



Laboratory for Sustainable Land Use and Ecosystem Services

Coordenação: Prof^a Doutora Maria Teresa Ferreira

Scientific areas

Scientific area 1	Agriculture, Forestry and Fisheries
Scientific area 2	Earth and Environmental Sciences
Scientific area 3	Agriculture and Food Biotechnology
Scientific area 4	Economic and Social Geography
Scientific area 5	Health Sciences

Thematic Lines

Thematic Line 1	Natural Capital and Sustainable Ecosystem Services
Thematic Line 2	Sustainable Agriculture, Forestry and Fisheries
Thematic Line 3	Products Processing and Circular Economy
Thematic Line 4	Society and Environmental Health
Thematic Line 5	Socioecological Systems, Planning and Policies

Research & Development Units and Institutions

Principal Institution	Management Institution	Instituto Superior de Agronomia	 INSTITUTO SUPERIOR DE AGRONOMIA Universidade de Lisboa
Participant management institution 1		Associação para Investigação e Desenvolvimento da Faculdade de Medicina (AIDFM/FM/ULisboa)	 AIDFM Associação para Investigação e Desenvolvimento da Faculdade de Medicina
Participant management institution 2		Instituto de Geografia e Ordenamento do Território da Universidade de Lisboa	 IGOT Instituto de Geografia e Ordenamento do Território UNIVERSIDADE DE LISBOA
Participant management institution 3		Universidade de Coimbra (UC)	 12 181 9 0 UNIVERSIDADE DE COIMBRA
Principal R&D unit and proponent institution		Centro de Estudos Florestais and Instituto Superior de Agronomia	 CEF Centro de Estudos Florestais
Participant Unit R&D 1		Centre for Functional Ecology - Science for People & the Planet	 CENTRE FOR FUNCTIONAL ECOLOGY SCIENCE FOR PEOPLE & THE PLANET
Participant Unit R&D 2		Centre of Geographical Studies	 CEG
Participant Unit R&D 3		Linking Landscape, Environment, Agriculture and Food	 LEAF
Participant Unit R&D 4		Environmental Health Institute	 ISAMB Instituto de Saúde Ambiental

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"This is why it is urgent to shift sideways and to define politics as what leads toward the Earth and not toward the global or the national. Belonging to a territory is the phenomenon most in need of rethinking and careful redescription; learning new ways to inhabit the Earth is our biggest challenge. Bringing us down to earth is the task of politics today."

Bruno Latour, "Down to Earth", 2018

A. Identification of the Associated Laboratory TERRA

1. Aims and presentation

Aims

The Associate Laboratory for Sustainable Land Use and Ecosystem Services (hereafter TERRA), brings together five highly qualified research Centres from the University of Lisbon and the University of Coimbra with about 400 researchers in total. The goal of TERRA is **to deliver innovative socio-ecological scientific evidence in support of best management practices and policy decision-making towards sustainable land use and bio-circularity and its derived products, while tending to the human societies they support**. With agricultural and forestry systems at the forefront, today's research is challenged by the need to recognize the interactions between anthropogenic activities and the environment. Addressing this challenge calls for systemic approaches. TERRA integrates the multidisciplinary dimension required to understand the common drivers and interactions that influence the sustainability of soil, water and energy, the conservation of biodiversity, ecosystems and their services. This understanding is key to the effectiveness of related sectoral and place-based strategies and policies. TERRA research activities covers the whole value chain from natural resources to societies and citizens, to monitor and insure a healthy and safe environment for humankind.

Emphasizing the foundational **intergenerational commitment of sustainability**, TERRA assumes the research community endeavor in alliance with public and private stakeholders, to embrace biocultural heritage, qualify socioecological systems, reduce social and spatial inequalities across land uses, and promote well-being. TERRA is committed to gender mainstreaming in its work and research centres, promoting research quality and equal opportunities, evidencing technology and innovation and its social relevance.

Composition

The **Forest Research Centre (hereafter CEF)** develops multidisciplinary research and outreach in the field of forestry and natural resources. Its mission is to foster research to understand how ecosystems respond to global change drivers, how ecosystem management may target the provision of the full range of ecosystem services and how to innovate segments of the forest value chain within a green economy framework. CEF's research is influential to integrate and fulfill society concerns and demands. "The quality, merit and relevance of the activities of CEF were excellent and also very relevant for increasing the knowledge of the structure, dynamics, function and management of forest and natural range systems at a global scale." according to the FCT's international evaluation panel in 2018. CEF is structured into 4 Research Groups that focus on four strategic areas: i) analysis of forest ecosystem structure and function, including responses to global change drivers, environmental stresses (e.g. drought) and disturbances (e.g. fire); ii) valuation, vulnerability assessment, protection, and adaptive management of forest and semi-natural ecosystems, and of market and non-market environmental services; iii) sustainable forest ecosystem management, plantation forestry, forest policy and economics; iv) wood and non-wood forest products, including product and process innovation, green chemistry and biorefineries.

The excellence of CEF's research is evidenced by its scientific productivity and is widely recognized as highlighted by the participation in several national and international scientific boards and by the membership

of over 20 editorial boards of international scientific journals. CEF's outreach activities build from this excellence and from over 40 years of experience in sharing and co-producing research with major public and private stakeholders, including central administration agencies responsible for forestry, land management, and nature conservation, municipalities, forest owners' associations, non-governmental organizations and the forest industry (e.g., cork, pulp and paper, and wood manufacturing networks). The success of CEF's knowledge transfer and capacity building strategies is highlighted by its contribution to the development of policies for the forest sector.

The **Center of Linking Environment, Agriculture and Forests (hereafter LEAF)** focus on the entire agri-food chain, at different levels, from cells and microorganisms through sustainable crop production and healthy foods to landscape design and planning, and aims for enhancing crop productivity and sustainability management of natural resources. The main objectives are: to improve sustainable crop production, with emphasis on yield and quality and the best management of natural resources (soil, water, waste, energy), aiming a circular-economy; to develop new processes to obtain healthy, safe, economic, and sensory acceptable novel and functional foods (and feeds), and products to design and plan SMART landscapes; to apply conservation strategies, anticipating shifts on both critical and endangered species and habitats. The research centre is structured within a matrix of 3 groups: G1-Resource Management & Landscape Architecture; G2-Plant Science & Crop Production; G3- Food & Feed and 4 transversal thematic lines: LT1 Grapevine & Wine; LT2 Olive & Olive Oil; LT3 Tropical Agriculture & Food Value Chains; LT4 Green & Blue Infrastructures, enrolling around 115 researchers from ISA but also from other Institutions, some of them private. The Thematic lines recently opened an internal call with international evaluators for projects addressing the issues referenced in the GreenDeal and within the 17 SDOs. LEAF researchers are involved in international projects e.g. Algae to Future (A2F)-from fundamental Algae research to Applied Industrial Practices, funded by the Research Council of Norway's BIONAER programme (2017-20219) and National projects, some in connection with the major food and feed Portuguese companies, with a tight link to the Innovation efforts for increasing competitiveness of our economy.

The **Research Centre of Geographical Studies (hereafter CEG)** is "one of the largest and more internationalized research centres in Portugal in the fields of geography and planning, destined to be a leading research centre in Portugal, comparable to other high-ranking research centres, across Europe", as stated by the FCT's international evaluation panel in 2018. CEG's mission is **to foster geographical research, promote and disseminate geographical knowledge, and contribute to social inclusion and development, sustainable use of environmental resources and territorial cohesion** through the lens of spatial justice. CEG conducts research in Geography and Planning and offers a vibrant research environment, benefiting from its presence in the main campus of the Universidade de Lisboa. The R&D unit is organized in 6 Research Groups (RG), whose work is global in scope and addresses cutting-edge topics of contemporary Human and Physical Geography and Planning. The Research Groups conduct internationally-oriented research on: climate change and environmental systems (Zephyrus), risk assessment and management (RISKam), modelling and spatial management and planning (MOPT), urban and regional change and policies (ZOE), migration, spaces and societies (MIGRARE), and tourism, culture and space (TERRITUR). The CEG disseminates its research results targeting high impact state-of-the-art journals. At the core of its publication strategy, with special relevance to its internationalization profile, the CEG edits continuously since 1965 the prestigious journal *Finisterra*, which is indexed in the Emerging Sources Citation Index – Core Collection Web of Science, SCOPUS and ERIH. CEG activity focuses on innovation, technology, city transformation and regional transition resulting in valuable knowledge for place-based policy interventions and urban theorization.

The **Centre for Functional Ecology - Science for People & the Planet (hereafter CFE)** is a R&D unit hosted by the Department of Life Sciences of the Faculty of Sciences and Technology of the University of Coimbra that **brings together researchers from all fields of ecology, integrating knowledge from genes to the biome level to disentangle the mechanisms responsible for biodiversity maintenance, and for the composition, structure and functioning of biological communities and ecosystems**. CFE holds a strong commitment to knowledge transfer to the general public and to the productive sector, with emphasis on the sustainability of territories and local communities. CFE is organized in 8 strategic Research Groups: Terrestrial Ecosystems and Global Change; Biodiversity, Conservation and Ecosystem Services; Marine and Coastal Ecosystems; Soil and Freshwater Stress Ecology; Forest Ecology; Forensic Anthropology and Paleobiology; Societies and Environmental Sustainability; and History, Territories and Communities (Nova/FCSH). In

addition, CFE inscribes two cross-cutting thematic lines: the UNESCO Chair on Biodiversity Safeguard for Sustainable Development and the Open Science Line. Members of this thematic line have been recognized as experts, supporting internationally bodies in decision making (e.g. EFSA, IPBES, EU Scientific Forum on Invasive Alien Species, MarTERA ERANET Cofund, IUCN Red List) and being involved in the FCT Thematic Agendas, namely “Agrifood, forestry and biodiversity” and “Circular economy”. The CFE's strategy is to continue to produce high-quality knowledge that truly matters for People and the Planet. The vibrant research dynamic achieved in the past, the incorporation of highly qualified researchers with strong international dimension, the number and quality of published articles and of approved projects, the established synergies with the private sector, and the participation of CFE researchers in international networks, including support in decision making, sustain a greater affirmation of CFE nationally and internationally.

The **Institute of Environmental Health (hereafter ISAMB)** was created in 2013 and recognized by FCT for funding as a research centre in 2014. ISAMB is a structural unit of the Faculty of Medicine, University of Lisbon, devoted to scientific research and training in the realm of Environmental Health (EH). ISAMB's work reflects its commitment towards the national/global EH improvement, through the prevention/reduction of the environmental-related burden of disease and protecting/promoting health and well-being.. ISAMB's five thematic programs are consolidated and managed five Research Groups: RG 1. *'Environment, Family Health and Society'*: healthy & active ageing, climate change, family health across lifespan & life-work perspectives, and vulnerable groups (special focus on health inequities). RG 2. *'Supportive Environments'*: impact of green-inclusive cities on health, smoking prevention/control initiatives, food promotion & interventions, physical activity promotion interventions, as well as digital health supportive environments. RG 3. *'Environment and Non-Communicable Diseases'*: environmental factors with potential to influence health/well-being, with emphasis on main non-infectious diseases/conditions, and new or improved diagnostic/therapeutic strategies integrated in healthcare practice. RG 4. *'Environment and Infectious Diseases'*: vector borne diseases (HIV/HIV-2 & associated infections), antiretroviral treatment, climate variation associated with agent-host infectious disease dynamics and impact of extreme weather events. RG 5. *'Eco-genetics and Human Health'*: relevant health behavioral risk factors (diet, tobacco, alcohol & coffee consumption), surrounding factors (e.g., light, noise), and environmental exposure to virus. Scientific research of each RG is complemented and integrated by two recent research labs: the “Environmental Health Behaviour (EnviHeB) Lab” and the “Environmental Health Microbiology (EnviHealthMicro) Lab”. Each lab is devoted to specific research objectives with cross-sectional relevance for the five RGs. ISAMB takes advantage of its privileged integration within the largest medical school and university hospital in Portugal for interconnections such as: i) public health, comprising the complementary perspectives of disease prevention, health protection/promotion, ii) specific clinical areas (ranging from non-communicable to infectious or work-related diseases), and gene-environment interactions (epigenetic processes).

Concept of TERRA

All landscapes record a history, and are nowadays mosaics of interconnected natural, semi-natural, forest, agricultural, human and urban ecosystems, crossed by river networks and bordered by coastal areas, and most are shaped by the millenary and ongoing human land uses and management activities.

