CENTER FOR CARBON RESEARCH IN TROPICAL AGRICULTURE (CCARBON)

Abstract

Brazil is one of the world's largest producers and exporters of food, feed, fiber and (bio)fuel. Estimates indicated that the country would need to increase its food production in 40% to meet global demands by 2050. Meanwhile, tropical agricultural systems must contribute to sequester carbon (C) and reduce greenhouse gases emissions, and consequently, to mitigate climate changes. Therefore, the challenge is to increase agricultural production reconciling environmental, social and economic sustainability. In this context, we propose the creation of the Center for Carbon Research in Tropical Agriculture (CCARBON), hosted at ESALQ/USP, one of the most respected Agricultural Colleges worldwide. The CCARBON mission will be to develop innovative solutions and strategies on carbon-based sustainable tropical agriculture to mitigate climate change and improve living standards and conditions. Our vision is to be recognized as a world-class leader center on low-C tropical agriculture and qualification of human resources through research, innovation, and dissemination activities. To achieve the CCARBON goals, strategic, multidisciplinary and innovative research lines will cover five major areas: soil, plant and animal, gases, climate and digital tools. The center will also be embedded into a large innovation ecosystem to support discoveries and new technologies through institutional-public-private partnerships. We designed multiple strategies to actively disseminate the knowledge and innovations, contributing to farmers and stakeholders to adopt more sustainable practices, as well as creating low-C public awareness, and supporting the elaboration of public policies. We expect our research center to identify the main challenges and develop and implement solutions to increase sustainable agri-food production in tropical agrosystems, reducing GHG emissions and increasing C sequestration through climate-smart management practices. The outcomes will pave the way towards a low-C economy and promote sustainable social development in the upcoming decades.

Justification for the center

Estimates indicate that the world's population is likely to approach 9.7 billion with a fourfold increase in global economy and twofold increase in food, fiber, and energy demand[1]. In this scenario, humans will continue to impact and pressure the resilience of natural systems[2], changing conditions that are known to maintain most life cycles[3]. Thus, there is unprecedented pressure on Earth's resources, more precisely accelerating the impacts derived from climate change[4]. Meanwhile, new materials and technologies, non-fossil energy sources, improved communication networks, and more efficient transportation expressways seem to enhance our ability to protect the systems substantially[5]. The challenge in the coming years will be to cope with an increase in the frequency of extreme weather events, such as droughts, floods and other natural adversities in the face of the low resilience of natural and agricultural systems, while promoting a transition to new agricultural production processes[6]. Such new agriculture system must be paved on decarbonization based on a circular economy, and must aim to reduce greenhouse gas (GHG) emissions and waste disposal, enhance carbon (C) sequestration, the development of new crops with enhanced biomass and yield and more resilient to natural adversities and improve human-being life conditions in terms of socially and culturally diverse communities[7].

According to FAO's projection for 2050, 40% of the food demand increase is expected to be met by the Brazilian agriculture. Brazil is one of the world's largest producers and exporters of food, feed, fiber and (bio)fuel, due to privileged conditions of soil and climate associated with tropically adapted technologies (e.g. plant and animal breeding, soil and water conservation management, diversified cropping systems, forestry). Therefore, the country has a tremendous potential to contribute not only to food security, but also to sequestering C and mitigating climate changes through implementing science-based, climate-smart agricultural solutions on a large scale. In this context, the **CCARBON mission is to develop innovative solutions and strategies on carbon-based sustainable tropical agriculture to mitigate climate change and improve living standards and conditions.** Our **vision is to be recognized as a world-class leader center on low C tropical agricultural systems and qualification of human resources through research, innovation, and dissemination.**

[1] United Nations, Department of Economic and Social Affairs, Population Division (2019). World Population Prospects 2019: Highlights.
[2] Smith, P. et al. 2021. The role of soils in delivering Nature's Contributions to People. Phil. Trans. R. Soc. B 376: 20200169.
[3] Giardini, C.A.J. et al. 2021. Nature-based solutions can help cool the planet – if we act now. Nature: 593:191-194.
[4] IPCC - Intergovernmental Panel on Climate Change. 2021. Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis.
[5] Lal, R. et al. 2021. The role of soil in regulation of climate. Phil. Trans. R. Soc. B 376: 20210084.
[6] Horton, P. et al. 2021. Technologies to deliver food and climate security through agriculture. Nature Plants, 7, 250-255
[7] Wei, Y.M. et al. 2021. A proposed global layout of CCS in line with a 2 °C climate target. Nature Climate Change 11, 112–118.

