FOSC

ERA-NET Cofund on
Food Systems and Climate

Finalizing FOSC
Outcomes of the Funded Projects

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Contents

Welcome by the coordinator

FOSC is an ERA-NET Cofund on Food Systems and Climate supported by the JPI Facce (Joint Programming Initiative on Agriculture, Food Security and Climate Change) and EC DG research. What makes FOSC special is that it is a European initiative that brings together Europe and Africa to carry out joint R&I projects on these themes, training activities, exchanges and beneficial pooling (equipment, platforms, best practices, etc.). FOSC was initiated as a continuation of the bicontinental LEAP-Agri initiative, with a different thematic basis and programmatic framework, but with the same objective: to help feed a growing population by 2050 while containing global warming within 1.5 or 2°C.

At the end of the 6-year program, including a one-year extension to overcome the difficulties of the Covid pandemic, FOSC can easily be summed up in figures: 17 co-funded projects and 5 nationally-funded projects with TRLs from 1 to 7, each involving at least two European and two African partners, a total of 23 million euros in R&I funding, 141 R&I teams mobilized, a consortium of 29 partners from 20 countries, including two from South America, training sessions on areas of shared interest (Capitalization of research outputs and outcomes, Managing freedom in science and science diplomacy) or more specific and disciplinary for students and researchers in the context of bilateral exchanges, joint multi-project valorisation, etc.

Beyond the figures, FOSC has been a platform for the exchange of harmonized R&I funding practices and international research standards, a place for exchanges and programming on subjects of joint European-African interest, so that their food systems can cope with climate change and ensure national and regional food needs, exchanges of foodstuffs and food products between countries, regions and continents, a better distribution of the added value of agricultural product processing, and a limitation of losses and waste.
FOSC bears witness to the fact that sovereignty is not about isolationism, but on the contrary about open cooperation so that each and every one of us can develop our food systems, particularly with regard to the points of vigilance defined in 2024 by the FAO in relation to the different food systems all represented in the FOSC consortium, from protracted crisis to industrial systems.

Over the medium term, FOSC has enabled the development of effective human consortia to harmonise funding, R&I progress and the dissemination of these results, some of which have been translated into recommendations for policy makers, while others have been implemented directly by small companies or local associations. This wealth is not quantifiable, but it is regrettable that the end of FOSC without a follow-up program or equivalent supported by Europe signals the short-term loss of this human capital, and the impossibility for many other projects to valorise the results obtained towards target users and policy makers. Financial and instrumental support from Europe for bicontinental collaborations, including financial participation from all partners, would offer unique opportunities for research to develop and propose solutions to help food systems evolve in terms of quantity, health and nutritional quality, notably through better adaptation to climate change.

Isabelle Hippolyte - French National Research Agency

About FOSC

FOSC is the European Reseach Area Network (ERA-Net) Cofund action on Food Systems and Climate. FOSC is built upon and supported by the experience from FACCE-JPI and LEAP-Agri. The consortium consists of 29 partners from Europe, Africa and Latin America. FOSC pulls together resources for a joint research programme and is supported by the European Commission through an ERA-Net Co-fund grant. FOSC started in October 2019 and will run until September 2025.

How to feed 10 billion people?

FOSC addresses one of our world's major challenges: How to feed 10 billion people by 2050. Ensuring food and nutrition security in the long-term while containing global warming within 1.5 or 2.5 °C, will require major changes on a societal-level and a systemic transformation of our food systems. Important aspects to acknowledge in this are:

- current patterns of food consumption and production increase pressure on already scarce natural resources;
- climate change undermines food systems and reduces food security;
- environmental degradation puts additional pressure on food production
- consumer behaviour patterns favour the predominantly short term vision of food systems; and
- availability of food is highly unequally distributed around the globe.

FOSC ambition

The ambition of FOSC was to implement a range of joint activities to contribute to the creation of a strong and effective trans-national research and innovation network between Europe, Africa, and Latin America.

FOSC aimed as well to contribute to the coordination and synergism between national and international research programmes that are relevant to food security under climate change.

The challenge of achieving food and nutrition security within the context of sustainable food systems calls for increased investment and collaboration. It was aspired that the partnership increased investments in R&D&I through a coordinated regional mechanism aimed at reducing fragmentation.

Activities of FOSC

FOSC initiates and organises additional activities to foster collaborations and enhance impact of research on food systems and climate in Europe and beyond:

- the preparation and implementation of a joint call for proposals (FOSC call 2019);
- the preperation and implementation of a joint call for proposals with ERA-NET SUSFOOD2 (FOSC and SF2 call 2021);
- the deployment of innovative instruments for alignment and collaboration in R&D&I;
- capacity strengthening;
- stakeholder engagement;
- support to policy making;
- organize trainings for researchers; and
- communication and dissemination of results emerging from activities.

FACCEJPI

LEAP-Agri

FOSC 2019 co-funded call

The first major activity of FOSC was the organisation of a trans-continental call in the field of food systems and climate. Aim of the call: to support scientifically excellent, trans-continental R&D&I projects that contribute to the knowledge base on food systems and climate change. The call had a funding budget of approximately 16 million euros, including the EC-cofunding. The call was launched in 2019 and used a two-step procedure. 17 Projects were selected for funding.

Key information

The joint call supports basic and applied research and is focused on the interactions between climate and food systems: assessing the consequences of climate change on agri-food markets and developing sustainable and resilient food value chains in the context of changing food need and patterns (diets).

The projects of the FOSC call are multidisciplinary and/or transdisciplinary and address the following topics:

- assess climate change-related risks for food value chains, including impacts on producers, prices, availability, quality, international trade and food security, and resulting changes in consumer behaviours;
- promote innovative technology deployment to build sustainable and resilient food value chains influenced by changing food needs and patterns, and to develop better efficiency of the inputs and outputs of food systems;
- improve resilience and reduce volatility in agri-food production and food markets to sustainably improve food security in the context of climatic variation; and
- reduce food losses under climate change, including novel approaches to valorise side streams and reduce food waste.

Consortia consist of teams from a minimum of 4 countries from 2 continents, with at least 2 European countries and 2 countries from Africa and/or Latin America. The projects have a maximum duration of 3 years and start in June-September 2021.

The ambition of FOSC is to address both spatial scales and time scales with the funded projects.
Spatial scales: local analysis for case studies at landscape and farm scales and projections at the regional level. This includes comparisons between different regions (and projects) as well as global analyses.

Time scales: the 2050 time-horizon is selected and transitions between current conditions and 2050 are studied considering relevant scenarios integrating multiple drivers, including climate trends and climatic variability with special attention to risks caused by extreme weather events and demographic evolution.

Expected impacts

Expected impacts from the outcomes of the FOSC 2019 co-funded call are:

- support of the transition to carbon neutral agriculture and food chains;
- increased understanding of the effects of climate change on global food value chains; and
- development of solutions posed by environmental changes to the food system.

Evaluation and outocmes

FOSC received 71 pre-proposals. From this, 43 consortia have been invited to submit a full proposal. Full proposals were evaluated and ranked by experts. The funding bodies followed the ranking list and 17 projects were selected for funding.

Joint call of FOSC and SUSFOOD2

The 14 partners of the Joint Call Board from the ERA-NETs FOSC (Food Systems and Climate) and SUSFOOD2 (SUStainable FOOD production and consumption) launched on May 17 2021 the Joint Call for Proposals on:

Innovative solutions for resilient, climate-smart and sustainable food systems

Key information

The joint network consists of partners from 13 countries: Algeria, Argentina, Belgium, Estonia, Finland, France, Ireland, Italy, Morocco, Norway, Romania, Turkey and the United Kingdom. They committed 7,8 million euro for transnational research. The call for proposals closed on 16 August 2021.

The scope of the call is to fund projects that facilitate the transition from current linear food systems to resilient circular systems, including an optimal use of resources and less vulnerability to shocks under consideration of the interdependencies within the systems and its stakeholders.

Submitted proposals include research on one of the following topics:

Topic I: Innovations to improve food systems sustainability, with a focus on increasing resource efficiency and reducing waste

Topic II: Food Systems adaptation and resilience to system shocks

FOSC and SUSFOOD2 envisage that the transition towards sustainable and resilient food systems requires a system approach including a multi-actor approach and a multi-disciplinary approach. These cross-cutting issues were to be considered and individually adapted by each project in order to increase the projects' value and impact.

The joint call received a total of 31 transnational research project proposals. Topic I received 23 proposals and topic II received 8 proposals. The submitted project proposals include collaborations of more than 195 research partners.

Evaluation and outcomes

The proposals were evaluated by international peer reviewers following the criteria and procedure stated in the call announcement and evaluation guidelines Based on this scientific peer review process and the limits of available national/regional funding, the Call Board recommended 5 research projects, consisting of 34 partners, for funding with a total requested amount of about 3 6 M euros Out of the five selected projects, four projects contribute to the first topic of the joint call:"Innovations to improve food systems sustainability, with a focus on increasing resource efficiency and reducing waste", and one project contributes to the second topic:"Food systems adaptation and resilience to system shocks" The projects started between April and May 2022 and had a runtime of 36 months.

Outcomes of the Knowledge Hub

FOSC organized a series of activities bringing together the 17 projects funded by the 2019 call and the 5 projects from the 2021 call. The aim of those activities was to valorise research results and to produce joint research products based on the shared knowledge and insights from the various projects. The Knowledge Hub produced five valorisation items engaging 13 FOSC-funded projects. The use of various formats ensure that the outcomes are tailored to different audiences across diverse regions.

Valorisation products

1. Manual: "Including Traditional Ecological Knowledge (TEK) in Agricultural Research: Guidelines and Lessons Learned"

Developed by the MedAgriFoodResilience and NUTRIGREEN projects, this manual guides young researchers on integrating Traditional Ecological Knowledge (TEK) into agricultural research. Published in April 2024 on Zenodo, it quickly became the most downloaded document on the FACCE-JPI profile, with 600 downloads and more than 860 views to date.

2. Animated Video on Solutions to Drought and Salinity Stress in Agriculture

Four FOSC projects—Bio-Belief, C4C, Trustfarm, and SALAD—collaborated to create this engaging animated video. The video presents the impacts of drought and salinity stress on crops like eggplants, tomatoes, and quinoa, offering concise, visually appealing solutions. Finalised in June 2024, it will be translated into multiple languages to reach a broader audience.

3. Animated Video on Diversifying African Food Systems for Resilience

The UrbanFOSC and SAFOODS projects worked together to produce an animated video highlighting the need for paradigm shifts in African food systems. The video illustrates the importance of crop diversification in building resilience, focusing on policy processes that can support this transformation.

4. Climate-Smart Farming Virtual Reality (VR) Game (VARM)

The VARM simulator is an innovative virtual reality (VR) serious game co-created by VU Amsterdam and the University of Twente (UT), incorporating insights from two FOSC projects: SALAD and Trustfarm. It has gained recognition through features in the Partners for Water podcast, The Salty Intruder, and the upcoming Climate Breakdown Podcast series.

During a hackathon co-organized by FOSC Projects (including Katarzyna Negacz, Osama Naser and Cristobal Marin-Rojas), the IVM VR Lab and Rick Hogeboom from UT, the concept evolved into a virtual farming game, merging agricultural, biodiversity, water, and climate insights into a cohesive challenge.

The primary objective of the VARM simulator is to convey cutting-edge research on sustainable agriculture and salinity issues exacerbated by climate change in an engaging and accessible format. It targets stakeholders such as students, farmers, and policymakers. To democratize science, students participated in a two-day hackathon to co-design the game. The winning team—Andres Lot Camarena, Li Pan, and Tim But—developed the simulator under SALAD and IVM team's guidance.

5. Perspective Paper on Waste Utilisation in Food and Feed Production

Seven FOSC projects— AlgaeBrew, BlueCycling, CHIAM, ClimAqua, Olive3P, PHEALING, and TrustFarm—jointly produced a perspective paper in the Sustainable Chemistry One World (ScienceDirect, Elsevier) journal. This document focuses on the barriers to implementing circular bioeconomy practices in food systems and propose recommendations for waste utilisation in food and feed production. The paper will provide policymakers with evidence-based insights for building a more sustainable and circular food economy.

URBANFOSC

Urban Food Resilience under Climate Change Challenges

Partners of the project

The Netherlands – VU Amsterdam (VU)
Kenya – Moi University (MU)
France – French Agricultural Research Centre for International Development (CIRAD)
South Africa – University of the Western Cape (UWC)
Algeria - University of Constantine 3 (UC3)

DURATION
01/06/2021 – 31/05/2024

TOTAL GRANT
€ 759.600

CONTEXT

Achieving food and nutrition security in African cities remains a pressing challenge. Rapid urbanization, climate change, and growing demands from international value chains continue to place stress on already fragile food systems. Climate disruptions—such as droughts, extreme heat, and erratic rainfall—threaten agricultural productivity, while urban expansion intensifies competition for land and water. At the same time, the structure of global supply chains influences what food is available in cities and how equitably it is distributed. Addressing these complex dynamics requires integrated, locally informed strategies that strengthen the resilience of urban food systems.