. Both managed and unmanaged ecosystems deliver multiple services based on ecological linkages at different scales. The sustainable provision of ecosystem services (water and other non-biotic materials, agricultural crops, livestock, wood and non-wood forestry products, fish and sea harvest) depends on how ecological integrity is maintained, at multiple scales. A delicate balance occurs between the ecosystem's built-in capacity to provide those services (soil, forests, agroforests and other landscapes, rivers, lakes and sea) and societies' demands. Environmental and mental health also profoundly depend on a good environment, both biotic and abiotic.

Managing natural resources, the environment, and the territory to deliver agricultural and forestry healthy food products within planetary boundaries, is a question that ranks high in research agendas and policy priorities. How such natural resources are managed, in the agro-food system, directly impact the ecological dimension, including their availability and quality, or their impact on climate change. Social dimensions such as rural territories' dynamics affect the livelihoods of farmers and communities and influence the use of landscape and rural life. There is a growing demand for a comprehensive assessment of the human health implications of these transformations, ultimately required by decision-makers. Truly embedding human societies within the

ecological framework (e.g. ecological agricultural intensification, agroforestry, short product-supply chains, green cities or nature-based engineering) and using emergent technologies (e.g. remote and precision tools, Decision support systems at farm/industry and landscape scales, genomic-based tools or artificial intelligence), is the way to move forward to build a resilient future for mankind and anthropogenic landscapes, paving the way for more efficient and sustainable farming. In addition, products from terrestrial and aquatic ecosystems enter often complex processing chains such as wood, food, feed or other raw materials. An exciting array of new developments are modifying these activities, e.g. new chemicals and endogenous genetic resources, products and value chains for bio-based markets, novel food trends and social attitudes, many profoundly linked with human health and nutrition, while environmental concerns become guidelines, e.g. eco-efficiency, 4R implementation, life cycle assessments. Implementation of this knowledge guides the food industry in playing a role in the reduction of environmental impact of human activity.

Sustainable ecosystems and land use should build on knowledge, data and evidence, both empirical and predictive simulations, to allow for an adequate and adaptive multilevel land management. Present times encompass a digital transformation that will shape the way we manage the land, the industry and natural ecosystems, also shaping our behaviors and introducing profound changes in human societies, promoting citizen science and engagement, with strong societal consequences.

Uniqueness and complementarity of TERRA

The five research centres joining TERRA are complementary in the knowledge they currently produce, and unique in scope. CFE deals mostly with ecosystem services and ecological management, CEF is mainly dedicated to forest environments and product chains, LEAF has a strong expertise in agriculture, agro-food and landscapes, CEG is a leader in territorial and human society planning, and ISAMB focus on the interactions between human health and the environment (Figure 1). Key-words for the TagClouds were obtained from the most cited of five key-words obtained from each researcher that integrates TERRA. Therefore common research traits pop-up in the pooled Cloud. Please note the expressions food security, planning for sustainability, forest management and crop production, global changes, epidemiology and human well-being and ecosystem services, and biodiversity.

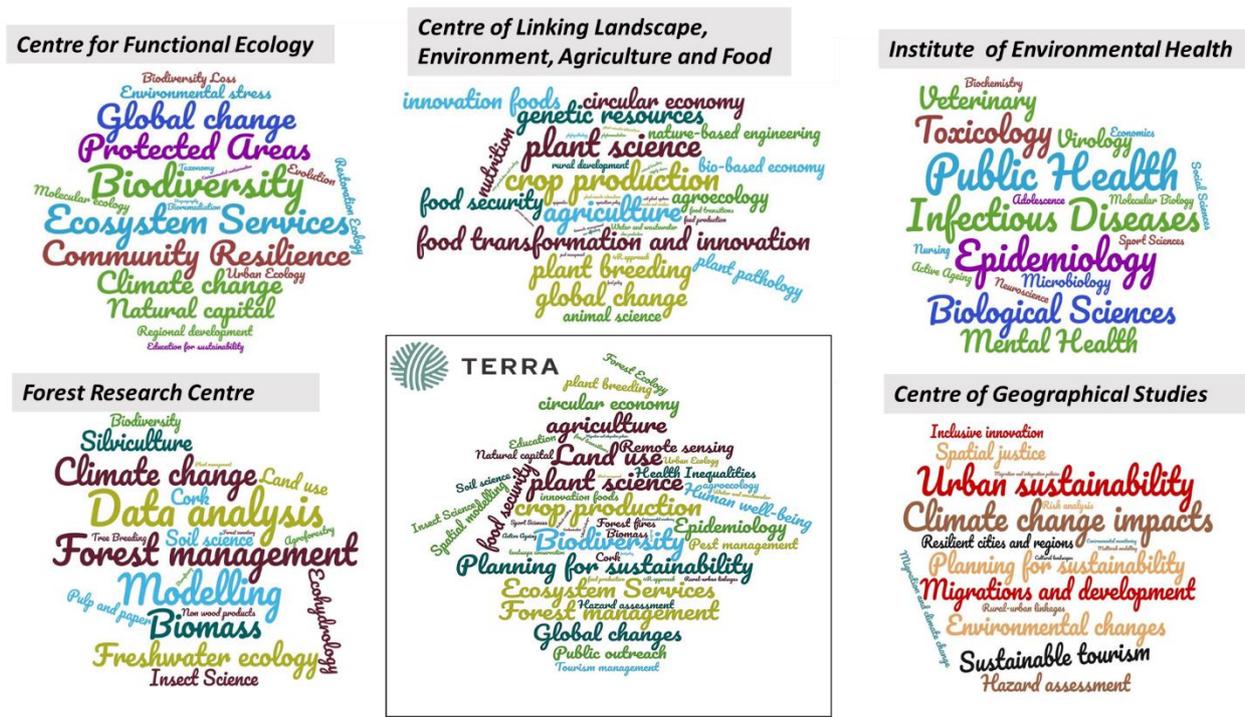


Figure 1. Tag Clouds representing the expertise of the five research centres that integrate the TERRA consortium, and the joint competences of the TERRA Associate Laboratory (bottom, center)

The partial overlap of subjects considered from different perspectives, and a **common language concerning the need for sustainability in the use of the land** (both from the ecosystem's, and human point of view),

will foster synergies and interdisciplinarity, and will produce the best combination to support public policies and strategic development related to the subject of study. Therefore, while the expertise of the five research centers is highly complementary and synergistic, there is a solid common ground to build upon and strengthen the most needed bridges among such complementary views of the global challenges ahead.

The thematic scope of TERRA encompasses the human journey and footprint in global ecosystems, and research led by TERRA centres has wide temporal (human development from the origin), and spatial (local to European data and joint experimentation, and beyond, via research networking) dimensions. Such broad experience is a most valuable asset when supporting public policies and streamlining effective and timely advice.

The experience of the researchers encompasses the entirety of the Portuguese territory; however, TERRA has **a strong territorial focus in the Central and Southern parts of Continental Portugal, involving all its ecosystems, land uses, management practices, historic-societal context, and territorial aspects, as a living Lab.**

2. TERRA researchers and researchers' management

The five Centres are embedded in the research universities of Lisboa and Coimbra, and present a strong composition of researchers in academic careers (Table 1). By dedicating a part of their time to teaching, TERRA researchers contribute towards a more prepared society to deal with the sustainability challenges related to land use and have easy access to recruit young and promising researchers both at national and international levels, *via* the large number of MSc and PhD programs, including some international (e.g. FLUVIO, MEDFOR, VINIFERA, IMAE) or supported by FCT (SUSFOR, DeMIG).

Academic careers also include a relevant number of researchers from technical institutes and other public or private institutions. Many of these institutions do not have research centres and thus the TERRA centres also encourage, envelop and harbor the research activities developed by such members, promoting effective research transfer, e.g. Agriculture or Tourism Polytechnic Schools, European University, Open University, Science Museums and Botanical Gardens, or even Public Administration Institutes. Particularly interesting is the proportion of such researchers in ISAMB, related to the interaction of the centre with human motion, clinical, medical and nursing schools and institutes, public or private, evidencing a strong network and its connections with the case-studies of patients.

Table 1. Research careers in the Centres (in percentage)

	CEF	LEAF	CFE	CEG	ISAMB
Professor contracts, permanent, all types, from the institution	35.2	58.7	28.8	51.7	26.4
Professor contracts, permanent, all types, from other institutions	<1	<1	15.9	26.8	57.2
Research contracts, permanent, including technicians wit PhD	24.9	11.9	<1	<1	<1
Research fixed contracts (early and late stages)	37.9	27.6	37.7	19.4	14.9
Scholarships	<1	<1	16.6	<1	<1

Another important group are researchers with permanent positions, including the technical staff with PhD, collaborating in research development. The group is heterogeneous in provenance, as it depends on the availability of institutional conditions and its historical evolution. In LEAF and CEF, a large number of such positions relate with agrifood and environmental research in tropical areas. An important number of present-day fixed-term research contracts resulted from long-term scholarships. Fixed-term contracts are held by young researchers, who compete for permanent positions, either at the institutions or outside, academic or only research. The potential of these researchers should be highlighted: they have considerable experience and publication track-record, they enhance particular and novel aspects pertaining to the focus of the institutions;

therefore the centres are particularly attentive and there has been a large effort supporting them and obtaining permanent positions. Most of these are obtained in academic careers with teaching component. Fixed-term contracts also include early-stage researchers hired within research projects, usually for 3 years. Scholarships are transitional contracts, and they represent a low number in the centres. These young researchers are recruited usually among recent doctorate researchers, and represent very early stages of their academic career. Nonetheless, they should be encouraged and fostered, attending their needs to develop a research mindset.

3. Plan of contracts and future management of researchers

The management of researchers is different according to their career stage and other commitments. Professors must consolidate their academic positions by developing their own research and the supervision of early researchers and PhD students, with the important task of student selection and recruitment. Long-term researchers should be encouraged to follow their own paths, either in TERRA or in other research Laboratories or in private companies. TERRA has a network of companies, institutions and sister universities and research centres, to encourage the pursuing of such careers. Patents, novel products and services, and their business plans, will be encouraged and supported. Importantly, high-level quality recruitment, especially for permanent positions, will avoid inbreeding, and open positions will follow the highest standards of transparency and fair competition, enabling the recruitment of high-quality researchers from other European countries and other regions.

Selected PhD researchers must have an excellent research track-record and proven international experience. They are expected to be leaders capable of collaboration and innovation and able to develop new lines of research complementary to those already existing. A strong focus on the demonstration of scientific independence will be given, measured by scientific competence, novelty and international recognition, by experience in supervision, and by the competitive research funds attracted.

The five TERRA centres are university-based, and recruitment for career development stems naturally from the academic environment. We expect that many of the young researchers will apply and succeed to obtain positions in the university, either national or international. Nonetheless, the TERRA consortium commits to create 24 new permanent positions for non-academic researchers, within the 5-year horizon defined (Table 2), which is a considerable effort for universities and institutions. The positions will open in the first two years and are expected to become permanent research contracts by 2024 and 2025 after a trial period. Adding to these, there will be a variable number of positions for research technicians, to be open in the 10-year horizon of the Laboratory, for which a reliable prediction is difficult.

Although good facilities and equipment are important, a large part in the success of a researcher is due to a good research environment, cooperative and enthusiastic, and these traits should be replicated in TERRA. Group cooperation will be stimulated, nurturing a highly productive, healthy environment.

Table 2. Permanent contracts to which the TERRA Consortium is committed

	2021	2022	2023	2024	2025
Permanent research contracts in TERRA	30	30	30	30	54
New research contracts resulting from TERRA	12	12	0	0	0

Intra-group and inter-group transfer of research outputs, and the permanent discussion of concepts and results, is the key to new ideas, new analytical approaches and conceptual breakthroughs, ultimately leading to novel solutions for land use problems ensuring sustainability. TERRA will pool together the experience of its centres and create a research environment where people will be happy to show their research and discuss it, with emphasis on multidisciplinary and transdisciplinary subjects, across centres. This will be achieved by i) organization of monthly workshops, seminars and brainstorms using common specific topics, ii) inter-change of researchers between centres, for short stays to develop complementary skills; iii) development of common

research topics along the thematic lines; and iv) promotion of metadata and big data sharing and analysis, to develop novel concepts and testing hypotheses.