Although the scientific research community is collaborating on an international scale, the level of collaboration is uneven within and among regions. Some research teams lack adequate infrastructure, training and access to wider international networks. Moreover, most of the identified knowledge gaps also address the social-economic dimensions of C sequestration technologies and, as a matter of priority, should form the core for a future strategic research agenda on increasing C sequestration and reducing GHG emissions in agricultural systems. Thus, CCARBON will provide the necessary opportunity for proper implementation of a variety of activities, including stocktaking and connecting existing research networks and projects to understand how international research cooperation is organized. The development of an international knowledge database will help researchers to increase international cooperation. The intended scientific contribution to sustainable carbon-solutions on tropical agriculture is new and, as part of a global problem, the research is complex and surely require long-term inter- and multi-disciplinary approaches involving challenging topics such as climate change, food security, water security, ecosystem services, ecological restoration, circular economy, circular agriculture and others directly associated to the UN Sustainable Development Goals. To achieve such excellence, the research needs to be addressed at state and national scales for at least one decade to be adequately carried out. Thus, as opposed to the existing financing of multiple and individualized projects by FAPESP, the CCARBON initiative clearly requires a CEPID type support to be properly accomplished and to generate sustainable and low-C emission agricultural products reconciling with ecosystem services that benefit people from nature (including food, water, C sequestration, soil reclamation, climate regulation, biodiversity, polinization, recreation, eco-friendly products, cultural values etc).

Our understanding is that the best place to host a CEPID on this subject is at "Luiz de Queiroz" College of Agriculture (ESALQ) of the University of São Paulo (USP). ESALQ/USP is currently considered a Center of Excellence for Undergraduate and Graduate programs in Agricultural, Environmental, Biological and Applied Social Sciences, recognized for its outstanding scientific and technical performance. ESALQ is part of the Agrifood 5 Alliance (Top5 Agricultural Colleges worldwide) with China Agriculture University; Cornell University, University of California Davis; and Wageningen University and Research. Its academic community comprises 800 faculty and staff members and nearly 3,400 undergraduate and graduate students. ESALQ offers seven undergraduate programs and 15 graduate programs (one international), in addition to one inter-institutional and two inter-unit programs, in its 12 departments and more than 130 laboratories. ESALQ houses a reference library in Agricultural Sciences for Latin America, four experimental stations, as well as an enterprise incubator (ESALQTec, Ceres Hub) and is one of the founders of the AgTech Valley (an arrangement similar to the “Silicon Valley” of the USA), a modern ecosystem composed by the AgTech Garage, Technological Park with startups, Embrapii, Innovation Mill etc. ESALQ houses one of the eight Remote Sensing Premium Labs of the world, recognized by FAO. Throughout its 120 years of existence, ESALQ has graduated over 16,500 students and it is the first Brazilian higher education institution to graduate more than 11,000 Agricultural Engineers. ESALQ/USP is responsible for a substantial proportion of the high-standard scientific papers published in agricultural and environmental science, provides data, information and broad-audience content to regional and national media platforms and contributes with the elaboration of public policies in multiple subjects (such as low-C agriculture, ecological restoration, biodiversity protection, water management). ESALQ has more than 90 agreements with foreign institutions, exchange of students and faculty members, and offers double degree programs in Agriculture and in Food Science with French institutions at the undergraduate level.