OBJECTIVES

The UrbanFOSC project aimed to contribute to the development of transformative adaptation strategies that enhance the resilience of urban food systems in Africa. It sought to deepen understanding of how climate change, urban development, and global food trade interact to affect food security in cities. Central to the project was a transdisciplinary approach that engaged local stakeholders—including government officials, civil society actors, and private sector representatives—throughout the research process. By working in three diverse African secondary cities—Worcester in South Africa, Nakuru in Kenya, and Constantine in Algeria—UrbanFOSC was able to explore a wide range of food system dynamics, generating insights that could be transferred to other urban settings across the continent.

KEY RESULTS AND OUTCOMES

UrbanFOSC combined food systems mapping, climate analysis, stakeholder engagement, and modelling to understand urban food vulnerabilities and design context-specific interventions. In Nakuru, research showed that agricultural expansion and charcoal production contributed to deforestation and declining water tables, while fruit tree farming offered a promising pathway for climate adaptation. In Worcester, the project highlighted the vital role of informal traders and early childhood development centres in food access, and identified how municipal policy could better support them. In Constantine, findings revealed that economic hardship restricted food choices, while aging and resource-constrained farmers remained committed to food production, underscoring the need for targeted support.

The project developed Bayesian network models to examine the relationships between dietary choices, food access, and socio-economic conditions. These tools allowed stakeholders to

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 862555

test potential interventions—such as improving local food sourcing or enhancing social safety nets—based on evidence. In Worcester, a systems model of the chicken supply chain informed concrete policy design, contributing to neighborhood-level food plans.

Stakeholder co-design played a central role throughout the project. Workshops helped shape realistic, community-driven solutions. In Worcester, this process led to new policy directions, including land audits for urban agriculture, enhanced support for early childhood nutrition programs, and plans for a fresh produce market. Climate modelling further supported local planning by identifying areas at risk of heatwaves, droughts, and heavy rainfall. These insights were complemented by farmer surveys and institutional consultations, building a shared understanding of risks and response strategi

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- Eichinger, M., & May, J.D. (under review). Systems Dynamic Modelling Chicken Supply South Africa

COORDINATOR CONTACT

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BIO-BELIEF

BIOfortification of common Beanto promote heaLthy dIEt and Food security in a context of climate variation

Partners of the project

South Africa – University of Pretoria (UP)
Kenya – International Center for Tropical Agriculture (CGIAR-CIAT)
Italy – Council for Agricultural Research and Economics (CREA)
Italy – National Research Council-Institute of Agricultural Biology and Biotechnology (CNR-IBBA)
France – Aix-Marseille University (AMU)
Brazil – Brazilian Agricultural Research Corporation (Embrapa)
Italy – Blumen Group SPA

DURATION
01/06/2021 – 31/05/2025

TOTAL GRANT
€ 588.200

CONTEXT

Common bean (Phaseolus vulgaris L.), a staple food in many regions in the world, is, as major source of dietary fibers, essential amino acid-rich proteins, vitamins and with a high content in essential minerals (e.g. iron, zinc, calcium), providing a major contributor to human health. About 60% of world-wide produced common beans are, however, grown in regions subjected to soil water deficit due to environmental drought conditions associated with a changing climate which greatly contributes to yield reduction.

OBJECTIVES

BIO-BELIEF, a trans-continental project with two academic stakeholders in South Africa, aimed to select new biofortified and drought-resilient bean lines, in order to promote a healthy diet in the general frame of food security. To achieve the objective, BIO-BELIEF analyzed a small and diverse common bean population consisting of both experimental and commercial bean accessions: biofortified (high amount of iron), reduced antinutrient content (phytic acid, lectins) and high temperature tolerance. A specific first objective was to characterize in beans changes in growth and seed mineral quality, particularly when plants with a modified seed antinutrient content (e.g. phytate) were grown under drought conditions in the greenhouse or in the field under a rain shelter. A second objective was to exploit biofortified bean lines with a low seed phytic acid content for preparation of bean-based recipes by characterizing their nutritional profile and micronutrient bioavailability/bio-accessibility.

KEY RESULTS

The project will release breeding lines with high nutritional values and develop nutritional improved and drought resilient beans suitable to be grown in Europe, Africa and Latin America (last two are regions where bean is a major staple food). BIO-BELIEF will capitalize previous works carried out by some partners that have selected biofortified lines with reduced level of PA, increased iron content and improved drought resilience. About 20 lines will be tested for seed quality in response to drought treatment in two continents. Meanwhile, the biofortification traits will be introgressed in the drought resilient genetic backgrounds. The innovative technology of Genome Editing will also be applied to explore and modify candidate genes involved in drought resilience and also in determining PA and Fe content. The biofortified lines will be exploited by preparing bean-based recipes, which will be characterized for their nutri-

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tional profile and micronutrient bioavailability. The selected lines will be used for testing by the consumers to validate new biofortified diets for European, African and South American populations.

OUTCOMES

First outcome of the BIO-BELIEF project was the successful morphological and agronomic characterization of a bean population including lines with important nutritional values such as high seed iron and low seed phytic acid content. A low seed phytic acid content, nutritionally desirable, has further little impact on bean growth and seed characteristics under both non-drought and drought conditions. Overall, this allowed not only the establishment of a genetic resource for lowering the seed phytic acid content in beans but also allows now introgression of plants with a low seed phytic acid content and better seed mineral bioavailability into a drought resilient genetic background. A first success in this regard has been the recent successful crossing of the lpa1 line with a commercial Italian cultivar. A second outcome of the BIO-BELIEF project was the preparation of bean-based recipes (Italy, Kenya, France) and characterizing them for their nutritional profile and micronutrient bioavailability. All recipes were an excellent source of protein, dietary fiber, Fe and Zn. Particularly recipes incorporating bean lines BAT 881 (high Fe) and lpa2 (low phytic acid) had high concentrations of Fe, reflecting the intrinsic nutritional profiles of the beans used.

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SOCIAL MEDIA

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BICEPS

Biochar Integration in Small-Holder Cropping Systems – Economy, Food, Product Value Chains, Climate Change Resilience and Soil Fertility

Partners of the project

Sweden – Swedish University of Agricultural Sciences (SLU)
Norway – Norwegian Geotechnical Institute (NGI)
South Africa – University of KwaZulu-Natal (UKZN)
Norway – Norwegian University of Life Sciences (NMBU)
Kenya – University of Nairobi (UONBI)

DURATION
01/04/2021 – 31/05/2024

TOTAL GRANT
€ 1.015.000

CONTEXT

Biochar is charred biomass that is used as a soil amendment for the purpose of carbon sequestration and improved soil fertility. The use and integration of biochar in small holder agriculture is a transformative adaptation of the food production system to achieve climate mitigation, climate resilience and sustainable intensification.

OBJECTIVES

BICEPS aims to quantify the contribution of biochar to climate change resilience, improved food security and profitability and to address knowledge gaps regarding biochar use in crop production in Kenya and South Africa. Further, the project aims to identify potential bottlenecks for the integration of biochar in small holder agriculture contexts in sub–Saharan Africa.

KEY RESULTS AND OUTCOMES

The project has interacted with local farming communities in Kenya and South Africa and tested biochar production and integration in workshops and on farm trials. Field experiments were conducted in contrasting soils consisting of loamy sand soil at Kwale along Kenyan coast, very fine textured soil from volcanic origin in Embu, Mt Kenya area and fine textured soil at Okhahlamba, Kwa-Zulu Natal province in South Africa. All experiments showed a positive effect on yield by using biochar, alone or in combination with fertilizer or manure. Even though the positive yield effect is general for the three sites, the more detailed investigations on the roles of water and nitrogen cycling revealed that the treatment effects are site specific. More pronounced differences in N cycling genes by treatments were observed in the least fertile soil in Kwale with a near-neutral pH, low soil carbon (C) and N content compared to the loamy soils in Embu and Okhahlamba with lower pH and higher soil C and N content. The results from one site showed that addition of manure increased the presence of denitrifying groups, but combining the manure with biochar led to a reduction in these groups, indicating that biochar may reduce denitrification. High resolution data on soil water content and soil temperature was collected using TDR sensors every two hours. In coarse textured loamy sand at Kwale, both manure and biochar applied at 6t/ha increased soil water content with biochar having a stronger effect throughout the growing season. Co-application of both manure and biochar instead reduced soil water content below control treatment level. In fine textured soils both at Embu and at Okhahlamba, biochar instead reduced soil water content while manure increased soil water content during the growing

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period. The reduction in water content by biochar was reversed by co-application of biochar with manure.

Analysis of the nutritional value of maize cultivated with or without biochar did not indicate any effect of biochar, i.e. biochar can increase the yield, but the quality of the produce remains the same.
Farmers that have tried biochar have been engaged in focus group discussions giving qualitative information important for the identification of bottlenecks for the biochar integration. One of the major issues is the availability of on-farm biomass for producing biochar and the scale of production. Biochar integration may require inter-farm collaboration for producing biochar or, alternatively, commercial producers in connection to industrial establishment that generate organic waste streams like sugar cane bagasse, coconut husks or coffee husks. One interesting aspect that has been brought up by several focus groups is the observation that biochar can suppress some plant pathogens. This is a novel observation that we have not been able to document but that merits further studies.
The results from the BICEPS project will be utilized to guide policy development on how biochar can be integrated in small holder farming systems, and how bottlenecks that prevent the integration can be identified and addressed. Two policy briefs, one on the results on biochar on yield, and one on how to produce biochar are currently drafted. The Increased use of biochar can contribute to Agenda 2030 SDG 1 No Poverty, SDG 2 Zero Hunger and SDG 13 Climate Action.

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SECUREFOOD 2050

Improving resilience and food security in 2050 climate through soilless precise agricultural techniques and irrigation with wastewater properly treated by innovative technologies to ensure food safety

Partners of the project

Italy – University of Florence (UniFI)
Algeria – University of Bejaia
Belgium – University of Liège (Uliège)
Egypt – National Research Centre (NRC)
Morocco – Cadi Ayyad University Marrakesh (UCAM)
Italy – University of Turin (UniTO)

DURATION
01/09/2021 – 31/05/2025

TOTAL GRANT
€ 556.000

CONTEXT

Agriculture is facing challenges related to a major population explosion, which will bring the world population to over 9 billion people by 2050. In addition, agriculture is already and will be increasingly affected by climate change, which is likely to reduce natural resources, especially fresh water and fertile soils. Indeed, climate change is already causing a substantial decrease in rainfall in the Mediterranean area, thus decreasing the availability of water for irrigation. This in turn causes a strong reduction in the resilience of food systems, threatening food security and/or exacerbating problems of price volatility of agricultural products in countries affected by water scarcity. It is a fact that the low availability of water for irrigation and fertile soils for cultivation are obstacles to achieving significant resilience of food systems. Together with water, soil is one of the most important key factors in agricultural systems. The availability of fertile soil is in fact essential to produce good quality products and maintain food availability. Unfortunately, climate change is also causing aridification as a result of land degradation, leading to desertification.

OBJECTIVES

SECUREFOOD2050 aims to mitigate the effects of climate change through the use of innovative technologies to (i) increase the availability of water suitable for irrigation, (ii) reduce water consumption and demand, (iii) reduce dependence on fertile land in countries with predominantly sandy soils by promoting soilless farming approaches, such as potting and aeroponics, (iv) increase farmer acceptance of the use of treated wastewater (TWW) and unconventional substrates such as biochar to replace freshwater and peat in soilless farming, and (iv) increasing farmer acceptance of the use of TWW and unconventional substrates such as biochar to replace freshwater and peat in soilless cultivation, and (vi) increasing consumer willingness to purchase agricultural products produced by irrigation with TWW.

KEY RESULTS AND OUTCOMES

Various biochars have been developed from waste plant biomass, also in mixture with biological sludge. These materials have been integrated into pilot-scale constructed wetlands achieving a significant improvement in the removal of nitrogen and emerging organic micropollutants. The wastewater treated with these systems has been used for the irrigation of soilless crops, including (i) pot cultivations using agricul-

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tural biochar as a substrate instead of peat and (ii) aeroponic cultivations. Biochar has shown significant potential as a soil amendment in soilless pot cultivation of tomatoes, strawberries, and rocket. In particular, the incorporation of appropriate amounts of biochar (10-20%), has proven to be an effective strategy to achieve high yields and product quality, comparable or even superior to those obtained with commercial peat-based substrates. Furthermore, biochar-enriched substrates irrigated with TWW have shown promising results, further improving both productivity and crop quality of tomatoes and strawberries. Aeroponics has proven to be a highly efficient system for the intensive production of green leafy vegetables, especially rocket. It is remarkable that the use of TWWs in aeroponic cultivation had no negative impact on yield, leaf quality or safety parameters (nitrates), while achieving significant freshwater savings, of at least 50%. These tests, also conducted in a controlled atmosphere simulating the CO2 concentration and temperature expected in future IPCC scenarios for 2050, showed higher rates of plant growth and productivity than in the current situation.

The risk analysis related to the possible transfer of emerging pollutants from TWW to food crops pointed out a negligible risk related to pharmaceutical compounds, while for perfluorinated compounds the very low acceptable intakes proposed by the Commission Recommendation (EU) 2022/1431 may represent in some specific cases a critical aspect worth to be further investigated. Interesting were also the results of the acceptance studies of the non-conventional agronomic strategies used in SECUREFOOD2050, which highlighted the importance of ensuring food safety together with a competitive price of substrates and final products.