4. Interaction with the National Infrastructures Roadmap

Research Infrastructures (RI) are hubs developed to promote research excellence and training of researchers, jointly addressing major societal problems and supporting science dissemination, while increasing efficiency and reducing operation costs for the national R&I system. National RI also play a role in the pan-European RIs, such as those in the ESFRI (European Strategy Forum on Research Infrastructures) Roadmap, and consortia of wider geography. The rationale for the creation of large international articulated and strategic RI resulted in the ESFRI 2002, and later the first European Roadmap in 2006, and the four following it, the later in 2018. The Portuguese Roadmap of RIs of Strategic Relevance (RNIE) currently includes a total of 56 RIs, across six thematic areas (similar to those of the 2018 ESFRI Roadmap). The Portuguese infrastructures Roadmap launched by FCT, has been summarized recently in a document¹. Teresa Ferreira, the Coordinator for TERRA proposal, is National Scientific Expert for RI and co-coordinator of the Monitoring Committee for the RI Environment Section.

TERRA involvement in six RI

The **Collaboratory for Geosciences (C4G <https://www.c4g-pt.eu/pt/>)** is a distributed Research Infrastructure that promotes networking of researchers and sharing of equipment, data, collections and tools in Solid Earth Sciences. C4G comprises disciplines of geology, hydrogeology, geochemistry, geodesy, geophysics, geomechanics, geoinformatics and geomathematics. It provides services in the crosscutting areas of georesources, natural and anthropogenic hazards and the environment, for the Portuguese territory, both onshore and offshore. C4G deals with Seismological data and networks, Rock physics geomechanics labs, Magnetic data and observations Paleomagnetic labs, and applied geophysics. C4G is the representative of Portugal in EPOS (European Plate Observing System), now legally implemented as an ERIC (European Research Infrastructure Consortium), where Portugal is one of the initial signatory countries. CEG is part of this RI.

PORBIOTA <http://www.porbiota.pt/> is the **Portuguese E-Infrastructure for Information and Research on Biodiversity**, a distributed e-infrastructure targeted at mobilising, organising and disseminating biodiversity and environmental data, providing a platform that connects academia, the public administration and the civil society. It fosters biodiversity and ecosystems research, making available high quality knowledge needed to meet societal challenges regarding environmental protection and sustainability. The consortium PORBIOTA includes top national research centres, natural history museums and is engaged with several ESFRI projects and landmarks, like LifeWatch-ERIC <https://www.lifewatch.eu/>, eLTER-RI <http://www.lter-europe.net/elter>, ICOS-ERIC <https://www.icos-cp.eu/>, DISSCo <https://www.dissco.eu/>, and with GBIF <https://www.gbif.org/>. GBIF Portugal platform is located in one of the centres of TERRA. CFE, LEAF, CEF, are involved in PORBIOTA.

The Portuguese Research Infrastructure of Scientific Collections, PRISC (<https://www.prisc.pt/index.php/prisc-homepage/about/>) - is a distributed physical infrastructure aimed at fostering full and open access of all Portuguese scientific collections and associated documentation for the benefit of research, education and culture. PRISC brings together expertise and resources to transform a heterogeneous and dispersed landscape into a coherent and sustainable national infrastructure of high-standard, well-preserved and accessible scientific collections, valuable in a wide range of cross-disciplinary fields. PRISC is a founding member of DiSSCo - Distributed System of Scientific Collections, integrated in the 2018 ESFRI Roadmap GenomePT - National Facility for Genome Sequencing and Analysis (<https://www.genomept.pt/>). CFE is involved in PRISC.

GenomePT National Facility for Genome Sequencing and Analysis (<https://www.genomept.pt/>) is a distributed genome sequencing and analysis RI for basic/applied genome research and advanced services, that potentiate the participation of Portuguese scientists in national and international genome projects, and promotes genome research in health, drug discovery, environment, marine and freshwater resources, agro food

¹ Portuguese Road Map of Research Infrastructures- 2020 update. Fundação para a Ciência e Tecnologia, 24 p.

biotechnology and green chemistry. GenomePT congregates researchers and technical personnel from several national research centers with technological capacity and expertise to sequence and analyze complex genomes. CFE is involved in this RI

ROSSIO – Social Sciences, Arts and Humanities (<https://rossio.fcsh.unl.pt/>) – is a Portuguese reference infrastructure, a platform for dissemination of digital content that provides a distinctive set of sources and resources for Social Sciences, Arts and Humanities (SSAH). ROSSIO mission is to aggregate, organize, connect, contextualize, enrich and disclose resources scattered in educational and cultural institutions. Through an open and free platform, ROSSIO makes available resources and services to be used in cultural and creative industries, stimulating new teaching methods, promoting research development and the internationalization of Portuguese scientific production. CFE is part of this RI.

FNH - Food Nutrition and Health Europe (<https://fnhri.eu/>) FNH-RI is an European research infrastructure for healthy and sustainable diets, consisting of 149 institutes from 24 countries, bringing together the main players – researchers, citizen, data scientists, industry and technology developers – to boost research on eating patterns. It offers standards and procedures for data sharing, and harmonized protocols for tools, facilities and training. Ultimately, the goal is to foster the transition to sustainable food system, the reduction of non-communicable diseases and the engagement of consumer and citizen. A proposal for inclusion of FNH-RI on the [ESFRI Roadmap 2021](#) has been submitted, recently and is currently under review. LEAF is part of this RI.

TERRA will endeavor to consolidate the RI it belongs to, and to make them more open to the scientific community and to society, stimulating their potential to provide services, to support public policies, planning and needs, actively promoting more sustainable land uses.

B. Strategic Planning for supporting public policies

1. Support of upcoming public policies, agendas and initiatives

TERRA will develop strategic lines and support to public policies along five thematic lines, which complement each other, along a gradient from green capital, least disturbed, conservation areas in green, on the left (Figure 2), to more disturbed, used or managed areas, determined by anthropogenic activities, in yellow on the right. While the former is chiefly dedicated to nature preservation and regulating, supporting, ecosystem services, the latter contemplates rules of sustainable use, and provision services, and the ethical and legal obligation of use without deleterious effects to ecosystems. Product value chains, from field to fork, are represented by the following thematic line, and relate to provisioning services. On the other hand, the two upper lines relate to supporting and cultural services, in a more anthropogenic perspective, both for human populations and the territories they use, at the landscape scale.

In that sense, TERRA thematic lines (TLs) encompass i) different levels of anthropogenic impact and land use intensity; ii) different spatial scales , i.e. from local to global approaches, iii) different levels of biological organization, from genes to ecosystems; and iv) different perspectives of environment, from ecocentric (biodiversity conservation and natural ecosystems) to anthropocentric (high population density and dynamics). Together, TLs from TERRA span the full gradient of land use intensity.

The Green Deal

A large number of strategic planning initiatives are taking place in Europe, for the horizon of 2020-2030 and further. Under the scope of TERRA, the most important is **the Green transition**, supported by the **European Green Deal**, boosting the efficient use of resources by moving to a clean, circular economy, and to restore biodiversity and reduce pollution, https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en. Among the policy areas related to the Green Deal,

- **EU Biodiversity strategy for 2030, to protect the environment and preserve biodiversity**, https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/actions-being-taken-eu-biodiversity-strategy-2030_en#key-elements-of-the-biodiversity-strategy
- The “**From Farm to Fork**” strategy, fostering access to healthy, affordable and sustainable food, <https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/actions-being->

taken-eu/farm-fork_en, including reducing the use and harmfulness of pesticides, reducing nutrient supplements and losses

- **Sustainable agriculture** in the EU, fostered by the common agricultural policy and aiming at economic, social and environmental sustainability, <https://ec.europa.eu/info/food-farming-fisheries/sustainability>, with key points of reducing antimicrobials in farmed animals and in aquaculture, and increasing organic farming.
- Climate action, **cut CO2 emissions by at least 55% by 2030**, and ensure that our forests and land contribute to mitigate climate change, <https://ec.europa.eu/clima/policies/>



Figure 2. Scope and relative position of the five Thematic Lines of TERRA

The European policies find echo in legislative and strategic frameworks at country-level. In **Terra Futura** (https://www.gpp.pt/images/Agricultura/TerraFutura_Ebook/), the National Innovation Agenda for Agriculture replicates the Green Deal targets (see pages 6-7), combining the research problems tackled in the TERRA Laboratory centres, e.g. emerging diseases, climate change, scarcity of natural resources, food consumption patterns, urbanization vs rural, and demography patterns. At present, Portugal has 42 national sectoral Plans supporting the EU strategy and **in most areas where TERRA can offer support**, including human health, human inclusion, product income and benefits, innovative materials, adaptation to climate change, carbon neutrality, irrigation, circular economy, biorefineries, and nature conservation.

In what concerns **climate adaptation**, the public policies are packaged in the Strategic Framework for the Climatic Policy (QEPiC) which includes the mitigation and adaptation in different activity sectors. Members of TERRA (Antonio Brito, Teresa Ferreira) have already collaborated in the writing of the first adaptation strategy for water resources, back in 2012. . To implement the present strategy, the follow-up National Strategy for Adaptation to Climate Change (**ENAAC 2020**) is in course, <https://www.apambiente.pt/index.php?ref=16&subref=81&sub2ref=118&sub3ref=955> and members of CEF, LEAF, CFE, ISAMB are involved in the WGs Agriculture, Biodiversity & Forests, and Human Health. Furthermore, CFE and CEG members have experience in the development of local adaptation plans to climate change.

The **Biodiversity Strategy** and the carbon neutral strategy are linked closely to land use, agriculture and forestry, by establishing protected areas, restoring degraded ecosystems at land and sea across the whole of Europe by increasing organic farming and biodiversity-rich landscape features on agricultural land, halting and reversing the decline of pollinators, reducing the use and harmfulness of pesticides, re-wilding and reforestation, restoring connectivity. Other targets of interest are clean energies, sustainable industries, a cleaner

construction sector, sustainable mobility and pollution elimination. TERRA research is strongly aligned with all these public policies.

Horizon Europe, research and innovation

The EU research policy will align these subjects for the EU Horizon 2021-27. The European Commission has just launched a €1 billion call for research & innovation projects funded by Horizon Europe and forms part of the European Green Deal, H2020-LC-GD-2020. In the words of EU Commissioner for Innovation, Research, Culture & Education Mariya Gabriel: “This investment will accelerate a just and sustainable transition to a climate-neutral Europe by 2050.” The call has eight thematic areas including increasing climate ambition, farm to fork, zero-pollution, toxic-free environments and biodiversity & ecosystems. All the TERRA centres are preparing consortium proposals.

Upon analysis of the Green Deal call text from Horizon, in the presently open period for proposals, there will be a strong component of the proposals related to the increased efficacy and sustainability of land use and human activities, and its implementation in practical terms, rather than exploring the theoretical components of the subjects and new experimentation. The TERRA consortium supports a deep understanding of the need to act and to develop a hands-on research attitude, profoundly needed in terms of land use sustainability and adaptation to climate change. In fact, already researchers from the consortium (LEAF, CEF) are linking and acting within European networks such as NEFERTITI FarmDemo, <https://nefertiti-h2020.eu/>, or being actively involved in the definition of EU policies regarding adaptation to climate change (Helena Freitas, CFE, is part of the EC Mission Board for Adaptation to Climate Change).

Societal initiatives

A number of ongoing European Initiatives dealing with sustainability exist within the scope of TERRA.

The agricultural European Innovation Partnership (EIP-AGRI), to which LEAF members belong (André Almeida, Cecilia Rego, David Fanguero, Joaquim Costa, João Paulo Melo e Abreu, Luis Goulão, Paula Alvarenga, Rita Fragoso, <https://ec.europa.eu/eip/agriculture/en/focus-groups>), fosters competitive and sustainable farming and forestry that 'achieves more and better from less'. It contributes to ensuring a steady supply of food, feed and biomaterials, developing its work in harmony with the essential natural resources on which farming depends, <https://ec.europa.eu/eip/agriculture/>.

Other European Innovation Partnership (CEG researchers involved already) is Smart Cities and Communities (EIP-SCC) <https://eu-smartcities.eu/>, working to improve urban life through more sustainable integrated solutions, including applied innovation, better planning, a more participatory approach, higher energy efficiency, better transport solutions, intelligent use of information and communication technologies and more. CFE is actively involved in the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (Helena Freitas is the National Contact Point) and in the International Union for Conservation of Nature (several members of CFE being experts for different conservation target groups, such as birds or fungi).