The CCARBON will provide accurate assessments not only of soil and biological C sequestration but also of GHG emissions for climate change mitigation to improve basic scientific understanding on C cycling in terrestrial agricultural and food systems as well as to provide policymakers with relevant information on C budget in the tropics. It will address various ***research techniques*** including physical, chemical, and biological attributes of soils; ecological restoration, digital agriculture, GIS mapping and prediction, energy balance, molecular plant breeding integrating the omics technologies to select better traits to further increase and promote stabilization of soil carbon, by selecting crops with higher root biomass and better interaction with the soil microbiota; simulation modeling on soil-plant-animal-atmosphere interactions; soil health, ecosystem services indexing; lifecycle assessment; socio-economic impact analysis on local, regional and global scales; development of environmentally friendly techniques to replace the incumbent technology for extracting, modifying, and fractionating major food components and bioactive compounds. Moreover, CCARBON will settle ***multidisciplinary components*** including soil, crop, food, environmental sciences, biosystems, molecular breeding and biotechnology, engineering, climatology, geology, economics, geography, social sciences, governance and public policy,

and communication. Finally, we understand CCARBON will have synergic interaction with the Research Centre for Gas Innovation also located at the University of São Paulo.

General lines of the Research Plan

The main goal of the CCARBON is to generate knowledge, technology, innovation, training of human resources and dissemination on carbon-based solutions for tropical agricultural systems conditions to reconcile the growing demand for food, fiber, and energy with sustainability (environmental, economic and social) goals. Our world-class research center will identify the main challenges and implement solutions to increase sustainable agri-food production of Tropical Agricultural Systems (focusing on annual crops such as soybean, maize, cotton, cover crops, sugarcane, pastures, integrated systems such as agriculture-livestock-forest and agroforestry, and forestry/ecological restoration programs) by reducing GHG emissions and increasing C sequestration through climate-smart management practices. To accomplish our mission, we established the main macro scientific challenges to be faced during 11 years (and beyond) of the CCARBON development, schematically illustrated in Figure 1.

The CCARBON **research** goals will be achieved based on inter- and multi-disciplinary activities that collectively cover five major areas: **soil, plant and animal, gases, climate** and **digital tools;** including:

▪ To provide interdisciplinary, comprehensive world-class research on terrestrial C sequestration and negative GHG emission techniques and technologies in the knowledge fields of tropical agriculture (agronomy, forestry, ecological restoration, animal husbandry, bioenergy crops, water management, food quality and security, socio-economic sciences, nutrient cycling, waste management, biodiversity and ecosystem services);

▪ To provide and visualize the spatial distribution of C in time and space in Brazil, from top to undersurface and its relationship with plant development and climate dynamics. This will allow the production of temporal C variation scenarios and of its environmental impacts, supporting decision-making for mitigation and adaptation. All areas that study C will need spatial information to realize where, how and when the degradation processes of this element are happening. The most advanced remote and proximal sensing techniques to achieve the information in all biomes will be developed;

▪ To better understand the impact on GHG emissions and C sequestration of the intensive ruminant production systems, including improved pasture management practices, improved cereal grains and byproducts feeding management, feed additives utilization, manipulation of the rumen and intestinal microbiota and the use of high genetic merit animals.

▪ To improve and sustain soil health and its functions through increasing soil C pool to meet the demands of a growing and progressively affluent world population through climate-resilient agriculture;

▪ To better understand the fate of crop residues, pesticides, organic, organo-mineral fertilizers and other inputs, as essential knowledge for developing evidence-based practices to maximize value of residue/organic waste management;

▪ To reduce the intensive use of synthetic organic pesticides by understanding pesticide metabolization and pesticide resistance evolution in holobionts to allow the designing and implementation of area-wide resistance management strategies, including the proposition of nationwide public policies;

▪ To identify new crop traits with increased plant biomass, yields, and resistance to pests by Integrating omics data (transcripts, proteins and metabolites) with large scale field phenotyping, genotypic and phenotypic biomarkers;

▪ To enhance the use of crop simulation models for estimating ideal and potential yield (CO_2, insolation, active photosynthetic radiation, air temperature, genotype), attainable (water, nutrients) and actual (weed, pest, diseases, crop management) productivity under current and prospective climate change scenarios;

▪ To create integrated crops/economics simulation/impact analysis models to assess the potential socio-economic implications of prospective scenarios and new technologies. Further integration with global models will allow the analysis of domestic policies and technological developments in the broader context of the global economy;

▪ To create new mathematical models within the field of optimization and inverse problems that will be applied to reduce GHG emission through several logistics optimization and pollution source detection. Improved taxation policies for the reduction of the impact of agricultural activities, can be obtained if competition between players is properly modeled and solved as bilevel optimization problems;

▪ To generate scenarios on the impacts of climate change on agricultural productivity and recommend adaptation and/or mitigation actions to simultaneously address sustainability, food security, climate change and human well-being issues.