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- Bini, L. et al. Agriculture, 15 (2025) 302. https://www.mdpi.com/2077-0472/15/3/302
- El Barkaoui, S. et al. Chemosphere, 372 (2025) 144067. https://www.sciencedirect.com/science/article/abs/pii/S0045653525000074?via%3Dihub
- El Barkaoui, S. et al. Biomass Conversion and Biorefinery, 2025, in press. https://link.springer.com/article/10.1007/s13399-024-06442-z

COORDINATOR CONTACT

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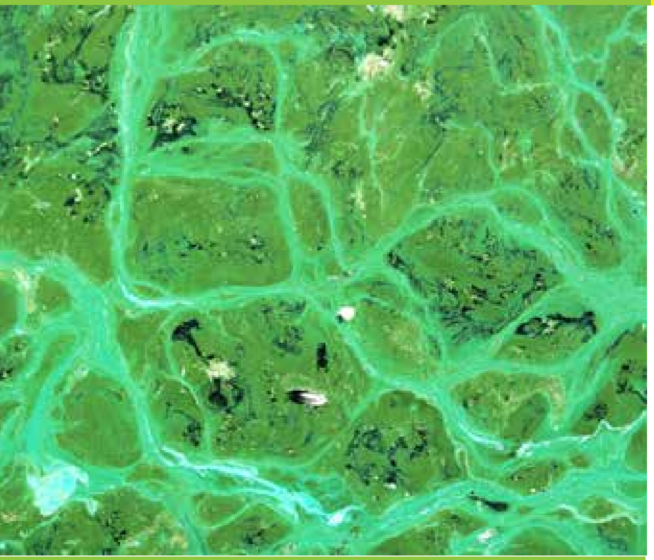
WEBSITE

https://securefood2050.eu/



CLIMAQUA

Establishing an innovative and trans-national feed production appoarch for reduced climate impact of the aqua-culture and future food supply

Partners of the project

Germany – Institute for Food and Environmental Research (ILU)

Germany – German Institute for Food Technologies (DIL)

Norway – Nofima

Norway – Norwegian University of Science and Technology (NTNU)

South Africa – Agricultural Research Council (ARC)

Kenya – Kenya Agricultural and Livestock Research Organization (KALRO)

South Africa – Institute for Environmental Biotechnology, Rhodes University (EBRU)

DURATION
01/06/2021 – 31/03/2025

TOTAL GRANT
€ 818.969

CONTEXT

About 87% of greenhouse gas emissions come from feed production. CLIMAQUA is working to develop a more sustainable food system based on aquaculture, which reduces its climate footprint. By combining technological and non-technological solutions, CLIMAQUA aims to create a more efficient and environmentally friendly feed production process that takes into account local environmental conditions. This approach has the potential to significantly decrease greenhouse gas emissions from aquaculture-based food systems.

OBJECTIVES

The experimental trials of CLIMAQUA involved the upscaled cultivation of microalgae, progressing from 50 L bioreactors to a 200 L prototype. These trials were designed not only to produce sufficient microalgae biomass for fish feed trials but also to gather critical data on energy and resource consumption. This information was used for a detailed Life Cycle Assessment (LCA) and to estimate production costs. The LCA encompassed the entire production chain and cycle (fish side-streams → microalgae → fish), following established practices and the guidelines of ISO standards 14040-14044.

KEY RESULTS AND OUTCOMES

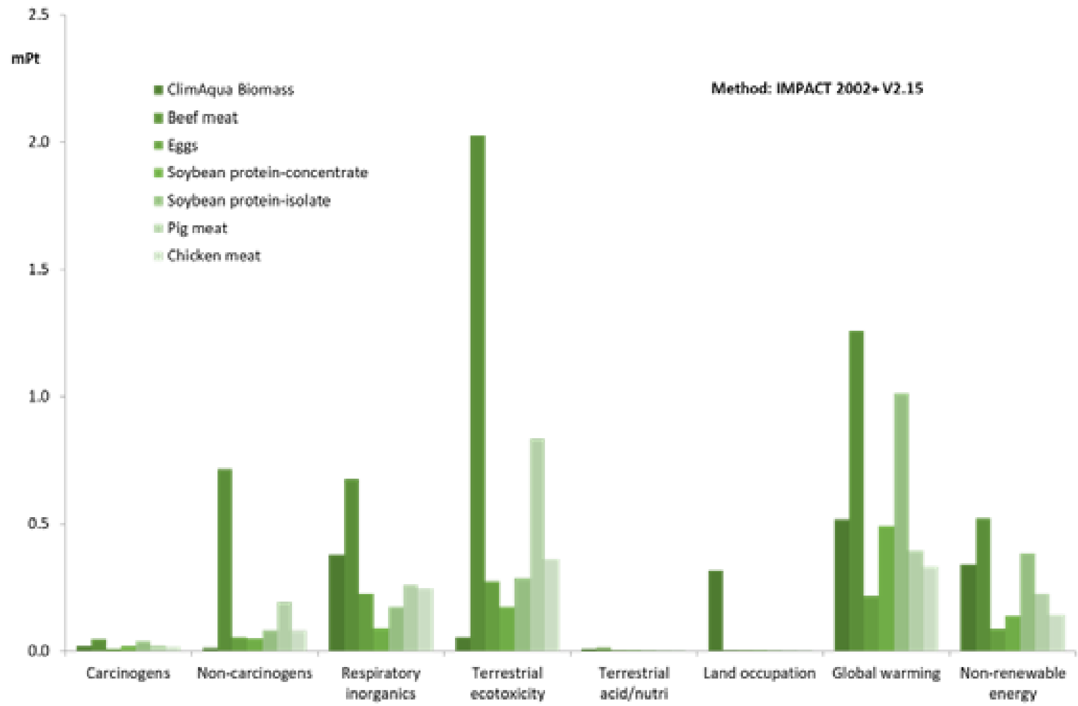
Preliminary LCA results highlighted that Galdieria sulphuraria microalga production exhibits comparatively high environmental impacts in certain categories when measured against plant-based protein sources. For instance, specific impact categories, such as global warming potential and non-renewable energy use, showed unfavorable results (Figure). However, microalgae were advantageous in categories like carcinogenic and non-carcinogenic toxicity, as well as terrestrial ecotoxicity. This indicates potential niche applications where microalgae-derived proteins could deliver environmental benefits.

It was also observed that fishmeal – a side-stream from naturally caught fish stocks – presents an environmental impact similar to that of plant-based protein concentrates. However, when microalgae produced at a small scale are incorporated into fish feed, the overall environmental footprint tends to rise. For example, Norwegian partner Nofima's fish trials demonstrated that substituting 5% of conventional protein feed with microalgae did not significantly affect the growth or performance of juvenile fish. Despite this, such inclusion led to a 5-21% increase in the environmental impact of fish production, depending on the specific impact category.

The largest environmental differences were noted in impact categories associated with global warming, non-renewable

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 862555

energy use, land occupation, and emissions of respiratory inorganics. These challenges were primarily linked to the resource-intensive aspects of heterotrophic microalgae production, particularly the use of glycerol as a carbon source feedstock and the energy inefficiencies of the upscaled bioreactor prototype. Significant heat losses due to inefficient construction further exacerbated these impacts, underscoring the need for technological improvements to enhance sustainability in future applications.



Environmental impact of heterotrophically produced CLIMAQUA biomass (Galdieria sulphuraria) in comparison to conventional protein sources (comparison basis 1 kg, normalized midpoint impact categories according to IMPACT2002+ method).

PUBLICATIONS

- Halim R, Iyer A, Esteves S, Milliken S, Kalai K, Pleissner D, Stephan L, Chentir I, Ahmed O, Nasri W, Mohamed S, Birkeland NK, Vanderschuren H, Zainuddin I, Mburu M. 2025. Is 'waste' an appropriate concept in a sustainable bioeconomy? Sustainable Chemistry One World, 5, 100044, https://doi.org/10.1016/j.scowo.2025.100044
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COORDINATOR CONTACT

Prof. Dr. Daniel Pleissner
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CRRIsP

Climate Resilient and Responsible Innovations in Potato

Partners of the project

Germany – TH Bingen (THB)
Ireland – Teagasc
The Netherlands – Wageningen University and Research (WUR)
Kenya – Kenya Agricultural and Livestock Research Organization (KALRO)
South Africa – North-West University (NWU)

DURATION
01/06/2021 – 30/03/2025

TOTAL GRANT
€ 887.600

CONTEXT

The events of climate change e g increasing temperatures, erratic rainfall, will lead to new or more severe abiotic and biotic stresses challenges in potato production systems globally, which are likely to affect the crops entire value chain The consequences are lower or even total loss of potato crop yield and the effects will differ in different agro-ecologies An understanding of the effect climate change will have on potato value chains will allow mitigation steps be undertaken from the perspectives of breeding, agronomy and socioeconomic adaptations.

OBJECTIVES

The research consortia aimed to add value on the state-of-the-art knowledge in potato-based production and value chain systems by:
i) analysing trade-offs and synergies of developed innovations and their applicability to different farming, market and food systems,
ii) deploying innovative tools and solutions in variety development, seed systems, agronomy, post-harvest loss reduction alongside mutual capacity building,
iii) engage in knowledge exchange and dissemination on production, storage, market and value chain related topics and
iv) develop and disseminate training and communication material for different audiences from lab to fork.

KEY RESULTS AND OUTCOMES

Events of climate change are impacting potato value chain from farm to fork –locally and globally. The project documented that an earlier start of the growing season in Europe and huge variability in the onset of rainy seasons in Africa is already happening. Increased risk of dry spells and extreme rainfall events during the growing season were observed. The increasing temperatures are affecting tuber set and tuber bulking behaviour. The earlier harvest in Europe will affect imports of early potatoes from North Africa and prolong storge periods for the main crop. At the same time preferences of consumers and processors do change more towards processed potatoes in both Africa and Europe. To address this the CRRIsP project set up a breeding population in Kenya combining disease and climate resistant cultivars and European cultivars with high processing qualities. It is expected that new resilient and market demanded varieties are available in 5-10 years for African potato producers.
Within the project lifespan an increasing climate change-related pest and disease pressure or shift towards other pests and

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diseases could be observed in south-west Germany. A serious outbreak of combined leafhopper transmitted infections with candidatus arsenophonus and phytoplasmas of the Stolbur group. Leading to yield losses of up to 75% and significantly reducing tuber qualities. Nine out of 104 tested potato varieties were identified which produced commercially viable yields and tuber qualities. Agronomic measures such as mulch cover and biostimmulants increased the crops resilience to diseases.
In trials in South Africa and Germany the reaction to abiotic stress such as drought and heat differed largely between varieties (genotypes): The best performing varieties under drought stress showed yield reductions of 10-35%, while others had yield reduction of up 40-70%, hence defining their specific requirements for supplementary irrigation.
Adapted agronomic practices such as mulching do offer reductions in stresses only under hot and dry weather conditions. On average, the use of mulch to a reduction of soil temperatures of about 1.6 °C and increased soil moisture levels by about 10% , which favoured root development and tuber formation. With improved Irrigation management using soil sensors the project time was able to reduce the amounts of irrigation water by 5-20% without affecting the yields.

KEY PUBLICATIONS

- Phungula, N. P. M., Hadebe, S. T., Schulte-Geldermann, E., Sithole, L., & Ngobese, N. Z. (2024). "Low-Hanging Fruit" Practices for Improving Water Productivity of Rainfed Potatoes Using Integration of Cultivar Selection, Mulch Application, and Different Agroecological Zones in Sub-Tropical, Semi-Arid Regions. Water, 16(23), 3422. https://www.mdpi.com/2073-4441/16/23/3422
- Kisinga,B., Klauk,B., Schulte-Geldermann, E. (2024): Variety screening for tolerance against Candidatus Phytoplasma solani and Candidatus arsenophonus phytopathogenicus. 22nd EAPR Triennial conference, Oslo, Norway, Book of abstracts. P. 307. https://nibio.pameldingssystem.no/auto/1/EAPR2024/EAPR2024-bookofabstracts-v02.pdf
- Nuijten, E. and Almekinders, C.J.M. -in preparation. Perspectives of Dutch organic farmers on climate change in relation to potato farming, the market, and research and innovation.

COORDINATOR CONTACT

Prof. Elmar Schulte-Geldermann
TH Bingen (THB) – Germany

NutriGreen

Promoting Green Nutrition for the Sahel region

Partners of the project

Sweden – Swedish University of Agricultural Sciences (SLU)

Germany – Centre for Rural Development/Humboldt-Universität Berlin (SLE)

Burkina Faso – National Center for Scientific and Technological Research (CNRST)

Senegal – Cheikh Anta Diop University (UCAD)

CONTEXT

Senegal and Burkina Faso are already exposed to an increase in extreme weather events such as droughts and floods, due to climate change. As a result, the yields of staple foods are set to decline significantly during the 21st century, adding more pressure on the already highly strained local food systems. An overlooked and underutilized group of plants that could fill this shortfall are indigenous vegetables and tree crops. They are well-adapted to the local climate, less affected by pests and diseases and therefore require fewer inputs. Moreover, many of them are highly nutritious and often part of the resident food culture.