TERRA will link, or is already linked, to stakeholder initiatives related to sustainability of land and the product chains. One such example is the Business Council for Sustainable Development, and its nucleus in Portugal, gathering companies bringing together professionals from all areas and sectors of activity to discuss sustainable development issues and how they apply to companies' daily lives, <https://www.bcsdportugal.org/en/>. Many companies with whom TERRA is involved (ALTRI, Amorim, Delta, SumolCompal, EDIA, Jerónimo Martins, SONAE, The Navigator Company, Águas de Portugal, Shell Thiogro, PETROBRÁS, DuPont, Danisco, and others) are part of this cluster that aims to accelerate the incorporation of sustainability into business models, and to access to the most recent briefings and sustainability trends. The initiative includes training programs of interest to TERRA university activities.

Assemblages of public organizations, individual stakeholders and companies, and research organizations are the way forward, in a common effort to promote sustainability of human development and behavior, and TERRA is well positioned in such lines of action. For example, the Coalition for Green Growth launched by the government, and its fund-raising platform <https://eco.nomia.pt/>, also gathers companies, research institutions, and institutions aiming at green growth, resource efficiency and environmental protection, circular economy, <https://www.crescimentoverde.gov.pt/pagina-inicial/visao-e-objetivos/>. The dimension, experience and strong critical mass of the Laboratory TERRA will enhance its

capability to engage in such initiatives, especially important for the researchers wishing to pursue professional careers in a company environment and promising fields of action for Earth sustainability.

In summary

A strong worldwide conviction exists that the current patterns of land use and resource consumption are not sustainable and show clear signs of rupture. In a unique feature documentary, David Attenborough, the celebrated 93 years-old naturalist, reflects in the film *A Life On Our Planet* upon the devastating changes he has seen during his life span. The associated interview <https://youtu.be/Li5Xi9mIvDg>, is a testimony of the need to adopt different approaches and solutions for land use, to stop such devastating and unsustainable trends.

The scope of TERRA is at the centre of important public policies and planning, both Portuguese and European. The research areas that TERRA aims to develop are crucial for the land, natural capital and natural resources, and determine the well-being of human populations sharing the landscapes, and its activities.

Briefly, at **the national level**, and most notably in Central and Southern Portugal, the TERRA Lab can support the national policies for agriculture and forestry, fisheries and national conservation, environmental human health, and human development, with all the tools and knowledge available, and more to be developed, social sciences and humanities will be crucial to narrowing our understanding of the drivers and causes of biodiversity loss.

On the **European context**, the Lab TERRA through its centres, already has strong links to the Green Deal, either using research funding channels (e.g. Horizon's Green Deal); or being involved in networks, such as the European Research Alliance ERA Pesticide Free, <https://www.era-pesticidefree.eu/>; or by joining the European Innovation Partnership for Agricultural productivity and Sustainability (EIP-AGRI), launched in 2012 with the task of contributing to the European Union's strategy 'Europe 2020', and to nurture smart, sustainable and inclusive growth <https://ec.europa.eu/eip/agriculture/en/about>.

On a **wider context**, the TERRA Lab focus is deeply framed by the United Nations SGDs related to the same topics (UN Goals 3, 6, 10, 11, 12, 13, 14, 15), with several members of TERRA (CFE, CEF) involved in the evaluation and implementation of European instruments to tackle the SDGs (e.g. H2020-SC5 proposals).

Considering the support to public policies, a two-way route will exist, namely: from the demand of the decision-makers to TERRA and its advisory boards (permanent or temporary), and from the TERRA research outreach to public needs. In time, we will strengthen a praxis of **combined translational approach** (Enquist et al., 2017)² where ecologists, stakeholders and decision-makers work collaboratively to co-develop ecological research via joint consideration of the sociological, ecological and political problems, leading to an improved environment-related decision-making.

2. TERRA Strategic Plan for the next decade

2.1 Thematic lines overview

There will be five thematic lines (hereafter TL) in TERRA, with specific goals and areas of influence. Because the five centres are complementary, the researchers have joined these lines individually and according to their principal research areas, such that the TL are transversal to all centres (Figure 3). This arrangement will promote different approaches of study for the same topic to be used for improved problem-solving, encompassing not only the physical and biological (non-human) aspects, but also the human and societal (collective) activities, and spanning spatial and biological scales from populations to landscapes and communities. This approach will promote the interdisciplinarity of solutions and vision, and will foster research cooperation.

TL will be the core of the response of TERRA. We expect that the calls for support will be

² Enquist, Carolyn AF, Stephen T. Jackson, Gregg M. Garfin, Frank W. Davis, Leah R. Gerber, Jeremy A. Littell, Jennifer L. Tank et al. (2017). Foundations of translational ecology. *Frontiers in Ecology and the Environment* 15, (10): 541-550.

- a) To aid the solution of pressing issues, by understanding, contextualizing and framing them in a societal and historical perspective, e.g. rural fires, disease outbreaks, toxicity and health issues, environmental pollution events, social movements across landscapes, communication frontiers,
- b) To support strategic needs for global policies and their national counterparts, or specific programs and strategies to be developed, such as water resources for irrigation, river restoration planning, definition of incentives for afforestation /reforestation or policies to support the reduction of the carbon footprint.

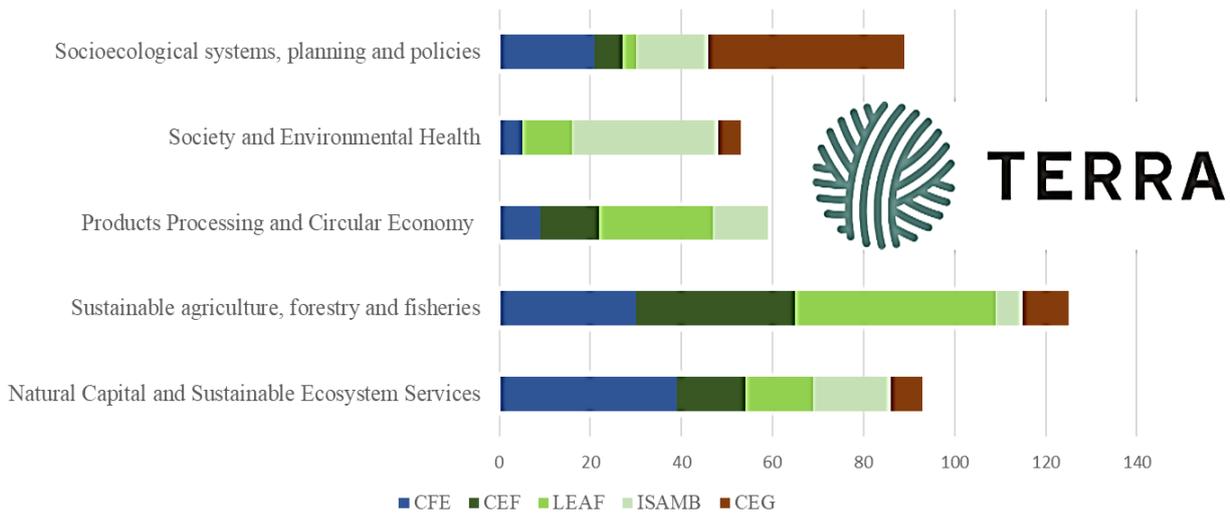


Figure 3. Distribution of researchers from TERRA centres in the Thematic Lines

For both situations, **we will likely need specialized advisory teams covering the different aspects of the topic.** For example, the support of a tailored plan for the response to rural fires may include researchers with expertise on risk assessment, rural demography, water pollution control and forest biomass utilization. The support of a policy to define an action plan for wastewater use in various contexts may need public health researchers, agriculture experts, natural resource economists, and soil ecologists.

The governance and response flow-chart of TERRA will be addressed in chapter C. The aim is to create a light and highly interactive governance structure, able to respond quickly and dynamically, to the needs of public policies, culture self-understandings and environmental and societal problems.

2.2 TL 1 Natural Capital and Sustainable Ecosystem Services

Coordination: Helena Freitas, CFE; Co-coordination: Teresa Ferreira, CEF; César Capinha, CEG; João Loureiro, CFE

The growing human population and increasing demand for food, fibre and energy are increasing the pressure on ecosystems, globally. Natural capital, the Earth’s natural assets, including soil, air, water, and living organisms, existing as complex ecosystems, provides a range of services to humankind. Depleting and degrading these natural resources may irreversibly impact the present well-being and the future of humanity. This research line brings together researchers from different backgrounds and a broad range of expertise **to explore the inter-links between biodiversity, ecological resilience, and nature's contributions to people well-being and its societal embedding.**

Our research and outputs intend to provide a clear mechanistic understanding of all current threats to biodiversity in terrestrial, freshwater and marine environments, their impacts on ecosystem functions and ecosystem resilience, how land and ecosystems are and should be used, and effective ways to mitigate and reverse those impacts, including to develop the sustainable use of ecosystem services. Researchers in this line integrate knowledge across all levels of biological organization, from genes to the biome level, aiming to disentangle the mechanisms responsible for long-term biodiversity maintenance and its effects on community functioning and its links to the sustainability of regulatory and provisioning ecosystem services. For this end,

we work intensively towards the develop of more informative indicators that will allow better planning and monitoring the effectiveness of targeted conservation measures, adequate establishment and management of protected conservation areas, and the identification of nature based solutions, as well as solutions based on ecosystem services, while contributing to the national policies regarding natural resources through working closely with relevant stakeholders.

This thematic line aims to explore the inter-links between biodiversity, ecological resilience, and nature's contributions to people well-being. The research and outputs of this TL intend to provide a clear mechanistic understanding of all current threats to biodiversity in terrestrial, freshwater and marine environments, their impacts on ecosystem functions and ecosystem resilience, and effective ways to mitigate and reverse those impacts, including developing the sustainable use of ecosystem services. This TL will work towards increasing the knowledge and critical understanding of the current patterns of biodiversity, contributing to an integrated view of the conservation of endogenous genetic resources towards a more sustainable agro-environment.

Members of this thematic line have been recognized as experts, supporting internationally bodies in decision making (e.g. EFSA, IPBES, EU Scientific Forum on Invasive Alien Species, MarTERA ERANET Cofund, IUCN Red List) and being involved in the FCT Thematic Agendas, namely “Agrifood, forestry and biodiversity” and “Circular economy”.

2.3. TL 2 Sustainable agriculture, forestry and fisheries

Coordination: Margarida Tomé, CEF; Co-coordination: José Luís Zêzere, CEG; Carlos Lopes, LEAF; José Paulo Sousa, CFE, José Guilherme Borges

The present world faces the challenge of reconciling what seems an impossible task: to fulfil the demands of a growing population while maintaining the quality of environment in order to guarantee the future of Humankind. This research line will focused on developing innovative community-based approaches for harvesting food, wood, fibre and wildlife materials from land, coastal areas and sea while safeguarding the integrity of natural biological resources in these ecosystems in order to address intergenerational societal needs and demands.

Land and landscapes are mosaics of interconnected natural, semi-natural, forest, agricultural and urban ecosystems crossed by river networks and bordered by coastal areas. Recognizing the spatio-temporal interactions of management options on each unit in the landscape mosaic over extended time-frames is key to the development of innovative land use strategies. Likewise, these strategies must take into account the impact of global changes on the outcomes of management options at lower organization levels. Making natural resources sustainable is a thus huge societal and research challenge, as land and water management are becoming more complex under a dense network of human activities, and there is a plethora of stressors acting simultaneously, across regions and economic sectors, with feedback loops at different spatial and temporal scales. Sorting out complex scenarios of land use and finding innovative and nature-based solutions, enhancing ecosystem services (e.g., biological control of agricultural and forest pests) and reducing or mitigating disservices (e.g., rural fires), requires a holistic collaborative and multidisciplinary approach to landscape-level decision-making that may engage natural, engineering and social sciences and humanities.

Strategic Line 2 will be developed and implemented by a multidisciplinary team that will conduct research of innovative community-based approaches and interdisciplinary solutions that may strike the right balance between the extraction of economic goods from natural systems - to fulfil increasing social demands – and the maintenance of the ecological capacity to provide them. The underlying goal of maintaining biodiversity and ecological integrity will be achieved if hazards – such as pests and diseases, drought and fire – can be understood and controlled. Thus, SL2 will build from this understanding to develop its innovative approach. Adaptive management and ecosystem management planning at several spatial scales requires constant ecosystem monitoring, good predictive models to guide decisions and target indicators to support such guidance. SL2 will integrate these models and indicators within innovative collaborative management planning methods aiming at increasing the efficiency and effectiveness of its interdisciplinary approach.

