle (Mohn Centre for Innovation and Regional Development, Western Norway University of Applied Sciences) teaches and conducts research on digital economy, SBMs, and innovation. Mæhle has extensive project leadership experience. She led the Norwegian part of a large European research project on sustainable food consumption (SUSCHOICE project). She has published widely in highly ranked international journals. With her expertise in SBM design Mæhle will lead WP3, WP5 and co-lead WP6.

Prof. Arnt Fløysand (Mohn Centre for Innovation and Regional Development, Western Norway University of Applied Sciences) teaches and conducts research on responsible innovation. He developed and chaired the PhD Programme in Responsible Innovation and Regional Development (RESINNREG), HVL. He sits in the Board of AFINO and leads the RCN-project Responsible Innovation in The Norwegian Salmon Farming Industry: Grand Societal Challenges, Dilemmas and Improvements. Fløysand will lead WP7.

Dr. Marit Kragt is an Associate Professor in agricultural economics, and Director of the Centre for Agricultural Economics and Development at the University of Western Australia (UWA). Dr Kragt will contribute her expertise on farmers' adoption of novel practices, non-market valuation, and discrete choice experiment methodology to KARBONMAT and co-author at one peer reviewed article in WP3 and WP4. Prof Mæhle and Dr. Otte who will be visiting scholars to UWA. Dr. Kragt will have two research visits to Ruralis to work with Dr. Farstad on the survey design and choice modelling in WP4 and attend the final conference.

Dr. Jonathan Verschuuren is Professor of international and European environmental law at Tilburg University. His current research interest addresses the relationship between climate change and food security. Prof Verschurren previously received a prestigious EU Marie Sklodowska Curie fellowship to develop a new regulatory framework for climate smart agriculture. He will be an international advisor for Karbonmat and particularly WP2. He will contribute with his expertise as a co-author to the planned article in WP2 and attend the project meetings. Dr. Otte and Prof. Mæhle will be invited as visiting scholars to Tilburg University as well for dedicated writing time. **Anders Næss** is project leader for the Norwegian Research Council project "Jordhelse og karbonfangst" and a PhD student in business, Ecological Economics at Nord University. Næss will work in WP1 and contribute to the farmer' s survey and be co-author in 1 academic publication in WP4.

Eirik Kolsrud has a degree in agriculture from the Norwegian College of Agriculture, with specialization in agricultural operation technology. Kolsrud is the director of Grønt Fagsenter Buskerud. He will participate in the annual multi actor panel meetings in WP6, manage WP1 and facilitate contact to the 19 farmers for WP4. In addition, the KARBONMAT team includes 3 external Norwegian partners. Their role is described in WP6.

3.2 Project organisation and management

Table 1 Roles and participation requirement

Roles	Costs (NOK)
The costs of the Project Owner and other research organisations participating as partners (Ruralis (project owner), partners: HVL, UWA, Tilburg University)	9.778.00
The costs of Norwegian partners from the business sector or other parts of society (Grønt Fagesenter Buskerud, Green House AS, Norges Vel, 2 farmers)	2.583.000
Total project cost	**12.361.000**
Participation (percent)	**21**

KARBONMAT allocates 21% of the total budget to stakeholders outside research, which is needed to carry out the environmental and social validation of SBM concepts and to secure user relevance and viability of the designed SBM concepts. A large share is allocated to Grønt Fagsenter Buskerud (NOK 2,4 million) who will lead WP1. Their environmental validation of the SBM concepts requires a larger budget for operational costs for a variety of soil measurements (see online application). In addition, all external stakeholders contribute with 50% own financing in WP6. Furthermore, UWA will include NOK 275.000 in-kind contribution.

The work plan is outlined in the Gantt chart and more details are provided in the online application.

Year	**2023**	**2024**				**2025**				**2026**			
Quarter	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
WP1	T1.1									T1.3			
		T1.2											
WP2	T2.1		T2.2	T2.3		T2.4							
WP3	T3.1	T3.2	T3.3										
WP4				T4.1-4.2		T4.3							
WP5							T5.1-5.2						
WP6	T6.1			T6.2				T6.2	T6.3		T6.2		T6.4
WP7	T7.1-7.4			T7.2				T7.3				T7.5	

WP8.1	T8.1		T8.1	T8.2	T8.1 T8.3	T8.1		T8.1 T8.3		T8.1		T8.3
WP8.2	T8.4-8.6											

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