OBJECTIVES

NutriGreen will research these traditional plants to understand how their production and consumption can be amplified through sustainable nutri-sensitive food value chains (VCs) to foster a climate-resilient local agri-food system, especially filling the food supply gap during the seasonal hunger period.

KEY RESULTS AND OUTCOMES

The NUTRiGREEN project was set to promote sustainable production, marketing and consumption of traditional plants through sustainable value chains to foster climate resilient local agrifood system. The NUTRIGREEN project researchers used livi ng lab (LL) to integrate farmers (especially women) with value chain stakeholders, local authorities and scientists, to apply climate resilient farm practices and connect farmers to the market. Moringa, Baobab, Hybiscus and Ocra were the nutritious traditional plants in farms in Zitenga Region in Burkina Faso and Thies in Senegal. The NUTRiGREEN produced both scientific and action research results. Through the NUTRiGREEN project four surveys, two in each country were undertaken, and analysis resulted in scientific articles, trained master students and two PHD theses (one completed in 2024 and one expected in 2025. Project researchers mplemented climate field schools in seven villages in Burkina Faso nd Senegal. In the climate field schools, knowledge about agro-ecological practices was imparted. In addition, the co-research approach was further developed, in which farmers, students and NGOs worked together to develop sustainable solutions. The LLs trained farmers and developed linkages between farmers-processors-traders. Outcomes of the LLs were signed contracts between producers-processors. Also a number of producers' cooperatives were formed as a follow-up of the LLs in Burkina Faso. The project invested in equipment that improved production and quality of products.

DURATION	TOTAL GRANT
01/06/2021 – 31/05/2025	€ 790.600

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 862555

KEY PUBLICATIONS

- Raising adaptive capacities through agrometeorological learning – lessons from Burkina Faso and Senegal, Sprenger Arvid, Silke Stöber, Eric Kabre Touinrimba, Fatimata Diop Tropentag 2024, Conference on International Research on Food Security, Natural Resource Management and Rural Development ,University of Natural Resources and Life, Sciences, Vienna, Austria, (BOKU University), September 11-13, 2024
- Innovative solutions for food security: Examining the nutritive gardens systems in Burkina Faso, Judith Henze, Robert Doulkom &Silke Stöber Tropentag 2024, Conference on International Research on Food Security, Natural Resource Management and Rural Development ,University of Natural Resources and Life, Sciences, Vienna, Austria, (BOKU University), September 11-13, 2024
- Effect of non-timber forest products (NTFPs) on multidimensional household poverty in Burkina Faso: A conditional mixed process approach. Magloire THIOMBIANO (UTS, Burkina Faso) African Journal of Agricultural and Resource Economics (Forthcoming)
- Effect of Non-Timber Forest Product (NTFP) on Food Security in Burkina Faso, Magloire THIOMBIANO (UTS, Burkina Faso), International Journal of Social Economics (Forthcoming)
- Determinants of demand for baobab, moringa and hibiscus in Burkina Faso: a multivariate probit model analysis. Magloire THIOMBIANO, Economie rurale (Forthcoming)

COORDINATOR CONTACT

Prof. Konstantinos Karantininis
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WEBSITE

https://en.nutri-green.net/

C4C

CropsForChange; Tackling the global warming effects in crops

Partners of the project

Italy – CREA Research Centre for Genomics and Bioinformatics

Italy – University of Milan (UniMi)

South Africa – Stellenbosch University (SU)

Turkey – Bati Akdeniz Agricultural Research Institute

Algeria – University Kasdi Merbah Ouargla (UKMO)

Morocco – Mohammed I University (UMP)

DURATION
01/07/2021 – 31/03/2025

TOTAL GRANT
€ 486.600

CONTEXT

Global warming has a direct impact on agriculture as drought, low water availability and supra-optimal temperatures negatively affect the plant reproductive processes thus limiting both crop yields and quality of fruit/grain production.

OBJECTIVES

Genetic enhancement to improve the response to heat, drought stress and water shortage in eggplant, rice and wheat, which are important species for human food supply. Identification of accessions tolerant to water and heat stress. Development of markers to aid the selection of tolerant plants. Identification of genomic region and candidate genes associated to water and heat stress. Evaluate the agronomic performances of selected accessions under field conditions for water and heat stress.

KEY RESULTS AND OUTCOMES

The main results gathered by the C4C partners are summarized below. Stellenbosch University (SU) in South Africa, in collaboration with University of Milan (UNIMI) and CREA-GB Research Center for Genomics and Bioinformatics (CREA) in Italy, set up a method using Enzyme Linked Immunosorbent Assay to study barley, rice and eggplant cell wall modifications caused by drought which may allow to identify biomarkers associated to water shortage.

UNIMI discovered genes involved in rice and barley seeds to the response to heat and drought stresses and, with the support from University of Kasdi Merbah Ouargla (UKMO) in Algeria, also identified similar genes in wheat. UNIMI obtained gene edited CAS9-free rice mutants for the gene Late Embryogenesis Abundant protein involved in response to drought, heat and water stresses. Functional studies and response to drought stress of such mutant were performed along while SU carried out a detailed cell wall profiling of the leaves. UKMO characterized for salt and drought stresses four local varieties of durum wheat adapted to the Saharian environment, UNIMI collaborated with UKMO to perform a genetic and developmental analysis of selected lines.

In eggplant, CREA highlighted, among the accessions of a large germplasm collection, a differential response to water-deprivement stress and RNAseq analyses is ongoing on selected contrasting accessions. Gene-edited eggplants for genes (e.g. MyB60, LBD40, Ald1, SDG33) involved in drought tolerance were also obtained and are under characterization.

Bati Akdeniz Agricultural Research Institute (BATEM) in Türkiye

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carried out a field experiment to evaluate the response to water shortage of Italian and Turkish eggplants. Moreover, BATEM developed water and heat stress tolerant eggplant inbred lines from an interspecific hybrid between eggplant and Solanum insanum. BATEM also tested 23 eggplant genotypes under drought stress and conducted molecular studies using IRAP and REMAP markers. Two field experiments conducted by UMP in Morocco allowed to collect information about several phenotypic and physiological parameters and identify the more tolerant eggplant genotypes to water shortage. UNIMI collaborated with UMP to obtain metabolome profiles in different tissues of selected contrasting eggplant genotypes exposed to drought to uncover metabolic switches in contrasting genotypes.

These genetic, molecular, cell wall and metabolomic profiling, and agroecological studies conducted in eggplant and rice, are being evaluated to identify a common mechanism of actions in monocot and dicot systems. This research will be a promising tool for the next steps in identifying new actors to improve plant resilience in these crops. Furthermore, the genetic tools and accessions identified in C4C project are potential exploitable methods and materials to improve crop resilience and productivity, especially on the Mediterranean area. Several scientific publications have been submitted or are in preparation. Moreover, multiple visits, seminars, academic exchanges of students were done between the partners involved in this period that supported the scientific and formative goals proposed.

KEY PUBLICATIONS

Publication presenting the C4C activities project in two national and an international Magazine:
(i) Afrique Agriculture (Page 56 October-November 2021);
(ii) Conjuncture (Pages 52-53, No 1084, June 2022);
(iii) L’Economiste (30 December 2021 and 15 August 2022)

Cebeci, E., Boyacı, H. F., Doğan, Y., Toppıno, L., & Rotıno, G. L. (2023). Determination of Heat and Drought Tolerant Lines in Segregating Populations Produced by Interspecific Crosses in Eggplant. Ekin Journal of Crop Breeding and Genetics, 9(2), 81-90. https://dergipark.org.tr/en/pub/ekinjournal/issue/79251/1335684

COORDINATOR CONTACT

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CREA Research Centre for Genomics and Bioinformatics – Italy

WEBSITE

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CHIAM

Integrated chia and Oyster mushroom system for Sustainable food value chain in Africa

Partners of the project

Kenya – Dedan Kimathi University of Technology (DeKUT)

Hungary – Pilze-Nagy Ltd. (PILZE)

Hungary – Bay Zoltan Nonprofit Ltd. for Applied Research (BZN)

Germany – University of Hohenheim (UH)

Egypt – Agricultural Research Center (ARC)

Morocco – University of Sultan Moulay Slimane (USMS)

Kenya – Keyrio Farm

Algeria – Scientific and Technical Research Center on Arid Regions (CRSTRA)

CONTEXT

Enhancing food and nutrition security in Africa is essential to improved livelihoods and life opportunities for resource-poor individuals and households. The efficiency of the primary production of African farms has to be improved and additionally, it is urgent to put more emphasize on the sustainability of farming systems. This means a significant challenge for the local agricultural communities

OBJECTIVES

CHIAM aims to create a complex agro system, which will result in novel functional foods and use their by-products to feed animals and create energy in a biogas plant.

KEY RESULTS AND OUTCOMES

- The project has succeeded in setting up a demonstration mushroom production system at Dedan Kimathi University (DeKUT).
- A container based substrate production was installed at PILZE's Kecskemet site and comparative trials of the technology were started.
- BZN started the life-cycle analysis of the substrate production techniques and developed the business plan for the model. In addition, the environmental life cycle analysis (LCA) of the technology was carried out.
- ARC has successfully registered the first chia variety in Egypt "Misr 1" via Field crops Research Institute, Agricultural Research Center.
- Evaluation of the irradiated and un-irradiated chia under six agro-ecological conditions for three consequent seasons and selection of elite high productivity new chia genotypes (black and white), which will be registered in the future.
- Registered Alternaria tenuissima strain AUMC 15742, which infests chia plants and causes leaf spot and blight disease, was registered at the National Center for Biotechnology Information by the accession No. of ON678182.1)
- Production of fortified products with chia and oyster mushrooms as functional ingredients

DURATION	TOTAL GRANT
01/06/2021 – 31/05/2025	€ 610.400

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 862555

KEY PUBLICATIONS

- Alice Ndunge Charles; Monica Mburu; Daniel Njoroge; Viktoria Zettel (2024). Chemical composition and consumer acceptability of oyster mushroom and sorghum-pearl millet based composite flours Discover Food Research. Springer
- Chemutai, S.; Mburu, M.; Njoroge, D.; Zettel, V. Effects of Ugali Maize Flour Fortification with Chia Seeds (Salvia hispanica L.) on Its Physico-Chemical Properties and Consumer Acceptability. Foods 2024, 13, 543.
- Gyalai-Korpos, Miklós, Monica Mburu, Peter Mwirigi, and Adrienn dr. Somosné Nagy. 2023. “Challenges of Establishing the Circular Oyster Mushroom Production Model in Kenya”. Review on Agriculture and Rural Development 12 (3-4):83-88. https://doi.org/10.14232/rard.2023.3-4.83-88

COORDINATOR CONTACT

Dr. Monica Mburu
Dedan Kimathi University of Technology (DeKUT) – Kenya

Sus-Agri-CC

Innovative biofertilizers boosting yield of crop: Toward Sustainability of Agricultural systems against the Climate Change in arid and semi-arid zones

Partners of the project

Morocco – Cadi Ayyad University Marrakesh (UCAM)
Morocco – Ibn Zohr University (UIZ)
Germany – Leibniz Institute of Plant Genetics and Crop Plant Research (IPK)
France – National Research Institute for Sustainable Development (IRD)
Turkey – Ankara University
Algeria – University of Mascara (UM)
Japan – Niigata University (NU)
Tunisia – University of Tunis El Manar (UTM)
Mexico – University of Sonora (UNISON)

DURATION
01/06/2021 – 30/06/2024

TOTAL GRANT
€ 487.600

CONTEXT

According to FAO estimates, the global population is expected to rise by 34% by 2050, which will necessitate a 43% increase in staple crop productivity. Currently, global crop yields are insufficient, with agricultural losses estimated at 20-40% due to abiotic and biotic stresses. In the context of climate change and declining arable land, plant and soil sciences play a crucial role in developing sustainable solutions for agriculture and biomass production. To address these challenges, it is essential to bridge fundamental knowledge with innovative agricultural practices to enhance both crop productivity and sustainability.

OBJECTIVES

Sus-Agri-CC aims at improving the growth and development of cultures with high interest by the adoption of innovative practices to improve soil fertility, preserving water resources, respecting the environment, and ensuring the development of sustainable agriculture. Our main goals are: (i) exploit sustainable biological practices integrating biological and organic biofertilizers (compost and microorganisms) that boost plant yield, quality or even novel functionality, and tolerance to abiotic stresses to improve agricultural production, (ii) understand the molecular traits of economically important crops under a variety of environmental conditions.

ACTIVITIES AND RESULTS

Our research activities encompass comprehensive greenhouse trials to evaluate the impact of biofertilizers, compost, and beneficial microorganisms on the growth, yield, and stress resilience of vegetable and cereal crops. These findings are further validated through two consecutive field growing seasons, ensuring their effectiveness under real agricultural conditions. Additionally, advanced omics-based molecular analyses, conducted in collaboration with our partners, provide deeper insights about pathways and mechanisms involved underlying crop responses to biofertilization and environmental stress.