Topics developed include production efficiency vs. marginal environmental costs, agroecology, land sharing versus land sparing, trade-offs between production and other ecosystem services. Stakeholder and administration involvement are key-factors in this optimal decision-support process leading to land

management planning models, integrating activities of landowners and land managers, community representatives, public administration and policy makers.

Members of this TL developed predictive models currently used in forestry and in crop production, and that have contributed to increase efficiency in the use of natural resources characteristic of present production systems, when only product yield is considered. They have also been deeply involved in parallel approaches developing close-to-nature practices with reduced ecological footprint of productive systems, in line with the major current public policies. They have further been involved in the development of decision support tools that encapsulate the state-of-the-art in ecosystem modeling and collaborative management planning methods to analyze ecosystem services provisioning at landscape scale under global climate and market change scenarios. Members of the TL are involved in the Standing Committee on Agriculture Research SCAR AKIS of the European Commission, in ERASMUS plus TRANSPEER for exchange of Good Practices, in the European Research Alliance towards a chemical free agriculture, in the European Innovation Partnership EIP-AGRI, Skan NETWORK for sharing Agrifood Knowledge, RAMIRAN, network on recycling agricultural and industrial residues, AGRINATURA, The European Alliance on Agricultural Knowledge for Development: They are coordinators of several units of the International Union of Forest Research Organizations. They have contributed to the development of national and international research agendas on topics relevant to ST2 as well as to the development of national policies, e.g. for biodiversity, climate change adaptations, wildfires, agrifood strategy, forest and water instruments of planning.

2.4. TL 3 Products Processing and Circular Economy

Coordinator: Isabel Sousa, LEAF; Co-coordinators: Jorge Canhoto, CFE; José Carlos Rodrigues, CEF

The target of this Thematic Line is the **sustainable processing to reduce the environmental impact of land use and generate eco-friendly products**. To achieve this, circular economy (CE) principles and tools are crucial. The 4.0 digital revolution will increase communication and information flow to enable application of CE principles (e.g., clustering, cascade processing), aiming at optimal use of the resources, materials and energy included, towards the minimization of waste. This thematic line gathers a multidisciplinary and complementary body of scientific expertise, from food, chemistry and engineering to human health, converging to work for these principles in line with national policies and attentive to the Europe Green Deal and main targets for 2050, keeping in mind the urging Sustainable Development Goals for 2030.

Our researchers have a track record on alternative sustainable sources of food with impact on health, from new to under exploited sources (e.g., macro and microalgae, starch sources like acorns, rustic pulses like lupins), as well as by-products from the food industry (e.g., beer spent grain- dreche, tomato pomace, rice bran, whey, hominy feed). Either by using as feed, but increasing the value by reintroducing it on food chains as well. Likewise, we are deeply involved in translation of knowledge to industry to foster innovation by direct cooperation and joint R&D&I projects, in support of inclusive, resilient and sustainable industrialization.

Most of our researchers have strong links with to the professional associations and companies, working closely with relevant stakeholders, and actively contributing to decisions regarding national policies, with an emphasis on the priorities identified in the FCT Thematic Agendas, namely “Agrifood, forestry and biodiversity” and “Circular economy” for which some of our researchers contributed.

2.5. TL 4 Society and Environmental Health

Coordinator: António Vaz Carneiro, ISAMB; Co-coordinators: Anabela Raymundo, LEAF; António Lopes, CEG; Andreia Costa, ISAMB

This research line embraces a broad perspective of environmental health, oriented to pursue an *adequate balance between human health and environmental sustainability.* Environmental Health is defined as the assessment and management of ‘modifiable’ environmental influences from chemical, physical, biological, digital, social, and psychological factors on human health and well-being, as well as on the assessment and management of behavior related to the physical, social and cultural environment. It is concerned with *all aspects of the natural and built environment that may affect human health*, from the earliest stages of development throughout life. The overall aim of Line 4, /“Society and Environmental Health”/ is inform decisions (at political, societal, scientific, among other levels) resulting from or impacting on interactions

between the physical and social environments and, on this basis, to develop preventive and sustainable approaches for humankind and the planet).

Among relevant lines of action, this TL will deal with the environmental factors that influence mental well-being, namely sound intensity, air and water quality, environmental borne diseases, the effects of old and new food products and diets on human health, the toxicological effects resulting from the inappropriate forms of land use, and direct toxicological effects resulting from harvested products and the transformation of these.

2.6. TL 5 Socioecological systems, planning and policies

Coordinator: Mário Vale, CEG; Co-coordinator: José Miguel Pereira, CEF; Paulo Nogueira, ISAMB

Understanding socio-ecological systems requires the integration of knowledge across different scientific areas. In the Anthropocene, environment, culture and societal integration in space and place is gaining momentum in academia and in the policy arena. As more people are moving to live and work in cities, combined with high-consumption economic processes and lifestyles, much of this urbanisation process follows unsustainable development paths. Thus, this research line will address **climate change impact on society, and adaptation and disaster risk management, intertwined with societal and cultural dimensions in space and place, examining opportunities for changing** entrenched resource-intensive patterns of contemporary society. Since **cities and rural areas** are parts of sub-national, national and supranational entities, depending on them for many critical functions (economy, finance, mobility, environment, rural-urban interaction, etc.), political and governance structures play a key role in sustainable transitions.

The policy relevance of this research line is underpinned by the Sustainable Development Goals (2015) <https://sdgs.un.org/goals>, the Sendai Framework for Disaster Risk Reduction (2015) <https://www.undrr.org/>, the Paris Climate Agreement (2015) <https://unfccc.int/>, and the New Urban Agenda (2016) <https://habitat3.org/the-new-urban-agenda/>, as well the recent EU Green Deal, <https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/>. The research line will inform decision-making processes to achieve more sustainable and inclusive regions and cities, engaging with public authorities and civil society in the co-producing of development policy analysis and guidance and integrated spatial planning recommendations. In concrete, it will give support to the National Program for Spatial Planning Policy (PNPOT), National Plan for Integrated Management of Rural Fires (PNGIFR), strategies and plans of climate change adaptation, among others. It will also contribute to the advance of the national thematic agendas of Research and Innovation (Urban Science and Cities for the Future; Agrifood, Forests and Biodiversity; Tourism, Hospitality and Leisure Management; Social Inclusion and Citizenship).

3. Success in supporting public policies and societal challenges

3.1 TERRA experience “in support of public policies and administration”

International and national panels and missions

The centres from TERRA are engaged in a number of panels and missions.

CEG conducts research in collaboration with ESPON, DGRegio, RIDOT-Iberian-South American Network for Territorial Analysis, RSA network, IMISCOE Research Network, EPB, COMNAP and FARO, SCAR, IASC, EGU. Particularly important is the coordination of the Portuguese Polar Program – that promotes and manages access of national researchers to both Polar regions, supporting a total of 98 projects, 168 researchers and 9 flights to Antarctica in 2012-20. CEG participated in the co-organization of major international events (e.g. EUCOP4, ATLAS conference-2015, V Workshop RIDOT-2015, 12th International Symposium of UPEA-2016; Annual congress of AESOP-2017). CEG provided scientific support in the environmental, social and spatial domains to accountable national public bodies (e.g. Ministry of Environment, Spatial Planning and Regional Development, PNRRC-National Platform for Disaster Risk Reduction, adapt.local-Network of Municipalities for Local Adaptation to Climate Change, ICNF-Institute for Nature Conservation and Forests, IHRU-Institute of Housing and Urban Renewal, ACM-High Commissioner for Migrations, CIG-Commission for Citizenship and Gender Equality, CCDR-LVT-Commission for Coordination and Regional Development of Lisbon and Tagus Valley). CEG has also collaborated with several municipalities, supporting several local

authorities in domains such as climate change adaptation, risk management, social inclusion, demography, housing, mobility, strategic planning.

CEF has been involved, through its members, in the coordination boards of one division and seven units of the International Union of Forest Research Organizations (IUFRO), e.g. Div. 4 Forest Assessment, Modeling and Management and its units Sustainable Forest Management Scheduling and Large Scale Forest Inventory and Scenario Modeling, as well as Div. 5 unit on Edible Forest Products, Div. 7 unit on Integrated Management of Forest Defoliating Insects, Div. 3 unit on Operations Systems and Analysis and Modeling and Div. 1 units on Silviculture and on Short Rotation Forestry. CEF participates in several advisory boards (e.g., European Forest Institute as well as its Mediterranean and Atlantic regional centers, International Savanna Fire Management, European Agroforestry Federation), the co-founding of SIADEB (Sociedade Ibero Americana para o Desenvolvimento das Biorefinarias) as well as the participation in several evaluation boards of the EU ERANETs, FP7, H2020, Marie Curie and Cost Actions programs and of other national research funding organizations in Europe, Asia and America.

CFE supports international bodies in decision making (e.g. EFSA, IPBES, EU Scientific Forum on Invasive Alien Species, MarTERA ERANET Cofund, IUCN Red List). Helena Freitas is the national contact point of IPBES, and a member of the EC Mission Board for Adaptation to Climate Change. JP Sousa represents Portugal in the European Food Safety Authority. CFE members belong to the International Evaluation Boards (EU Horizon 2020, Marie Curie, GACR, EEA Grants).

LEAF members are part of International Networks or Expert Panels (e.g. COST Actions, EIP-AGRI Focus Groups, EUFRIN, OENOVITI, WINETWORK, SCAR AKIS, Task Force on Reactive Nitrogen, IOBC-WPRS Groups). LEAF members have relevant roles in **international organizations and networks**, e.g. FAO – Forestry Genetic Resources, European Fruit Research Institutes Network (EUFRIN), European Network for Algal-Bioproducs, European Cooperative Program for Plant Genetic Resources, “IUCN Species Survival Commission (SSC) Macaronesian Islands Plant SG (MIPSG)”, Iberoamerican Network VALORAL, Rede Ibero Americana de Energia y Nuevas Tecnologias de Tratamiento de Biosólidos (RIENTTB) or the Programa Ibero Americano de Ciencia y Tecnologia para el Desarrollo (CYTED), the Sharing Knowledge Agrifood Networks (SKAN-CPLP), Industry-Academia Partnerships and Pathways (IAPP)-Marie Curie Actions. Highlighted is the networking around grapes and wine (e.g. GENET experts group at the Organização Internacional da Vinha e do Vinho (OIV), Vinifera Euromaster, OENOVITI International, ALABE - Associação dos Laboratórios de Enologia). **At national level**, LEAF coordinated the “Rede Inovar” and, inter alia, is engaged with Rede Rural Nacional (Innovation group), Portuguese Horticultural Association, and Rede Campus Sustentável.

Strategic agendas and Advisory Councils

TERRA researchers have been involved in a number of **National Research & Innovation Agendas, from FCT - Science and Technology Foundation** (Resolução do Conselho de Ministros n.º 32/2016) in the working groups. The more important participation was probably in AgroFood, Forests and Biodiversity Agenda, where CEF elements (Margarida Tomé, Teresa Ferreira) acted as group coordinators and writers (Margarida Tomé, Teresa Ferreira), besides other working group participations. Other agendas where TERRA researchers have been involved include Climatic Change (CEG), Urban Science and Future Cities (CEG), Circular Economy (LEAF, CFE), Tourism Recreation and Hospitality (CEG), Social Inclusion and Citizenship (CEG) and Health, Clinic Research and Translation (ISAMB). CEF was also involved in the development of International Research Agendas, e.g., Mediterranean Forest Research Agenda 2010-2020 by the European Forest Institute and the Forest Technology Platform (José Borges).

National and Regional Councils are important structures that advise Ministries and Secretaries of State in their respective political Agendas. Members of TERRA also participate or have participated in activities of such structures. Particular focus should be given to advisory activities and support for the National Water Council (CEF), Regional Water Council of Tejo and of Algarve (CEF), the National Forest Council (CEF), the National Education Council (CEF), the National Irrigation Council (LEAF), and the National Economic Council (LEAF). CFE has the Presidency of the thematic panel of Plant Health and the Council for OGMs of ASAE (Autoridade de Segurança Alimentar e Económica), and is a member of its Science Council.

Teresa Ferreira (CEF) is a **member of the Science Council of FCT**- Foundation for Science and Technology, Natural Sciences section, and a member of the National Science Council of INRAE, Institut National de la Recherche Agronomique et Environnemental. TERRA members cooperate in international Advisory Boards for example, JP Sousa from CFE in EFSA, European Food Safety Authority, M. Tomé and M. Branco from CEF in EFI regional centers, J. C. Pereira from CEF in the International Savanna Fire Management and J.G. Borges also from CEF in the Forest Science and Technology Centre of Catalonia.