For example, to generate knowledge from the bioactive profile of underutilized food plants that can play essential role in the development of new functional foods, given the threats of loss of valuable natural resources due to climate change;

▪ To generate knowledge on the impact of land-use change, fire and agricultural management practices to assess the degree to which C sequestration aligns with soil health, energy balance, and sustaining crop yield to provide synergy in tackling cross-sectoral pressures on food security, ecosystem services and climate change mitigation and adaptation;

▪ To assess the effects of C sequestration/GHG emission reduction and the socio-economic viability of different options, and the human dimensions, including education, communication and policy issues;

▪ To propose innovative and sustainable strategies to add value and maximize food product functionality, a key step towards the development of a sustainable approach, where health, process feasibility and environmental impacts need to be considered.

In addition to the research goals, CCARBON will have numerous actions focused on **innovation** and **dissemination**, with emphasis on the following:

▪ To establish a carbon-based integrated strategy to accelerate the convergence of research efforts, innovation, and dissemination to promote sustainability (environmental, economic, and social viability) of tropical agricultural systems;

▪ To develop, implement and disseminate innovative technologies to reduce GHG (CO_2, CH_4 and N_2O) emissions from agricultural, forestry and animal husbandry activities under tropical climate conditions;

▪ To develop, implement and disseminate innovative technologies to increase C sequestration in the production environment, with the introduction of the arboreal element in the production (silvopastoral, crop-livestock-forest system, forest restoration of riparian areas, agroforestry systems on marginal agricultural areas etc;

▪ To generate new sources of natural-based, bio-safe products for pest control and food production to ameliorate soil and water contamination and accelerate C sequestration by avoiding synthetic organic chemistries. These natural-based products will be discovered through the exploitation of holobionts and hologenomes;

▪ To provide relevant information to settle not only the voluntary C market but also the one under the UNFCCC, from projects focused on emissions avoidance/reduction that can help accelerate the transition to a decarbonized global economy, for example by driving investment into renewable energy, energy efficiency, and natural capital;

▪ To transfer knowledge and technology to the productive, public and third sectors, as well as knowledge-based evidence for state and national governments' formulation of public policies on sustainable food, fiber and energy production;

▪ To develop partnerships with companies and private/public organizations responsible for implementing public policies related to Brazil's commitments under the United Nations' actions against global warming and climate change;

▪ To encourage the formation of startups whose products or services incorporate research results developed by CCARBON, creating opportunities for stakeholders interested in investing in, supporting and implementing C sequestration, GHG emission reductions and adoption of good management practices on tropical agriculture, forestry and animal husbandry;

▪ To motivate and inspire young talents, stimulate the future generation of researchers, develop scientific initiation at all levels of education and disseminate the idea of a sustainable agriculture to teachers and students of the basic education system, mainly through our network established by our two licensing courses.

▪ To promote initiatives related to disseminating knowledge through the offering of in-person and online events, in the short, medium and long term, both aimed at the scientific community and events aimed at the lay public. Webinars, online panels, podcasts, debates, short courses and thematic workshops will be part of this set of activities. E-books will be made to disseminate knowledge for the public not linked to the scientific community. Interviews will be recorded with project researchers to disseminate knowledge on social media. A monthly bulletin should be created for real-time dissemination of the activities of the researchers and to convert the main results published in scientific journals into a language more appropriate to the lay public. The center should receive elementary, high school and undergrad/graduate students to disseminate the main research topics and results from the CCARBON.

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CCARBON

Figure 1. Schematic general structure and purposes of the Center for Carbon Research in Tropical Agriculture.