To complement these experimental approaches, modeling techniques are applied to analyze and predict crop performance under various environmental scenarios, optimizing resource use and improving decision-making for sustainable agricultural management.

The expected outcomes include enhanced plant productivity, improved soil fertility, and greater crop resilience to abiotic stresses, paving the way for more sustainable and climate-adaptive agricultural practices. By integrating inno-

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vative biological solutions with molecular research and predictive modeling, this approach contributes to strengthening global food security and sustainable farming systems, particularly in the face of changing climatic conditions.

KEY PUBLICATIONS

- Ouhaddou et al. 2024; doi: 10.3389/fmicb.2024.1432637
- Ikan et al 2024; doi: 10.3390/agronomy14061316
- Ouhaddou et al. 2023; doi: 10.1007/s10343-022-00827-8
- Ikan et al. 2023; doi: 10.1080/11263504.2023.2229856

COORDINATOR CONTACT

Prof. Abdelilah Meddich
Cadi Ayyad University Marrakesh (UCAM) – Morocco

ThermoK

Thermophilic breakdown of keratin-laden biomass waste

Partners of the project

Norway – University of Bergen (UiB)
United Kingdom – University of Exeter (UoE)
France – French Alternative Energies and Atomic energy Commission (CEA)
South Africa – University of the Free State (UFS)
Kenya – University of Naïrobi (UoN)
Norway – Norwegian Research Centre (NORCE)

CONTEXT

Keratin is a robust, fibrous structural protein and the third most abundant natural polymer after cellulose and chitin. It forms key components of feathers, hair, hooves, horns, nails, and claws. Due to its highly cross-linked chemical structure, keratin is resistant to biological, physical, and chemical degradation. This presents a major challenge for industries dealing with keratin-rich waste, such as the poultry sector, where feathers, comprising over 90% keratin, are generated in large quantities. Most feather waste is either discarded, incinerated, or inefficiently processed into low-value products like animal feed or fertilizer. Similar challenges exist for other keratin-based biomass waste, necessitating innovative solutions for sustainable waste management.

OBJECTIVES

This project investigates the application of anaerobic, thermophilic bacteria optimized for feather keratin degradation. It aims to identify key enzymes responsible for breaking down keratin and assess enzyme cocktails for cell-free degradation. The ultimate goal is to develop efficient, scalable biotechnological solutions for processing keratin waste.

KEY RESULTS AND OUTCOMES

A diverse set of thermophilic bacteria from the Fervidobacterium genus was screened for feather-degrading abilities. Seven highly active species were identified, with whole-genome sequencing and comparative genomics revealing potential keratin-degrading genes. In three strains, transcriptomic analyses under feather- and glucose-based growth conditions have identified genes that are upregulated during keratinolysis. Proteomics further confirmed that specific proteins are secreted in response to keratin degradation. In total, approximately 20 protease- and peptidase-encoding genes were found to be significantly upregulated under keratinolytic conditions, indicating their key roles in feather breakdown.
To further characterize these enzymes, seven keratinases from Fervidobacterium pennivorans were cloned and successfully expressed as soluble proteins in Escherichia coli. Six of these were purified, crystallized, and structurally analyzed, representing different protease families (S8, M3, M32, M42, and M55). Structural comparisons with other proteases are ongoing to understand their unique adaptations for keratin degradation. Purified enzymes have confirmed keratinolytic activity, and their complementary functions are being studied to determine their synergistic roles in feather degradation.

DURATION	TOTAL GRANT
01/06/2021 – 30/06/2024	€ 991.251

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Additionally, other thermophilic enzymes, including pyroglutamyl carboxyl peptidase (Pcp), a newly identified S8 protease, and a disulfide reductase, were cloned and overexpressed. These enzymes, when combined in cocktails, demonstrated significant feather degradation potential. The breakdown products are being analyzed using mass spectrometry to identify bioactive peptides with potential applications in the cosmetic and nutraceutical industries. The Pcp enzyme structure has been resolved with an inhibitor bound, and additional enzyme structures have been modelled using AlphaFold.

Proteases from a metagenomic DNA library were also investigated, leading to the identification and expression of a C40 protease and a DoP protease. This DoP protease exhibited feather-degrading activity, further expanding the potential for diverse enzymatic solutions. The use of feathers as feedstock and the production of keratinase through fermentation are being optimized through process scale up. Larger fermentation volumes will also allow the production of feather hydrolysates for bio-fertilizer and other higher-value products.

ThermoK has significantly advanced our understanding of microbial keratin degradation and provided insights into optimizing these microorganisms and their enzymes for industrial applications. The discovery of robust, thermophilic enzymes presents opportunities for cost-effective, scalable, and controlled enzymatic feather degradation. These findings contribute to the development of sustainable food systems and align with circular economy principles by transforming keratin waste into valuable commercial products, such as proteins, peptides, amino acids, animal feed, and fertilizers.

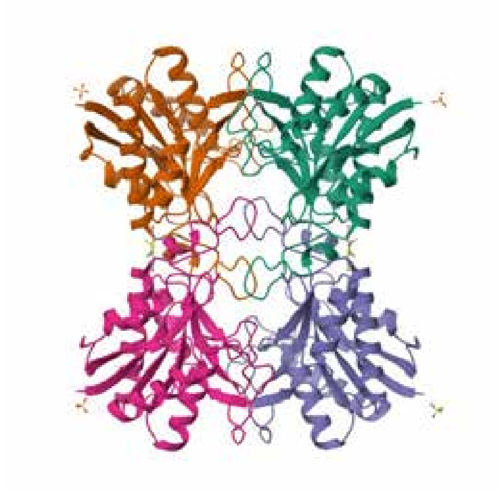

Figure: Quaternary structure of a hyperstable Pyrrolidone Carboxyl Peptidase (Pcp) responsible for the hydrolysis of N-terminal pyroglutamate residues from peptides and proteins (PDB: 1A2Z).

KEY PUBLICATIONS

- Javier-López, R et al. (2024): Comparative genomics of Fervidobacterium: a new phylogenomic landscape of these wide-spread thermophilic anaerobes. BMC Genomics, 25 (1), 1248. DOI: 10.1186/s12864-024-11128-x
- Halim, R et al. (2025): Is ‘waste’ an appropriate concept in a sustainable bioeconomy? Sustainable Chemistry One World. 5, 100044. https://doi.org/10.1016/j.scowo.2025.100044
- Javier-López, R et al. (2025): Transcriptomic and proteomic insights into feather keratin degradation by Fervidobacterium. Frontiers in Microbiology. Accepted for publication.
- Singleton et al. (1999): X-ray structure of pyrrolidone carboxyl peptidase from the hyperthermophilic archaeon Thermococcus litoralis. Structure, 7:237–244

COORDINATOR CONTACT

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BLUE-CYCLING

Integrated aquaculture and agriculture for resource-efficient food production

Partners of the project

Sweden – University of Gothenburg (UGOT)
The Netherlands – Wageningen University and Research (WUR)
Germany – Leibniz-Institute of Vegetable and Ornamental Crops (IGZ)
South Africa – Stellenbosch University (SU)
Norway – SINTEF Nord
United Kingdom – University of Greenwich (GU)
Kenya – Maseno University (MU)

DURATION
01/06/2021 – 31/03/2025

TOTAL GRANT
€ 1.869.300

CONTEXT

One of the greatest challenges imposed by climate change is the ability to provide sustainable management of land and water resources to secure food for a growing population. Integrated aquaculture-agriculture (e.g. aquaponics) is an exemplary resource-efficient technology that allows for nutrient, water and energy recycling within the concept of safe and sustainable food production. Due to its controlled environment, aquaponics is able to deliver fresh food with minimal resource inputs despite external climatic conditions (e.g. cold/dark winters or drought in arid regions).

OBJECTIVES

BLUE-CYCLING aims to advance current aquaponics designs with the goal of developing this technology from farm to fork through innovation in existing integrated fish production techniques and state-of-the-art greenhouse designs in conjunction with permaculture and agroforestry approaches. Such technology, based on optimal use of water, waste and energy, will aid in achieving sustainable development goals for human health and nutrition, resilient food value chains, and regional/local food production.

KEY RESULTS AND OUTCOMES

Germany - Leibniz-Institut für Gemüse und Zierpflanzenbau (IGZ) investigated resource use efficiency (RUE) in aquaponics. Aquaponics produced vegetables are more strongly influenced by crop-specific physiological traits than by the nutrient solution source. RUE of aquaponics is highly geographic site-specific, demanding detailed model-based analysis of aquaponics systems planning. Volatile fatty acids (VFAs) as by-products in aquaponics can be used as plant growth promotors. The dosage must be carefully chosen to avoid damage to the rhizosphere. A combination of physical sensors with stomatal conductance-based evapotranspiration models can be applied to optimise re-circulation, strongly increasing the environmental foot-print of decoupled aquaponics.
Kenya - Maseno University ascertained the effectiveness of Nutrient Film Technique (NFT) aquaponic systems in enhancing productivity, nutrient utilization, resulting in a 42.9% water-use efficiency with Nile tilapia and African catfish with leafy green vegetables. The NFT system significantly outperformed traditional pond systems in fish growth and feed efficiency. Comparing crop yields across different systems, lettuce consistently outperforming all other crops.
Netherlands – Wageningen University - In the study on 'Design-

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 862555

ing Aquaponics for High Latitudes' optimal aquaponic designs co-digesting fish sludge with chicken manure enables a RAS of 100 m³ to sustain a hydroponic greenhouse of >11.000 m² maintaining a closed-loop nitrogen and phosphorus cycle with zero water discharge. The study on 'Operating Aquaponics in Tropical and Seasonal Climates' (Cairo, Egypt) found that as climate variability increases with distance from the equator, an external mineralizable organic waste source is required to compensate for fluctuations in crop nutrient demand with zero water discharge. Regarding the impact of VFAs in liquid organic fertilizers on two hydroponically grown lettuce cultivars using an NFT system, applying effluents from methane-producing digesters at night or after a short storage period can help secure non-harmful VFA levels in hydroponic greenhouse production.

Norway – SINTEF's investigation on concentrated RAS water replacing mineral fertilizer in conventional hydroponic leaf vegetable cultivation in a vertical farm found that the concentrate remains stable with regards to microbial activity, EC, pH, and composition of plant-available macro- and micronutrients during storage for 180 days. Thus concentrating and storing wastewater from RAS enables flexible use as fertilizer in highly seasonal food production areas reducing the dependency on mineral fertilizers.

Sweden – University of Gothenburg - A pilot aquaponics farm was designed with in-line fish solids remineralization and biogas production. Major costs (labour, electricity) vary significantly across high-income countries; design choices must minimize CAPEX, whereas OPEX costs scale linearly. Revenue comes mostly from biogas, profitable only at ~3000 T fish production annually, and tipping fees if other waste streams are integrated. Nutrient-rich effluent was not profitable and only useful internally.

A literature review on coupled/decoupled systems informed a model on optimal ratios within aquaponic systems—the first-ever sensitivity analysis.

South Africa – University of Stellenbosch - Inconsistent energy supply and costs constrain the uptake / expansion of Aquaponics. Green energy options do not support project scalability/roll-out. The supply of training ioutstrips the demand. Most training is not accredited providing unrealistic performance forecasts, with many underperforming and failing operations. Vegetables and fruits were preferred to freshwater fish in the market. Aquaponics cannot yet compete with conventional mass-produced vegetables, fruit and herbs. Although aquaponics can be deemed "organic" premier prices associated with organic produce do not occur. The pocket guide received supportive comments from training participants and Aquaponics farmers.

United Kingdom – University of Greenwich trials on alternative fish feed for tilapia:

Feed trials demonstrated that fishmeal can be replaced with black soldier fly meal at 50% and with spirulina powder at 45% without significantly impacting yield in a polyculture of tilapia, chili and basil in coupled aquaponics.

Comparative life cycle assessment showed that the black soldier fly meal performed better than spirulina at the feed production stage, while spirulina performed better at the use stage.

A screening life cycle assessment showed the potential benefits of on-farm feed production using spirulina cultivated in aquaculture wastewater and black soldier fly larvae fed with local food waste.

COORDINATOR CONTACT

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CREATE

Cross-Border Climate Vulnerabilities and Remote Impacts of Food Systems of the EU, Turkey and Africa: Trade, Climate Risk and Adaptation

Partners of the project

Turkey – Ankara University Water Management Inst. (ENSTITUSU)
The Netherlands – FutureWater (FW)
The Netherlands – R2Water Research and Consultancy (R2W)
Morocco – National School of Agriculture (ENAM)
Morocco – University of Sultan Moulay Slimane (USMS)
Turkey – GTE Carbon, Sustainability and Energy Consultancy Co. (GTE)

DURATION
01/09/2021 – 31/01/2024

TOTAL GRANT
€ 709.000

CONTEXT

Nowadays, climate risk and impact assessments of food-systems focus typically on the production within a geographic area only. Consequently, knowledge and research on the cross-border climate vulnerabilities of food-systems have hardly received any attention.