LEAF members were engaged in the following policies: Landscape planning - revision of National Ecological Reserve (REN) and PNPT and on criteria to tax rural properties. Agriculture - grapevine breeding and support to public policies, such as the RESOLUTION OIV-VITI 564A-2017 (OIV process for the clonal selection of vines) or the OIV process for the recovery and conservation of the intravarietal diversity and the polyclonal selection of the vine in grape varieties with wide genetic variability; participation in the National Confederation of Farmers CAP Strategic Plan; political resolutions concerning public procurement in food short supply circuits; action Plan for *Drosophila suzukii* control (plant protection). Forestry - elaboration of the Operational Program for Public Administration for Conservation and Breeding of forestry genetic resources – PROGEN, participation in the National Technical Commission “Wood” - sub-commission 3 on wood preservation. Food - Technical Commission for Normalization of Essential Oils under the scope of ISO, scientific cooperation under the cope of ASAE as EFSA’s focal point. Scientific Policy; national delegates in the EC SKAR-AKIS (Agriculture Knowledge and Innovation Systems) Working Group and in the High Level Policy Dialogue Working Group on “Science, Technology and Innovation for Food and Nutrition Security and Sustainable Agriculture” in EU-Africa cooperation; an European Commission initiative towards a jointly funded EU-Africa Research and Innovation Partnership. LEAF holds coordination roles in European Commission Service contracts (managed by Agrinatura) aimed at supporting scientific policies, such as the “Nutrition Research Facility” or the “Capacity Development for Agricultural Innovation Systems”.

CEF (Margarida Tomé) belongs to the Fórum da Sustentabilidade, an initiative of the NAVIGATOR Company to promote dialogue and cooperation with the stakeholders to promote sustainability and of the New Generation Plantations, a WWF platform to promote a new way of managing plantation that benefit the environment and communities.

Due consideration is given to diets as a key driver of nutritional status, but also to the social determinants of nutrition and aims to facilitate better connection between research and decision-making by strengthening the dialogue in a way that is useful for policy development and programming. Given the planetary challenge of eradicating malnutrition in all its forms for the attainment of many SDGs, the EU Farm to Fork Strategy for a fair, healthy and environmentally friendly food system, positions nutrition and healthy diets as a key focus of international cooperation. Under the EU Action Plan on Nutrition (2014-2025), a growing body of evidence shows that accelerating progress in fighting malnutrition requires improvement in the design of nutrition public policies, programs, and interventions that are adapted to countries’ institutional contexts. LEAF members are engaged with the EU “Nutrition Research Facility (NRF)”, implemented by **Agrinatura**, established in 2020 to provide evidence-based research and M&E expertise to the Commission, EU delegations (EUDs) and partner countries. NRF deals with questions on nutrition-sensitive interventions arising from various sectors of activity.

Supporting Directives and its implementation

Water Resources Planning has a European legislation framework set in motion in 2000 under the Portuguese European Presidency. The transposition of the framework to Portuguese legislation has boosted an unprecedented amount of work related with water planning, either collection, systematization and consolidation of basic data on aquatic ecosystems as on water resources. LEAF and CEF members have been very actively involved in water resources planning, in the implementation of water governance (AG Brito LEAF), in the development of the official indices and manuals of ecological quality for Portugal, in the leadership of the common quality intercalibration exercise for the Mediterranean region (T Ferreira, CEF). Members of CEF have participated in all of the Water Resources Planning exercises, and as advisors of regional and national water administration.

Members of LEAF, CFE and CEG (Dalila Espírito-Santo, José Carlos Costa, Carlos Neto) have been deeply involved in the **European Red List of Habitats**, (re)published in 2017, with reviews of the status of all natural and semi-natural terrestrial, freshwater and marine habitats and highlights the pressures they face,

https://ec.europa.eu/environment/nature/knowledge/redlist_en.htm. In addition to the assessment of threat, a unique set of information underlies the Red List for every habitat: from a full description to distribution maps, images, links to other classification systems, details of occurrence and trends in each country and lists of threats with information on restoration potential. This information is used to monitor habitat changes and assist policies aimed at ecosystems preservation. LEAF, CEF and CFE members are involved in the Red Books, notably the **Red Book of Portuguese Vascular Plants** and the Red Book of Freshwater Fish, <https://listavermelha-flora.pt/inicio> and <https://livrovermelhodospeixes.pt/>. Since 1994, LEAF researchers have been developing and updating the Portuguese Flora Red List, and to monitor and map Natura 2000 Sites, **contributing to assist ICNF in sectoral policies** to preserve and restore biodiversity and ecosystems. Recurrently, ICNF uses LEAF research expertise to elaborate the Sites management plans (currently 9).

Collaborative Laboratories

Collaborative Laboratories are structures based on shared funding, sponsored by FCT, that gather companies and researchers from different centres around a topic of interest. The final purpose is to solve problems, or to develop new products or processes that companies need or can implement. TERRA institutions are an active part of FOUR Collaborative Laboratories. The experience is quite valuable, as it is a heart link between university and companies.

CECOLAB – Collaborative Laboratory Towards Circular Economy (<http://www.cecolab.pt/>), a private, non-profit institution, headquartered in Oliveira do Hospital, in the Central region of Portugal. Founded in 2020, the Association started its activities in February 2020. This CoLAB is built over a consortium within which successful collaborative R&D&I activities are already well established, and will now be expanded to a much broader multidisciplinary and holistic approach to tackle circular economy challenges. CECOLAB develops sustainable Circular Economy market solutions, on the value chains that are the focus of the collaborative laboratory, with a spillover effect upon other value chains of the Portuguese economy. The CECOLAB aims to create an innovation-friendly environment that facilitates great ideas to be turned into products and services. Its mission is to provide high quality innovation management consulting services, advice and knowledge transfer to corporations, investors, governments and universities, adding value and enabling economic growth at all levels.

Colab4Food (<https://colab4food.com>) (CFE) has a clear purpose to redefine the way we innovate collaboratively between academia and industry for a sustainable growth and competitiveness of the sector. Colab4Food combines expertise and creativity to develop more sustainable food processes to reduce their carbon footprint, innovative and nutritious foods for consumers delight, health and well-being as well as tailored services for our associates and customers to boost their turnover. The main goal is to bridge the science and knowledge available in the Portuguese academic entities with its own highly qualified team and the applied know-how and market needs of the agri-food industry. Conversely, Colab4Food aims to scale up the knowledge from academia to implement efficient technology transfer processes for solving prevalent industrial needs.

CoLAB VINES&WINES (<https://www.colabvinesandwines.pt/en/#about>), an initiative led by ADVID – the Association for the Development of Viticulture in the Douro Region, which is the national Vine and Wine Cluster, together with the Portuguese viticulture ecosystem, aims to be the ideal partner in the innovation of products, processes and services of companies in the Portuguese wine sector. The mission is: to generate and communicate **knowledge and technology** that; supports the ambition expressed by the sector to increase the export value of Portuguese wines, and ensures that the Portuguese wine system becomes **more efficient, resilient and flexible** in order to respond to climate, demographic and economic challenges. The major challenges: **competitiveness** – defining and delivering the Portuguese wines consumers will want to buy and **sustainability** – designing and delivering a resilient Portuguese vine and wine system.

FORESTWISE– Collaborative Laboratory for Integrated Forest & Fire Management (<http://www.forestwise.pt/>), a private, non-profit institution, headquartered in Vila Real, in Northeastern Portugal. Aiming at innovative multidisciplinary research and knowledge transfer in integrated forest and fire management, responding to the national priorities of the Council of Ministers Resolution no. 159/2017 <https://dre.pt/web/guest/pesquisa/-/search/114123459/details/maximized>, through joint efforts of the university, public administration, and industry, ForestWISE was awarded the CoLAB title granted by FCT in

2018. It involves in its network associates and stakeholders representing the academia and all segments of the forest value chain and with strong experience of research and outreach cooperation. The Forestwise emphasis is on knowledge transfer that brings together the multiple interdisciplinary areas that are relevant for building up a holistic and cohesive approach for the problem of rural fires and the directly related problem of the valorization of forest (market and non-market) products and services.

Centres of Competence, Operational Groups and Spin-offs

The Ministry of Agriculture and Rural Development has defined a strategy that includes the creation of Centres of Competence (CC), and Operational Groups (GO), clusters of Laboratories and entities for research and innovation, the former to promote problem-solving activities and the later to propose research actions. In the moment, there are 22 CC, and members of TERRA (CEF, LEAF, CFE) are involved in the **CCs of Cork-Oak and Cork, Climate Change for the Agroforest sector, Aromatic, Medicinal and Spice Plants, Apiculture and Biodiversity, Maritime Pine, Tomato for Industry.**

CEF and CFE have been also very active in GO research projects (PRODER2020), such as +PINHÃO, FERTIPINEA, NUTRISUBER, UNDERCORK, i9K - InovKiwi, GI (PiN) - Gestão Integrada do Pinhal/Nemátode da Madeira do Pinheiro, MultiForest, FITOGLOBULUS and SUBER, executed in close cooperation with the wood, cork and forest product industries. Also LEAF members were engaged in 18 GO projects, e.g. JAAP, LACTIES, APROXIMAR, MicroSUINO, ProENERGIA, MobFood, OceanOils, GREENTASTE.

CFE has been involved in the creation of two regional networks: CULTIVAR - <https://icultivar.pt/> (CENTRO2020) - Network for sustainable development and innovation in the Agrofood sector. CULTIVAR aims to respond to the challenges faced by the sectors of the Agrofood sector in the Central Region, namely to characterize, conserve and valorize the regional endogenous genetic resources in areas of low density, through a strategy of territorial development, promoting and consolidating collaboration between science, technology and higher education institutions and the Agrofood cluster. F4F - Forest For Future, <https://www.forestforfuture.org/en/> (CENTRO2020) - Pilot Project for the constitution of a regional network for the valuing of the forest sector in Centro region. The project is focused on pilot initiatives aimed to map and assess forest ecosystem services, actively monitor forest resources, and the straight involvement of producers and stakeholders.

In 2012, CFE created the scientific spinoff **FitoLab, the Laboratory for Phytopathology hosted at the Instituto Pedro Nunes (IPN)**, which acts on the detection and research of plant pests and diseases affecting horticulture, fruticulture and forestry. This spinoff was designed to promote rapid and effective tailor-made responses to public stakeholders and private companies in the area of phytopathology and, for the past five years, it has been delivering key services to society and research. FitoLab-IPN achieved the DGAV (Portuguese National Authority for Food and Animal Health) certification for the detection of several A1 and A2 EPPO relevant quarantine organisms. Also, FitoLab-IPN participated in various national prospection programs for several quarantine organisms and established numerous consortiums to address the challenges raised by the most important agroforest sectors. Both CFE and FitoLab-IPN are involved in research projects with national authorities, private organizations and companies in the area of plant pests and diseases, simultaneously creating knowledge on disease profiles and practical solutions for the industry.

LEAF research also originated two spin-offs: the Cooking Lab (<https://pt-pt.facebook.com/cookinglab.net>) dedicated to molecular gastronomy services and David Picard's Belém urban winery (<https://www.adegabelem.com/winery-company/>).

Free tools, community services and products

Free webtools, models and patents are current outputs of research projects available to societal uses, and TERRA centres currently produce them.

In LEAF, five International Patent families (BLAD, BLAD-A to C, and TOM.ESCA) were granted in a vast number of countries, and a provisional Patent Application concerning "DEFLAMIN: Therapeutic protein" was submitted in PT and to the International Patent System (PCT). Different Models such as CSS_Zoner, Crop Zoning (www.mdpi.com/2071-1050/9/11/2003/s1), CSSPear (Pear Crop) or FlowerCalc (simulating the dates of flowering of the olive) (www.gesrocha.pt) were developed.

CEF has developed a set of models, simulators and decision support tools in the framework of its outreach activities that are made available in the web (e.g., <http://www.isa.ulisboa.pt/cef/forchange/fctools/en/home>). These tools build from CEF's research and address current challenges faced by forest managers, namely the need to extract tangible economic products from forested landscapes while safeguarding ecological values and the sustainability of land use.

The national Manuals for River Quality Assessment, and three of the official indices used in the national monitoring exercises, were developed by CEF members for the Portuguese Environmental Agency. RivTool Kit <http://rivtoolkit.com/>, a new software for river networks data extraction, were developed and released for public use. CERTAGRI, a new certification for the environmental sustainability of farming and agroproduct chains, developed by CEF/LEAF in collaboration with the company ADENE, was granted a prize for entrepreneurship <https://www.adene.pt/projeto-certagri-e-premiado-na-edicao-nacional-dos-european-enterprise-promotion-awards/>.