OBJECTIVES

CREATE contributes to understanding climate change risks by introducing the embedded resource use and trade dimension in food systems. Enhanced risk information, in turn, may enrich existing policies and create new ones to reduce associated risks. To this end, CREATE aims to contribute to the improved understanding of remote climate impacts on food-production systems and policy development.

KEY RESULTS AND OUTCOMES

Key traded crops were identified as apricot, fig, grape, hazelnuts for Turkiye; potato, grape, rice, orange for Egypt; and orange, tangerine for Morocco. The selection was based on trade dependency, including identification of key-trading partners, dependencies on water use in producing regions, and the economic significance of traded products to the EU's economy and to the producing regions.

Crop-specific climate risks were assessed by identifying the multiple climate sensitivities specific to each key crop, assessing changes in crop-specific climate indices predicted by a CMIP6 climate model ensemble, and analyzing the implications of climate change impacts to the agri-food value chain between the EU, Africa and Turkiye for the 2036—2065 horizon.

The results show that southern and western regions of Turkiye will be less suitable for key traded crops. Under the SSP245 scenario, approximately 80% of key crop production will be under medium and high risk. In Morocco, approximately 55% of key crop production will be under medium and high risk, while in Egypt, the associated risks were estimated as 63%.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 862555

KEY PUBLICATIONS

- T. Schults, C. Nolet, B. D'Haeyer, E. Ercin, T. Pilevneli, G. Capar, A novel methodologyto assess crop-specific climate risks: A cross-border case study of agri-food tradebetween Turkey and the EU, Cross-border Climate Change Impacts and SystemicRisks in Europe and Beyond Conference, 16-18 Oct., 2023, Postdam Inst. for ClimateImpact Research, Germany.
- G. Capar, Science-Policy Interaction in Water Management, UN 2023 Water Conference, 22-24 March 2023, NY, USA.
- E. Ercin, B. D'Haeyer, C. Nolet, E. Alkaya, D. Mahsunlar, S. Ennahli, H. Hafida, A. Shehata, A. Aboukheira, T. Pilevneli, G.Capar, "A novel methodology to assess cross-border climate vulnerabilities of agri-food systems: A case study of trade between Europe, Morocco, Egypt and Turkiye", Mediterranean Geosciences Union Annual Meeting, MedGU, 27-30 November 2022, Marrakesh, Morocco (Best Paper-Award in Atmosphere/Climate Track).
- G. Capar, O. Taskin, B. Ucar, T. Pilevneli, E. Ercin "Water footprint of apricotproduction: A key exported crop in Turkey", 8th International AgricultureSymposium – AGROSYM 2022, Bosnia Herzegovina, 6-9 October 2022.
- T. Pilevneli, B. Ucar, G. Capar, An evaluation of water footprint of bread wastes in Turkey, 9th International Conference on Sustainable Solid Waste Management, Corfu, Greece, 15-18 June 2022.
- G. Capar, O. Taskin, B. Ucar, T. Pilevneli, E. Ercin, "Cross-Border Climate Vulnerability of Agri-Food Trade Systems: Turkey, EU, Africa, IV International Conference of Food, Agriculture, and Veterinary Sciences Conference, 27-28 May 2022, Van, Turkiye.
- G. Capar, O. Taskin, B. Ucar, T. Pilevneli, E. Ercin, "Organic Production and WaterFootprint of Grape in Gediz River Basin", 4th International Conference on OrganicAgriculture in Mediterranean Climates: Threats and Solutions Conference, 27-29 May 2022, İzmir, Turkiye.

COORDINATOR CONTACT

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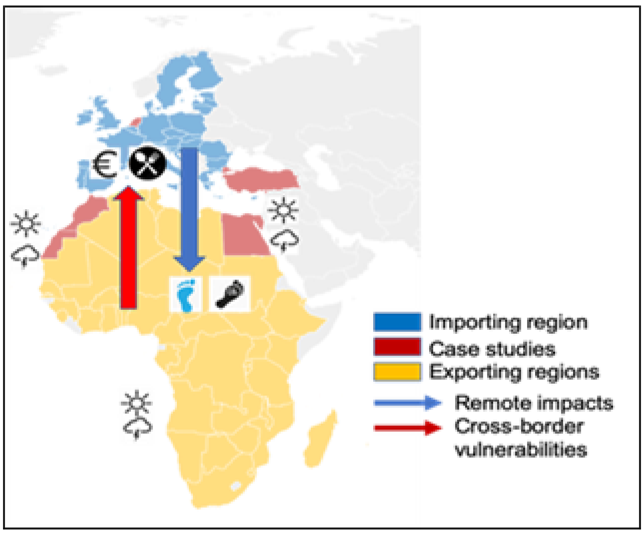

SALAD

Saline Agriculture as a Strategy to Adapt to Climate Change

Partners of the project

The Netherlands – VU Amsterdam (VU)
Belgium – Flanders Research Institute for Agriculture, Fisheries and Food (ILVO)
Belgium – KU Leuven
Egypt – Kafrelsheikh University (KFS)
Germany – Carl von Ossietzky University Oldenburg (UoL)
Italy – University of Florence (UniFI)
Morocco – Mohammed VI Polytechnic University (UM6P)
The Netherlands – The Salt Doctors BV (SD)
The Netherlands – Salt Farm Foundation (SFF)
The Netherlands – University of Applied Sciences Van Hall Larenstein (VHL)
Morocco – Cadi Ayyad University Marrakesh (UCAM)

DURATION
01/06/2021 – 31/05/2024

TOTAL GRANT
€ 1.312.300

CONTEXT

Climate change impacts coastal areas by sea level rise and more frequent droughts. These events increase the salinity in agricultural soils, affecting food systems overstretched by an increasing global population. Progressing salinisation is one of the major drivers of soil degradation in Europe and North Africa, exerting increasing pressure on conventional farming.

OBJECTIVES

SALAD aims at improving the resilience of food production in saline and potentially saline agricultural areas in the Mediterranean and North Sea regions by:

1. supporting the development and sustainable use of innovative salt-tolerant crops;
2. identifying and further developing crop cultivation suited to saline conditions;
3. exploring and testing innovative market development techniques and instruments with the goal of upscaling crop/food chains across the regions;
4. exchanging knowledge and transferring practical and adaptive solutions among stakeholders.

KEY RESULTS AND OUTCOMES

The SALAD project adopted an innovative approach to implementing climate-smart agricultural solutions in saline environments. It concluded with six main results: (1) evaluating the potential for upscaling the cultivation of four crops—potatoes, New Zealand spinach, quinoa, and tomatoes—under saline conditions; (2) investigating soil–plant–atmosphere interactions and associated crop models; (3) assessing stakeholder perspectives in salt-affected regions; (4) mapping the governance landscape, including relevant EU and North African policies and international collaborative initiatives; (5) developing future sea-level rise scenarios to assess regional salinization risks; and (6) analysing opportunities and constraints for scaling up saline agriculture in participating countries.

The project concludes that salinization is a growing threat in Mediterranean and North Sea regions, demanding urgent integration into climate and agricultural policy at all levels. Successful case studies demonstrate that crops such as potatoes, quinoa, tomatoes, New Zealand spinach, and carrots can be cultivated on saline soils, highlighting a promising but underutilized avenue for food and fiber production.

However, significant barriers to upscaling remain, including knowledge gaps, the absence of robust value chains, cultural resistance, policy deficiencies, and inadequate financing mech-

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anisms. Stakeholder analyses and demonstrations across five countries reveal both a willingness among farmers to adopt saline agriculture and the critical need for policy support to address prevailing market failures. Technological innovations—including genetic screening, enhanced organic fertilization, and improved water management—can mitigate some challenges, but policy integration is essential to achieving broader adoption.

Recommendations include:
Short term: Initiate at least ten new pilot projects in the North Sea and Mediterranean regions within two years.
Medium term: Embed saline agriculture into EU and EU–North Africa agricultural and climate policies within five years.

KEY PUBLICATIONS

- Negacz, K. K., van Tongeren, P., Ferone, L., Martellozzo, F., & Randelli, F. (2022). Saline Agriculture Initiatives in Mediterranean and North Sea Region. Technical Report. VU Amsterdam.
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- van Holst, A., van Tongeren, P., Vellinga, P., & Negacz, K. K. (2023). Advancing towards a Climate-Resilient Future: Putting Saline Agriculture on the European Policy Agenda: Policy Brief.
- El Mouttaqi, A., Sabraoui, T., Belcaid, M., Ibourki, M., Mnaouer, I., Lazaar, K., ... & Hirich, A. (2023). Agro-morphological and biochemical responses of quinoa (Chenopodium quinoa Willd. var: ICBA-Q5) to organic amendments under various salinity conditions. Frontiers in Plant Science, 14, 1143170.
- Comparini, D., Mozzo, G., Thiers, L., Vanderborght, J., DeSwaef, T., Mancuso, S., Garré, S., Atzori, G. (2024) Exploring tolerance mechanisms and root morphological development of New Zealand spinach and quinoa across salinity levels. South African Journal of Botany 171:10-2
- Estrella Delgado, D.C., De Swaef, T., Vanderborght, J., Laloy, E., Cnops, G., De Boever, M., Hirich, A., El Mouttaqi, A., Garré, S. (2025) Modeling quinoa growth under saline and water-limiting conditions using SWAP-WOFOST. Agricultural Water Management 309, 109356, https://doi.org/10.1016/j.agwat.2025.109356.
- VARM Simulator VR Game, 2024

COORDINATOR CONTACT

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PHEALING

Post Harvest losses mitigation by improved plant hEALING

Partners of the project

Belgium – KU Leuven
Germany – Rheinische Friedrich-Wilhelms-University Bonn (Uni Bonn)
Kenya – University of Nairobi (UONBI)
Kenya – South Eastern Kenya University (SEKU)
South Africa – University of KwaZulu-Natal (UKZN)

CONTEXT

Plant healing may represent an important genetic potential to reduce post-harvest losses with limited reliance on storage facilities that are costly and energy consuming. The use of natural plant healing mechanisms and microbial antagonists have the potential to lead to methods that can be applied across a wide range of varieties preferred by growers, consumers and industries.

OBJECTIVES

The specific objectives of PHEALING are to:

1. study and characterize plant healing mechanisms in model crop species (fruit (tomato), tuber (potato) and storage root (cassava));
2. identify conditions conducive for plant healing in order to start exploitation of this natural process;
3. identify and characterize genetic diversity for plant healing in the selected crop species to help tapping in this yet unexplored genetic potential;
4. test novel biocontrol approaches including bacteriophages and priming molecules to induce plant healing and to reduce post-harvest losses.

KEY RESULTS AND OUTCOMES

Harvest losses mitigation by improved plant hEALING (PHEALING) project are aimed at exploring and harnessing plant healing mechanisms to reduce post-harvest losses in key crop species. This involves studying and characterizing the natural healing processes in model crops, including fruits like tomatoes, tubers such as potatoes, and storage roots like cassava. By profiling the molecular mechanisms involved in wound responses, researchers can identify the optimal environmental and physiological conditions that promote plant healing, paving the way for the practical application of this natural process in agricultural systems. Furthermore, the project seeks to identify and characterize genetic diversity related to plant healing within the selected crop species, unlocking an untapped reservoir of genetic potential that could enhance crop resilience and productivity. In addition to genetic exploration, PHEALING also focuses on testing innovative biocontrol strategies, such as bacteriophages and priming molecules, to stimulate plant healing responses and further minimize post-harvest losses. Our previous transcriptomics analysis identified at least 12 Suberin Candidate Genes (SCGs) in cassava, including key transcription factors. Functional validation of this gene in model species using the agroinfiltration approach confirmed the role of selected

DURATION
01/10/2021 – 30/06/2024

TOTAL GRANT
€ 680.100

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transcription factors in regulating the expression of SCGs in this species. Additionally, our results demonstrated that priming molecules, such as sorbitol, trans-ferulic acid, and phenylacetic acid can induce wound tissue formation in cassava storage roots. Interestingly, certain chemical treatments that successfully delayed deterioration in potatoes may also have the potential to slow down postharvest physiological deterioration (PPD) in cassava.

To further investigate the natural healing capacity of cassava, we assessed over 20 farmer- and consumer-preferred cultivars grown in Kenya, identifying cultivars with contrasting PPD responses. These cultivars are currently undergoing suberization measurements at one of the partner institutes (University of Bonn) to better characterize their wound-healing mechanisms. In parallel, novel biocontrol strategies were tested at the University of Kwazulu-Natal to reduce post-harvest losses in tomatoes and potatoes. This involved applying lytic bacteriophages targeting both human and plant pathogenic bacteria, including *Salmonella enteritidis, Serratia marcescens, Pseudomonas aeruginosa*, and *Pectobacterium polaris.* Through phage isolation and characterization, all of the phage isolates presented the head-tail morphology typical for the class Caudoviricetes. Notably, host-specific phages, targeting S. enteritidis and S. marcescens, demonstrated effectiveness in eliminating biofilms of these bacteria. These findings provide valuable insights into plant healing mechanisms and the potential for biocontrol applications to develop durable post-harvest management strategies. Ultimately, the outcomes of this project are expected to contribute to sustainable, cost-effective agricultural practices that benefit not only growers but also consumers and the broader agricultural industry.