LEAF maintains a relevant activity in **management of germplasm collections and botanical gardens**: in the direction committees of the “Ajuda Botanical Garden” (including Herbarium and Seeds Bank) and “Tropical Botanical Garden and Herbariums LISI, LISC and LISFA, as curators of the “Tapada da Ajuda Botanical Park and Nature Botanical Reserve D. António Xavier Pereira Coutinho”. LEAF members also manage “PORVID – Associação Portuguesa para a Diversidade da Videira”, which holds a collection of intravarietal variability of native grapevine varieties and maintains 30,000 genotypes. PORVID brings together several public and private entities in Portugal to promote the conservation of vine varieties in its territory.

Also of outstanding importance is the work on coffee rust diseases by the CIFC group, which is a reference worldwide (<https://www.isa.ulisboa.pt/en/cifc/impact-of-cifc-research>) as more than 90% of cultivated resistant coffee varieties worldwide were created from the studies carried out at CIFC.

In 2014, the **UNESCO Chair on Biodiversity Safeguard for Sustainable Development**, was awarded to the University of Coimbra. Held by CFE coordinator, the main goals of this Chair are to act as an integrated platform for education, research, information and science communication, in the fields of biodiversity, ecology, conservation and sustainable use of biological resources, between Portugal and Portuguese-speaking countries. In the last 4 years, the Chair worked in close cooperation with the UNESCO “Man and the Biosphere” Programme and with the Biosphere Reserves in Portugal, organizing specific training for the various actors involved, and disseminating good practices for promoting sustainable local communities.

Societal engagement and citizen science

Memory for All/Memória para Todos® is a research program from CFE committed to promoting the study, organization and dissemination of Portugal's heritage, developed in collaboration with different institutions. The Program records, preserves and shares stories and memories, including oral testimonies, documentation and personal and family objects, valuing life and community History.

“Nós Propomos” initiative [We Propose] is a CEG/IGOT project to raise local citizenship through geographical education among students from secondary education level. It mobilizes schools from all over the country (around 1,600 students and teachers of Geography in 2016) on the identification of local problems and the presentation of ideas for their resolution by the students. The project has also been implemented in Brazil and Spain, a proof of its international impact.

“Invasoras.pt” is a CFE citizen science platform (one of the first in Portugal) that is aimed to engage citizens to map invasive alien plants (IAP) using smartphones or Web apps, gathering data for scientific research, and supporting management, while simultaneously raising general awareness about IAP. Since its creation it has grown steadily in users (2400) and sightings (>15000).

“Plant Letters” (<https://www.zooniverse.org/projects/catedraunesco/plant-letters/about/research>) is a project of the UNESCO Chair in Biodiversity Safeguard for Sustainable Development of the University of Coimbra in collaboration with the Botanic Garden and the Department of Life Sciences of the University of Coimbra. The main purpose of this project is to track plant species, locations and scientists in the correspondence of the Botanic Garden of the University of Coimbra received in the 19th and 20th centuries. To do so, the public is invited to transcribe letters, handwritten or typed, received by the Botanic Garden between about 1870 and 1928, from more than 1100 correspondents from around the world.

“Explorator” (<https://coicatalogue.uc.pt/explorator/>) is a crowdsourcing platform where citizens are invited to help in databasing the specimens of the largest biological collection in Portugal, the Herbarium of the University of Coimbra. Also, within the i9Kiwi project, a citizen science initiative was developed, with farmers and kiwi producers being involved in the collection of data regarding insect diversity in their orchards.

LEAF contributed to society in initiatives such as the “Aliança Contra a Fome e Má-Nutrição Portugal” or the Cascais Municipality “Contextos Favoráveis à Saúde - Estratégia Local de Promoção da Saúde”, and participates in “Ciência Viva” Initiatives.

Support to Portuguese Speaking Countries

Since 2013, CFE has been implementing **collaborative scientific actions with Portuguese-speaking African countries**, especially Angola, Mozambique, and São Tomé and Príncipe (STP). Portugal’s long shared history with these nations creates not only the opportunities, but also the responsibility to cooperate for the development of much needed knowledge and know-how required for the preservation of these countries’ biodiversity, ecosystems, and natural resources.

LEAF has a long-standing cooperation with the Portuguese-speaking countries (advanced training, students and researchers exchange, and common projects). Protocols **were** established with institutes from tropical countries: Univ. Eduardo Mondlane, Lúrio and Zambeze - Mozambique, Parque Nacional da Gorongosa, Univ. Eduardo dos Santos e IDA - Angola, Univ. de Cape Verde, Escola Sup. de Ciências Agrárias e Ambientais e INIDA - Cape Verde, Unipiaget-Guinea-Bissau, Univ. Federal Espírito Santo - Brazil. LEAF has the Coordination of the Mechanism of Liaison of the Universities to the Food Security and Nutrition Council of the Community of Portuguese Speaking Countries (CONSAN-CPLP). LEAF is part of Networks and Expert Groups: SKAN CPLP. Sharing Knowledge Agri-food Networks. Technology Transfer Platform in the Agri-food Sector – CPLP, EU-Africa High Level Policy Dialogue on Food and Nutrition Security and Sustainable Agriculture, World Bank African Centers of Excellence Program, MU-COSAN-CPLP. Also it has projects directed to developing countries (e.g., EU-CDAIS, Capacity Development for Agricultural Innovation Systems and EU-BREEDCAFS, envisaging adapting coffee varieties for agroforestry).

CFE developed TREASURING - Environmental, historical and social dimensions of nature conservancy in Gorongosa: implications for biodiversity safeguard and sustainable development - Camões - Programas, Projetos ou Ações de Cooperação para o Desenvolvimento 2018; ECOASSESS - A biodiversity and ECOlogical ASSESSment of soil fauna of Gorongosa National Park (Mozambique) (PTDC/BIA-CBI/29672/2017) - PT2020 - 02/SAICT/2017 - Projetos de IC&DT; Herbário Nacional: Referência para o Conhecimento e Conservação da Diversidade das Plantas de São Tomé e Príncipe - CEPF - Small Grants 2016 (Hotspot de Biodiversidade das Florestas Guineenses da África Ocidental); and Implementation of Agroforestry Systems in the Buffer Zone of Natural Park in S. Tomé e Príncipe as a model for sustainable intensification of agriculture - African Union Research Grants - HRST/ST/AURG-II/CALL1/2016.

Five case-studies in which TERRA researchers were engaged.

3.2 Rural fire, a strong need for land management

Research on rural fires at CEF has resulted in multiple interactions with the public administration, the private sector and the media over the last 25 years. In the policy domain, and after the severe fire of 2003 and 2004, we were asked by the Ministry of Agriculture to coordinate the Technical Proposal for the National Plan for Forest Protection Against Wildfires (2004-2005). Following the deadly fires of 2017, we collaborated in the drafting of Resolutions of the Council of Ministers n.º 159/2017 – *Research Programme on Forest Fire Prevention and Suppression*, Foundations for Science and Technology, Ministry for Science, Technology, and Higher Education, and of Resolution of the Council of Ministers n.º 1/2018 – *Programme for Revitalizing the Interior Pinelands*, Presidency of the Council of Ministers. We also collaborated with *Assembleia da República*, Portugal’s parliament, having participated in hearings on fire policy issues in 1992, 2014, and 2017. The Agency for Integrated Management of Rural Fires (AGIF) is headed by a former CEF member and has relied on CEF for technical support and discussions on policy-related issues.

Our research outputs have also been applied in support of fire management decision making, both by public and private organizations. We developed annual burned area maps under contract with ICNF over the period

1995 – 2009. Our expertise has also been sought to produce fire risk and fire danger maps by ICNF, DGT, and NAVIGATOR, Portugal's main forest pulp and paper corporation. We developed landscape-level fuel management planning tools, including the delineation of the 6000+ km *National Primary Fuelbreak Network* for ICNF, and recommendations for improving fuel management under contract with Portugal's main electric power distribution company, EDP-Distribuição. A CEF member coordinated the *Programme for Rehabilitation of Coastal Forests*, promoted by ICNF after the 2017 fires.

It is worth highlighting a recent experience of collaboration on the topic of fire danger mapping between two TERRA proponents: CEF and CEG were partners in a project jointly promoted by the Portuguese Forest Service (ICNF) and the Directorate-General for Territory (DGT). Under the scope of this project, we updated the *National Fire Danger Map*, for ICNF, and produced a novel *Fire Risk Map for Peri-Urban* areas, for DGT. The media have recognized the expertise on fire-related issue available at CEF and we are often interviewed for TV stations *RTP1*, *RTP2*, *RTP3*, *SIC*, *SIC-Notícias*, *TVI24*, *TSF*, *AR^{TV}*, *RTP-N*, *Porto Canal*, and radio stations *RDP-Antena2*, *Rádio Renascença*. Recently, we were asked by *SIC-Notícias* and by *RTP 3* to comment on severe fire seasons in the Brazilian Amazon and in Southeastern Australia. Our research work and commentary on fire issues of interest to the general public have also been sought by printed media, including *Expresso*, *Público*, *Observador*, *Diário de Notícias*, *Jornal de Notícias*, *O Primeiro de Janeiro*, *Grande Reportagem*, and *Visão*. Public Radio One (NL), *Libération* (FR), and The New York Times (USA) interviewed a CEF member in relation with exceptional fire events in Portugal in 2003 and 2017. We look forward to the funding of TERRA, since it will strengthen our capability to provide articulated technical support and policy advice in a broader range of topics such as ecological and public health impacts of fires.

3.3 Food safety and plant protection, towards an ecological paradigm

CFE has been collaborating actively with the European Food Safety Authority (EFSA) in the development of scientific opinions and guidance documents for the ongoing improvement of risk assessment schemes of plant protection products (PPPs) in the EU, focusing on pollinators, non-target arthropods and in-soil organisms. This included the development of the recently adopted approach by the European Commission (DG Sante) of using the ecosystem services concept to define specific protection goals for different organism groups aligned with the regulation EC 1107/2009, and also the development of holistic (multistressor) landscape-based approaches to assess the risk of PPPs towards pollinators and pest control agents. This active participation of CFE in EFSA and DG Sante activities reveals the international recognition of CFE research in the area of environmental toxicology and risk assessment, and places CFE in the center stage of supporting public policies in this sector of food safety in Europe.

3.4. Sustainable foods products

Leaf has been very active and compromised with supporting Innovation for the Portuguese food companies (e.g. Sumol Compal; Sonae; Nobre-CampoFrio; Queijos Santiago; Campotec; HIT/Kagome; Novarroz; Panidor; Metalogonde; El Mandarin) servicing for developing new sustainable foods with positive impact on health, under the principles of circular economy (e.g. reducing sugar, salt, introducing plant antioxidants, microalgae, plant based proteins, starch from industry by products- broken rice and broken chestnuts flours) being recognized not only by the companies but having received a series of awards: i) the first Born from Knowledge tree from ANI (2017-RiverRiceSugar), and 2 more trees (2019 -Delichi and 2018- Deflami); ii) Food and Nutrition awards honorable mentions from 2013 - till present; iii) a 1st prize in Food I&DT for the most innovative Food Technology- DeTOxVega at the ALIMENTARIA Iberian Fair; iv) and an European award with the EUROSTAR LycopenRaman project, rated as the 2nd Success Project on the Eureka Innovation award 2014 for the category 'Added Value', obtaining 190 points out of 200.

3.5. Supportive healthy environments

ISAMB's collaboration with the World Health Organization ³ to act on health promotion and disease prevention throughout the creation of health supportive environments has a consolidated background, with

³ WHO Regional Office for Europe. Setting research priorities in environment and health. Copenhagen, Denmark; 2017

several research and outreach initiatives undertaken in the last years. The Health Behaviour in School-Aged Children (HBSC) study is a WHO collaborative survey implemented since 1994, which now includes 50 countries across Europe and North America, with its execution in Portugal being led by ISAMB researchers. The HBSC gathers information about young people's health behaviour and well-being in their life contexts. This regular survey (every four years) provided a background dataset on several behavioural and health-related domains, as well as on health and well-being determinants, such as digital contexts and climate change. A different area of health promotion where ISAMB has been working on with WHO, together with the Portuguese Directorate-General of Health, is in the study (the Nutr-HIA project) of how nutritional information at the time of food purchase can be used as nudge to efficiently promote healthier choices and improve peoples' health and well-being throughout the life course. The outcomes of the NUTR-HIA study will inform health policies concerning nutritional labelling in Portugal, a subject that is currently under discussion by the competent national authorities. Finally, in 2017 ISAMB held with the WHO Regional Office for Europe the workshop "Setting research priorities in environment and health". The report resulting from this meeting that gathered several international experts who discussed key research priorities and strategies in environmental health was approved and made available at the Sixth Ministerial Conference on Environment and Health, on 13–15 June 2017 in Ostrava, Czech Republic.