KEY PUBLICATIONS

- Zainuddin IM, Lecart B, Sudarmonowati E, Vanderschuren H. A method for rapid and homogenous initiation of post-harvest physiological deterioration in cassava storage roots identifies Indonesian cultivars with improved shelf-life performance. Plant Methods. 2023 Jan 18;19(1):4. doi: 10.1186/s13007-022-00977-w. PMID: 36653871; PMCID: PMC9847153.
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COORDINATOR CONTACT

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TRUSTFARM

Towards Resilient and sUStainable integrated agro-ecosystems Through appropriate climate-smart FARMing practices

Partners of the project

Germany – Leibniz Institute of Agricultural Development in Transition Economies (IAMO)
Egypt – Cairo University (CU)
Italy – University of Bari (UniBa)
Morocco – National Institute for Agricultural Research (INRA)
France – French Agricultural Research Centre for International Development (CIRAD)
Morocco – Mohammed VI Polytechnic University (UM6P)
Senegal – Cheikh Anta Diop University of Dakar (UCAD)
Morocco – Cadi Ayyad University Marrakesh (UCAM)

DURATION
01/06/2021 – 30/04/2025

TOTAL GRANT
€ 1.171.037

CONTEXT

TRUSTFARM promotes sustainable agriculture through climate-smart farming practices designed to improve resilience, productivity, and food security. By integrating innovative techniques across different contexts the project addresses water scarcity, soil degradation, and the need for eco-friendly farming solutions.

OBJECTIVES

The main aim of the TRUSTFARM is to design integrated agro-ecosystems (incorporating livestock production into cropping systems for enhancing ecosystem services in smallholder) based on the conservation principles of using natural resources and the circular economy in order to make production systems more resilient to climate change.

KEY RESULTS AND OUTCOMES

Egypt Case Study: Enhancing Drought Tolerance in Crops

- Combining compost and effective microorganisms (EM) significantly improves wheat's drought resistance.
- Increases photosynthetic efficiency, nutrient uptake (N, P, K, Fe, Zn, Cu), root ATP content, and membrane stability.
- Boosts soil microbial activity by 20 times, enriching soil biodiversity and resilience.
- Reduces water consumption while maintaining or increasing yield.
- Promotes 100% organic farming, reducing chemical dependency.

Italy Case Study: Climate-Resilient Crops

- Sorghum: Uses 20% less water than conventional grains; thrives in saline, nutrient-poor soils with only 20% yield reduction under minimal irrigation.
- Quinoa: Requires minimal irrigation; retains stable grain yields and offers high protein content with essential amino acids. Local demand grew by 300% since 2019.
- Amaranth: Withstands heat and drought; provides nutrient-dense, gluten-free grains rich in iron and calcium. High demand in organic markets.
- These crops offer water efficiency, soil health improvement, and diverse economic opportunities.

France Case Study: Sustainable Livestock Systems

- Achieves 78% feed autonomy and 91% forage autonomy, reducing reliance on external inputs.
- Improves nutrient management with 80% manure recy-

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cling, enhancing soil fertility and minimizing nitrogen leaching.
- Requires only 0.1 kg of mineral fertilizer per liter of milk, reducing costs and environmental impact.
- Promotes biodiversity and healthier ecosystems through circular farming.
- Supports sustainable milk production with lower land and resource use.

Senegal Case Study: Integrated Agro-Ecosystems
- Implements sustainable irrigation to reduce water consumption while boosting crop resilience.
- Trials on millet, maize, sorghum, cowpea, and groundnut show improved yield and climate adaptability.
- Conservation farming practices enhance soil fertility, reducing chemical fertilizer dependency.
- Interviews highlight key challenges in soil fertility and market access, informing tailored solutions.
- On-farm trials and seed innovations improve productivity and access to high-quality seeds.
- The Reduce-Reuse-Recycle (RRR) model fosters sustainable agricultural business opportunities.

TRUSTFARM demonstrates the potential of integrating organic amendments, climate-resilient crops, and sustainable livestock systems to enhance agricultural resilience and productivity. Across diverse environments, these approaches conserve water, reduce chemical dependency, and improve food security.

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SAFOODS

Strengthening African FOOD Systems in the face of climate change and food insecurity

Partners of the project

France – French Agricultural Research Centre for International Development (CIRAD)
United Kingdom – Natural Resources Institute, University of Greenwich (NRI)
Senegal – Senegal Agricultural Research Institute-Bureau of Macro-Economic Analysis (ISRA-BAME)
Côte d'Ivoire – Nangui Abrogoua University (UNA)

DURATION
01/07/2021 – 31/05/2025

TOTAL GRANT
€ 515.300

CONTEXT

West African countries face significant food and nutrition security challenges, affecting increasingly urban populations. There is strong evidence that consuming more fruits and vegetables (F&V) contribute to improve diets and nutrition, hence the importance that city-region food systems deliver sufficient and affordable F&V. Climate change poses serious threats to the functioning of F&V food systems, with potential impacts on yields and increased post-harvest losses (PHLs) resulting in stronger supply and price fluctuations by 2050. There is therefore an urgent need to identify locally-adapted innovations to make F&V food systems more resilient.

OBJECTIVES

SAFOODS' goal is to enhance the resilience of F&V food systems through developing adaptation strategies in four city-regions: Dakar and Ziguinchor in Senegal, Yamoussoukro and Abidjan in Côte d'Ivoire. Objectives are to assess climate change-related risks on F&V food systems and to co-design innovations with stakeholders in mango, tomato and green leafy vegetables food chains, thereby contributing to filling research gaps on the issue of F&V and climate change.

KEY RESULTS AND OUTCOMES

Analysis of secondary data on household food consumption shows that F&V consumption is well below the nutritional recommendations for the majority of households in Côte d'Ivoire. The share of F&V expenditures in total food expenditures is higher in Senegal (25%) than in Côte d'Ivoire (15%) but increases with income, especially for fruits. Focus group discussions and participatory photography with women about their food environment in a precarious neighbourhood of Ziquinchor reveal the limited fruit consumption but also challenges in accessing vegetables.

Global estimates (all cities and products) of PHLs are low for 2022 compared to literature and mostly qualitative than quantitative. However, estimates vary depending on food chain stages and products: e.g., local mangoes have the highest quantitative PHLs (6,2%) at retailer stage while qualitative PHLs were higher for leafy vegetables (11,4%); producer experiment high PHLs for the local tomato chain that are more qualitative (11.9%) than quantitative (3.9%). Beyond technical pre and post-harvest practices, PHLs depend on marketing practices (short circuits, diversification of export and domestic outlets, selling agreement before sale...). Diversification strategies along the

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 862555

F&V chains are key to reduce PHLs and strengthen the food system's resilience.

An evidence map based on 169 meta-analyses reveals that climate change impacts have been specifically studied for only 25 horticultural species and most studies focus on individual climate factors despite the multifactorial nature of climate change. The results show both positive impacts (e.g., increased CO2 leading to higher antioxidants) and negative effects, with the latter likely offsetting the benefits. The effects of climate change set aside, the use of a predictive model to estimate nutritional post-harvest flows in the mango chain in Côte d'Ivoire, shows that the projected future increase in mango production shall be nutritionally beneficial to more Ivorians, helping to address micronutrient deficiencies in the population.

As part of innovation testing on local tomato, the use of Hevea wood ash proved to be effective to reduce the loss of firmness and extends their shelf life to 6 weeks at room temperature. This technology is also accessible to producers and sustainable (recycling, reduced use of pesticides).

Using a participatory approach, an ideotype of a resilient agri-food system was codesigned in Yamoussoukro with food chain actors based on combined innovations. The backcasting exercise that followed identified the transition paths to reach the ideotype under different climate and economic conditions. In Ziguinchor, foresight resulted in various scenarios of the future territorial food system that can be used by the local authorities in their policy to re-locale F&V production, and was followed by an ideotyping exercise to move towards the desirable scenario. An enabling policy environment for more resilient city-region F&V food systems requires increased support for the F&V small-scale operators supplying the domestic market and better collaboration between Agriculture, Environment and Health from both local and national governments.

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COORDINATOR CONTACT

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FOSC

ERA-NET Cofund on Food Systems and Climate

MedAgriFoodResilience

Socio-environment a l shocks assassment and resilience empowerment in Mediterranean agrifood heritage systems: Italy, Morocco, Algeria FAO GIAHS sites

Partners of the project

Italy – Univeristy of Florence (UniFI)
Morocco – Mohammed VI Polytechnic Univeristy (UM6P)
Algeria – Univeristy of Biskra (UMKB)
Algeria – Scientific and Technical Research Center on Arid Regions (CRSTRA)
Morocco – Univeristy of Ibn Zohr (UIZ)

CONTEXT

Traditional agroforestry and agri-food systems are increasingly receiving attention at international level, thanks to their multifunctional role, to the different Ecosystem Services they are able to provide to rural communities, and as sustainable examples for alternatives to agricultural models based on maximizing productivity. The importance of traditional agri-food systems is recognized by the Food and Agriculture Organization (FAO) and the establishment of the Globally Important Agricultural Heritage Systems (GIAHS) Programme. The GIAHS Programme has the aim to identify and preserve worldwide sites characterized by agricultural systems created and managed over time by local communities, that today represent examples of local adaptation and mitigation towards global challenges, contributing to food security and sustainable development of rural communities.

OBJECTIVES

The MedAgriFood Resilience project focuses on three GIAHS sites (terraced olive orchards in Italy, argan forest in Morocco, traditional oases in Algeria) applying a multidisciplinary approach to identify the possible social and environmental shocks impacting agroforestry and agri-food heritage systems in the Mediterranean area, linking together landscape structure, climatological studies, social role and biodiversity assessment. The results of the project led to the identification of the best practices to be replicated in other traditional agroforestry and agri-food systems to increase the adaptation and resilience to social and/or environmental systems shocks.

KEY RESULTS AND OUTCOMES

The project identified criticalities and best practices in three Mediterranean traditional agri-food systems. Dissemination and training activities contributed to spread the knowledge about sustainable practices that can be supported by local authorities and replicated in other GIAHS sites or in other Mediterranean traditional landscapes.

The network of the Mediterranean GIAHS sites that has been established during the projects led to common activities for the valorization of traditional landscapes, including the participation to an Interreg EURO-MED call with a project, called MED-GIAHS and coordinated by the Junta de Andalusia, that has been selected for funding.

DURATION
30/04/2022 – 30/06/2025

TOTAL GRANT
€ 370.000

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 862555

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- Faci, M., Oubadi, M., & Madi, M. (2025). The Ghout Agricultural System: Between Survival and Disappearance. Agricultural Research, 1-8.

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FOSC

ERA-NET Cofund on Food Systems and Climate

IPSUS

Climate smart food innovation using plant and seaweed proteins from upcycled sources

Partners of the project

United Kingdom – Natural Resources Institue, Univeristy of Greenwich (NRI)
Italy – University of Parma (Unipr)
Turkey – Istanbul Sabahattin Zaim University (IZU)
Morocco – National School of Agriculture in Meknes (ENA)
Romania – BEIA Consult International (BEIA)
Italy – Experimental Station for the Food Preservation Industry (SSICA)
Morocco – Mohammed B University (UM5)
Turkey – Kaanlar Food Inc.
France – KEDGE Business School

CONTEXT

Food choices impact human and planetary health. The negative environmental impacts of the food system, increasing food insecurity and the prevalence of unhealthy diets are driving policymakers, scientists, companies and consumers to demand sustainable solutions. Globally, livestock emits 14.5% of greenhouse gasses, is associated to 30% of biodiversity loss, and, with meat demand is projected to double by 2050, transitioning to diets that include more sustainable sources of protein is crucial. Plant-based proteins are currently the fastest growing food trend but are unsustainably dependent on soy.

OBJECTIVES

The IPSUS project will exploit inter-disciplinary and eco-innovative approaches to explore opportunities for upcycling plant and seaweed proteins from agri-food raw materials otherwise destined to join the ~1.6 billion tonnes of annual global food loss and waste (FLW). The quantity, quality, and upcycling opportunities of FLW occurring along the value chains of six protein-rich commodities (pumpkin, hazelnut, grape, potato, brewers' spent grain, and seaweeds) will be investigated in the UK, Italy, Romania, Turkey, and Morocco to contribute towards achieving Net Zero through linking sustainable protein shift and food waste valorisation.

ACTIVITIES AND RESULTS

The types and quantities of FLW with protein upcycling potential within the focal value chains were explored and compared. Novel protein extraction methods were assessed to identify and optimise less energy-intensive and more sustainable techniques. The nutritional quality and safety of the plant and seaweed sources and upcycled proteins were assessed, taking bio-accessibility and potential allergenicity into account. In addition, incorporation of upcycled proteins into meat alternative and dairy alternative formulations was tested at lab-scale, followed by prototype development at pilot-scale by the industrial partners. Functional and sensory acceptability of the prototypes were evaluated along with improved nutritional (low salt/sugar/fat) and cleaner label (fewer food additives) offerings, which were previously lacking in the plant-based meat and dairy alternatives. Exploration of consumer behaviours, preferences, and the enabling regulatory and policy environment revealed drivers and barriers of the sustainable protein shift via upcycled plant proteins.

DURATION
14/04/2022 – 13/04/2025

TOTAL GRANT
€ 830.000

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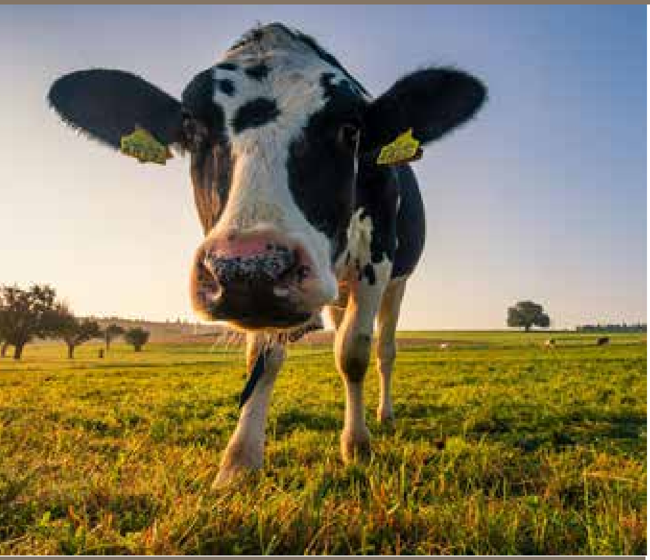

SmartDairy

Climate-smart Dairy: Assessing Challenges, Innovatin, and Solutions

Partners of the project

United Kingdom – University of Sussex
Italy – University of Ferrara (UNIFE)
Finland – University of Helsinki
United Kingdom – University of Reading
United Kingdom – University of Bristol

DURATION
01/04/2022 – 31/12/2025

TOTAL GRANT
€ 796.000

FOSC
ERA-NET Cofund on Food Systems and Climate

CONTEXT

Dairy is part of our daily lives, but it also contributes to climate change. Producing milk, cheese, and butter requires farmers to manage cows, land, and resources, while emissions are generated at every step of the process. From methane released by cows to carbon emissions from transportation, dairy's climate footprint is considerable. The SmartDairy project explores innovative solutions to make dairy more climate-smart.

OBJECTIVES

SmartDiry takes a multi-actor, multidisciplinary approach across four European countries to explore the interconnections and consequences of climate-smart innovations in the dairy sector. Our goal is to identify, co-design, and evaluate strategies that reduce greenhouse gas emissions while maintaining a sustainable and resilient dairy system.

We collaborate with stakeholders, including farmers, consumers, policymakers, and industry representatives, to develop and assess viable solutions for emission reduction in dairy production and consumption.
In Ireland, we examine farmers' acceptance of carbon markets and consumers' willingness to support carbon offsetting as a tool to mitigate dairy emissions.
In Italy, we analyze how new policies and business models affect different actors in the dairy supply chain, ensuring feasible and effective pathways toward emission reduction.
In the UK, we investigate consumer willingness to pay for different climate-smart innovations, including technological, nature-based, and emission reduction based innovations. Additionally, we assess farmers' perspectives on adopting these practices.
In Finland, we examine cultural attitudes toward milk and dairy alternatives, providing insights into potential shifts in consumer behavior that could support sustainability goals.

KEY RESULTS AND OUTCOMES

Farmers are more likely to adopt climate-smart practices when they see clear financial benefits. Technical solutions without benefits for farmers face significant adoption challenges. Market-based schemes such as cap-and-trade, may not be sufficient to drive widespread change. This scheme receive limited support from farmers, partly because it is perceived as complex. Yet, we did find industry interest in cap-and-trade schemes. In general, our findings indicate that overly complex policies and high adminstrative burdens deter participation. In addition

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farmers feel unfairly blamed for climate change, underlining that positive framing of their role in sustainability efforts is key to gaining their support.

Consumers have limited awareness of climate impact of dairy, but dairy products are part of their culture, daily lives and routine. Yet, consumers need knowledge, skills, and motivation to integrate plant-based alternatives into their diets. In relation to farm practices, consumers have generally limited understanding of production methods. Some emission reduction methods are less acceptable to consumers and even trigger an emotional response. Yet, well-framed information (e.g., co-benefits like animal welfare and local sustainability) can improve acceptance. Consumers also show higher willingness to pay for climate-smart dairy products and carbon-offsetting could be an opportunity to be explored.

Dairy processors can drive climate-smart innovation adoption by incentivizing sustainable practices among farmers. Yet, reliably and comparably quantifying emissions at farm level remains a challenge, and needs to be resolved before measures such as cap-and-trade becomes feasible.

Across all stakeholders—consumers, farmers, and industry—there is an expectation that governments should step in to implement climate action measures. As such, clear incentives are needed to drive a climate-smart dairy sector. Tax and fines reduce emissions but drive structural change. Yet, stronger and coherent policy interventions are required and anticipated by farmers.

A successful transition to a climate-smart dairy sector will require a combination of clear incentives, well-communicated policies, and collaborative efforts across farmers, consumers, industry, and government to ensure that sustainability goals are both achievable and widely supported.

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FOSC
ERA-NET Cofund on Food Systems and Climate

AlgaeBrew

Unlocking the potential of microalgae for the valorization of brewery waste products into omega-3 rich animal feed and fertilizers

Partners of the project

Ireland – University College Dublin (UCD)
Italy – University of Camerino (UNICAM)
Turkey – Bilecik Seyh Edebali University (BU)
Morocco – National School of Agriculture in Meknes (ENA)
Belgium – Lambers Seghers (LS)
United Kingdom – Swansea University (SU)
Romania – University of Agronomic Science and Veterinary Medicine (USAMV)

CONTEXT

As one of the largest agri-food industries, beer production generates large amounts of nutrient-rich wastewater and spent grain. The conventional linear "collect-treat-discharge" way of handling waste is costly and environmentally unsustainable. AlgaeBrew will use microalgal biotechnology to convert these wastes into useful products, thereby creating new revenue streams for breweries, decreasing their environmental impacts, and promoting a circular bioeconomy. By recapturing waste nutrients, microalgae *Nannochloropsis* can help breweries treat their waste products while producing sustainable Eicosapentaenoic fatty acid (EPA). This will be a win-win solution for both breweries and EPA producers. AlgaeBrew is undertaken by 7 universities, a beer producer, and an animal feed producer (Lambers Seghers) across 4 EU (Ireland, Belgium, Italy, Romania) and 3 associated countries (Morocco, Turkey, and the UK). Our estimation suggests that the brewery-microalgae system proposed by AlgaeBrew has a future potential to treat up to 26.8% of spent grain and 19.3% of brewery wastewater produced globally, while replacing the global demand for 21.6% of fish oil.

OBJECTIVES

AlgaeBrew aims to develop scalable processes that use *Nannochloropsis* to upgrade brewery wastewater and spent grain into high-value EPA for the feed industry. The residual *Nannochloropsis* biomass after EPA extraction will be developed into biofertiliser to achieve a zero-waste goal. The project will address technical challenges associated with *Nannochloropsis* cultivation on brewery waste, EPA extraction, feed formulation and socio-economic analysis.

KEY RESULTS AND OUTCOMES

The AlgaeBrew project has made significant progress by achieving key milestones across multiple work packages. Brewery wastewater (BWW) was thoroughly characterized and confirmed to be suitable for microalgae cultivation, with microfiltration emerging as the optimal pretreatment method that effectively reduces bacterial contamination while preserving essential nutrients. Among the five microalgae species tested, *Nannochloropsis oceanica* demonstrated robust growth and high nutrient removal efficiencies (81–95% for nitrate, 59–90% for phosphate, and 100% for ammonium), making it the preferred candidate for scale-up. A pilot-scale cultivation in 4,600 L photobioreactors was successfully completed over two growth cycles, yielding a total of 3.5 kg of biomass. This biomass was

DURATION
01/04/2022 – 31/03/2025

TOTAL GRANT
€ 1.300.000

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then incorporated into aquaculture feed formulations, with feeding trials on shrimp and sea bream showing promising survival rates and growth performance, especially under strategies that partially or completely replaced fishmeal using intact biomass, disrupted biomass, and EPA-rich lipid extracts. Additionally, microalgae-derived fertilizers formulated with defatted biomass and spent coffee grounds were developed, demonstrating enhanced soil moisture retention and improved germination at lower concentrations. Environmental and socio-economic assessments are currently underway, utilizing life cycle analysis tools to evaluate and optimize the sustainability and economic viability of microalgae-based solutions.

KEY PUBLICATIONS

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Olive3P

Innovative sustainable food system for olive oil production converting soild and liquid by-products into edible yeast and biopesticide

Partners of the project

Algeria – Ecole Supérieure des Sciences de l'Aliment et des Industries Agroalimentaires (ESSAIA)
Morocco – Cadi Ayyad University (UCAM)
Morocco – University of Sultan Moulay Slimane (USMS)
Turkey – Olive Research Institute, General Directorate of Agricultural Research and Policies (GDAR-ORI)
Turkey – DÜZEN Biological Sciences R&D and Production Inc.

DURATION
01/05/2022 – 30/04/2025

TOTAL GRANT
€ 361.000

FOSC
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CONTEXT

The Olive3P project aims to revolutionize conventional olive oil production by transforming it into an integrated and sustainable food system. The project addresses the environmental challenges associated with olive mill waste by developing innovative solutions to valorize both solid and liquid by-products. By integrating biochar production, polyphenol recovery, and edible yeast cultivation, Olive3P seeks to enhance sustainability, resource efficiency, and economic feasibility for small-scale olive oil producers. The initiative aligns with the principles of circular economy and bio-based solutions, offering new perspectives for the agricultural and food industries.

OBJECTIVES

1. **Biochar and activated carbon production:** Biochar isproduced from olive branches and stones via carbonization and activated for enhanced adsorption properties. The biochar and activated carbon is used to capture polyphenols from olive mill effluents, allowing their recovery as natural biocontrol agents.
2. **Biocontrol agents (biopreservative & biopesticide) based on captured/extracted polyphenols:** Polyphenols will be extracted using green solvents. The extracted compounds are tested as natural preservatives for table olives. Additionally, the polyphenol-enriched biochar is applied as a soil conditioner and evaluated for its biopesticide potential against soil-borne pathogens affecting olive crops.
3. **Carotenoid-rich yeast biomass cultivated on raw/pretreated OME and cheese whey:** Olive mill effluents (OME), after appropriate treatment to reduce polyphenol toxicity, will serve as a growth medium for edible yeast. Cheese whey will be added as a low-cost nitrogen source to optimize biomass production. The harvested yeast, rich in carotenoids, will be assessed as a functional feed ingredient for fish farming.

KEY RESULTS AND OUTCOMES

1. Production of biochar and activated carbon from olive solid wastes and their application in olive mill wastewater treatment. UCA, GDAR-ORI and USMS have successfully developed biochar and activated carbon from olive pomace, pruning residues, and olive stones, transforming these by-products into valuable materials for environmental and industrial applications. By optimizing the production process, the research teams have significantly enhanced the adsorption properties of these materials, making them highly efficient in capturing polyphenols

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from olive mill wastewater. These advancements contribute to the reduction of environmental pollution while promoting the circular economy by repurposing olive industry waste into functional bio-based materials. Additionally, UCA has explored the potential agricultural applications of biochar-treated wastewater. Through germination trials on lettuce and radish seeds, researchers have assessed the impact of treated wastewater on plant development, providing insights into its safety and benefits. The results show biochar's multifunctionality as a key player in wastewater treatment and as a soil amendment that could enhance crop resilience and productivity.

2. Optimized yeast cultivation for enhanced biomass and nutritional value. ESSAIA has cultivated oleaginous yeast in highly polluted olive mill wastewater by optimizing physical and chemical conditions, resulting in increased biomass and improved nutritional quality. The biomass is enriched with proteins, essential polyunsaturated fatty acids, and bioactive carotenoids, making it a strong candidate for aquafeed. Trials show its inclusion in fish feed enhances larval survival and growth, highlighting its potential as a sustainable, functional feed additive. DÜZEN and ESSAIA are now scaling up production through large-scale fermentation, advancing the commercial viability of this renewable ingredient and supporting circular bioeconomy goals.

3.Biocontrol strategies against olive tree pathogens. ESSAIA's in vitro studies identified optimal concentrations of polyphenols from olive mill effluent for inhibiting Verticillium dahliae, a major olive tree pathogen. GDAR-ORI is now conducting in vivo trials using polyphenol-loaded biochar on the Manzanilla Gemlik cultivar to test field efficacy. This research promotes sustainable farming by offering an eco-friendly alternative to synthetic fungicides, improving olive crop protection while minimizing environmental impact.

KEY PUBLICATIONS

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- Ronald Halim, Ajay Iyer, Sara M. Esteves, Sarah Milliken, Katalin Kalai, Daniel Pleissner, Loreena Stephan, Imene Chentir, Osama Ahmed, Waâd Nasri, Sameh Mohamed, Nils-Kåre Birkeland, Hervé Vanderschuren, Ima Zainuddin, Monica Mburu, (2025). Is 'waste' an appropriate concept in a sustainable bioeconomy?, Sustainable Chemistry One World, 5,100044.
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FOSC

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