3.6 Lisbon Metropolitan Area and climate change adaptation

Since the technical and scientific coordination of PNPOT (2002-06), CEG has been very active in the collaboration with public administration on several Territorial Management Instruments at local and regional scales. Recently, a successful case of societal collaboration is the involvement between CEG/IGOT and AML in the elaboration of Lisbon Metropolitan Plan for Climate Change Adaptation (PMAAC-AML). This plan aimed to be a tool to promote adaptation measures to tackle climate change and to assess the vulnerabilities of territories and exposed population to natural hazards (from heat waves, to strong winds, sea level rise, etc.), in the Lisbon Metropolitan Area (AML). It is an operational instrument for strategic sectors (from urban areas to transportation, forests, energy, etc.), oriented to conduct more detailed plans and actions to each one of the 18 municipalities involved. Promoting the adaptations needed to the sustainable development of the region, this plan became a key factor to empower institutions and communities, to share knowledge and to ensure a culture of adaptation and awareness of the AML environmental problems. https://www.aml.pt/susProjects/susWebBackOffice/uploadFiles/wt1wwpgf_aml_sus_pt_site/componentPdf/SUS5BD0A09029884/PMAAC_AML_P021_VOL1_CENARIO_BASE_ADAPTACAO.

C. Organization and governance of TERRA

1. Organization of the Consortium

TERRA will be a large Associate Laboratory with about 400 researchers, with a well demonstrated capacity for a wide range of highly relevant activities across multiple sectors and policies, notably:

- a) research and innovation;
- b) scientific networking;
- c) teaching, student supervision and early-career support;
- d) development of national strategies and policy planning;
- e) support public administration in their demands and needs (*with hands-on examples taken from previous contributions of TERRA members*):
 - i) voluntarily support when a pressing situation occurs, e.g. control of biological invasions, and diseases/pests outbreaks, wine quality benchmarks, post-fire rehabilitation, flood control and land sliding;
 - ii) being contracted to actually do the applied research and field or public interventions needed, e.g. a new plant hormone and pheromone products' development, removal or transposal of riverine physical barriers, forest biomass disposal, a disease characterization;

- iii) developing predictive tools, e.g. risk assessment maps; regional climate models, tsunami alert system, forest modelling;
- iv) active support of planning policies, e.g. water resources, climate adaptation, biodiversity and biological collections preservation, soft mobility planning, spatial municipal planning, policy external evaluation, urban sustainability indicators.

There are consequently many possibilities in TERRA for the support of public entities, in policies, planning and problem-solving of concrete issues, that will occur at the same time as other research activities. TERRA will develop a fluid and transparent governance with the following principles:

- a) Light and cooperative, where specific researchers from particular fields of different centres, will be called to support a topic, according to their expertise;
- b) Efficient and fast response, with a rapid identification of the best available researchers to tackle each topic,
- c) Integrative and transparent, by way of keeping a track record of researchers and their achievements, publicly available, and easy to use.
- d) Decentralized and branched, to reach out quickly, to assemble the multifaceted teams that are called to support public needs and policies.

Central governance

TERRA will be governed by a Directory Board (TERRA DB) of 10 members, two nominated by each centre, and a President of the Board elected by the ten members and excluding these. The TERRA DB will be mandated for periods of 4 years. The TERRA DB will meet monthly (or extraordinarily when needed) to analyze and debate the actions of the Laboratory TERRA, to support the activities of researchers, to avail external demands and its response, and to make sure that the annual plan is progressing well.

Each year, an Annual Report of past activities and the Activity Plan (for the next year) will be presented by the Chief Executive Officer (TERRA CEO). The TERRA CEO will supervise the execution of all actions within the scope of TERRA, and its support of public policies, with the help of an executive Management Board, and he/she will insure the visibility of TERRA researchers, promote common research developments and data sharing, and link with the Directive Boards of each Thematic Line whenever necessary. The CEO TERRA is a contract position for science management, specifically designed for TERRA, obtained under an international competitive call, occupied by a Senior Researcher with experience in the management of research groups and projects.

The management board structure (TERRA MB) will be composed of the CEO, and two researchers associated to the data platform TERRA, and contracted under international competitive calls. They will supervise the technical assistance staff that will maintain and populate the online platform, while developing their own research subjects dealing with metadata and large datasets, available at the platform and other data repositories like RI PORBIOTA. Once a year there will be a General Assembly of TERRA - the TERRA GA, to present, discuss and approve the Annual Report and Activity Plan.

The TERRA DB nominates the TERRA Thematic Lines Directive Boards (TLDB) for the period of each mandate. The TERRA CEO and the TERRA DB are responsible for the dynamization of activities among researchers, especially within each Thematic Line and its TERRA TLDB. The Directive Bodies are composed by the coordinator and the co-coordinators (indicated on the TL text, and belonging to different centres), and between three and five in number. Researchers proposed to TLDB have their profiles described in the end of this text. The TL have their own aims for each mandate, researcher composition and activities. Therefore, researchers will have joint interests, potentiating intra-TERRA collaborations, but also more probabilities to join forces to support policies and respond to societal demands. TERRA CEO and TERRA TLDB will promote outreach activities and responses to community needs; they will write research and policy briefs; they will identify research themes and opportunities, stimulating potential collaborations and synergies across Research Lines in international and national competitive bidding programs, namely Horizon 2020, FCT and other calls.

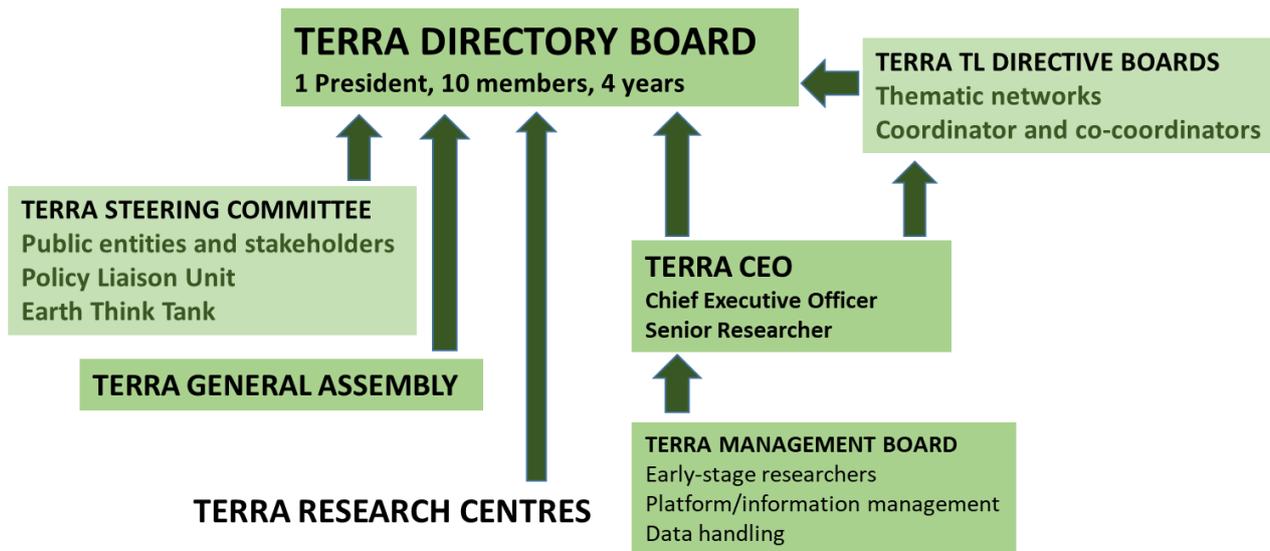


Figure 4. Governance structure of TERRA Laboratory.

Policy briefs will be presented to TERRA DB, TERRA GA, and especially the Steering Committee, TERRA SC. The TERRA SC is a corps with representatives from the public institutions that are giving support to the Laboratory TERRA, and a variable number of representatives from stakeholders and other organizations, related to TERRA aims and scope (list in part E of this text), serving as two-way receptor and giver of information. In special occasions, the Steering Committee may have Policy Liaison Units to consolidate the translational research process and co-creation of solutions. Once a year, there will be a public meeting of an Earth Think Tank, with a special topic, relevant in the moment, an event dully publicized, gathering the entities represented in TERRA SC and other know relevant researchers and policy-makers.

Governance across Thematic Lines (TL)

The TERRA Lab is deeply committed to the open science agenda and in promoting effective collaborations and data usage within and beyond the TERRA members, including the productive sector, relevant stakeholders and policy makers. The online TERRA platform will be instrumental in this endeavor (Figure 5). It will be multipurpose and will have a crucial role of interface between the Laboratory and the external activities and support to society. The TERRA platform will have two physical locations for management purposes, in Lisbon and Coimbra, though in Lisbon and ISA will be located the main facility. The TERRA platform will be populated by three types of information with different aims:

- a) **Data on research** performed within TERRA, with the aim to create a visible and update interface with stakeholders and public administration that will showcase the available facilities, infrastructure, integrated competences and activities of the Laboratory;
- b) **Data on researchers'** profiles, achievements and career paths, with the aim to create a visible and updated view of researchers activities, promoting the visibility of their work, either using the outputs or soliciting novel work and partnerships;
- c) **Raw data and metadata**, both in open-access or in TERRA intranet, that will gather the enormous amount of data collected by the TERRA researchers in different data sets, by environment (soils, water, vegetation, fish, etc), at different spatial scales (from individuals to landscape) and for different time scales (spanning the length of mankind activities and natural world repositories, including tropical).

The three data types will compose the TERRA installed capacities (Figure 6). Data will be collected, curated and shared in the light of the FAIR (Findability, Accessibility, Interoperability, and Reuse) guiding principles for scientific data management and stewardship. These will serve three purposes:

- a) To create intra-TERRA research synergies, upscaling data treatment and the possibilities of testing theoretical ideas on gathered experimental information, primarily collected in the field, but also indirectly gathered, or remote;
- b) To maintain a forefront of visibility for TERRA researchers, that will help external entities to understand what they can use, forging participation and societal outreach, with a growing network of interactions, and ultimately of usefulness.
- c) To maintain an updated portfolio of expertise, able to help early career researchers to progress in their professional paths in industry, companies, academia and administration, and eventually to foster spin-off companies.

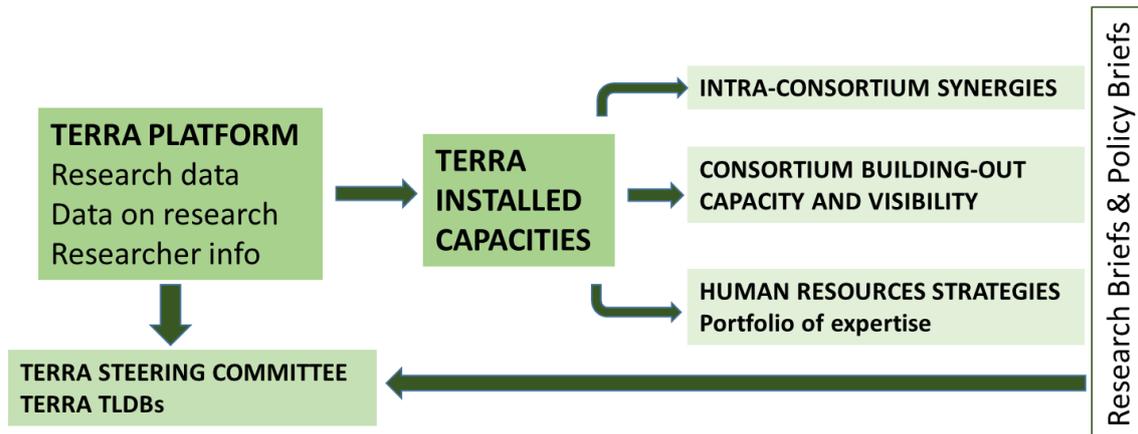


Figure 5. TERRA platform and its functionalities.

Swift response to external demands will be based on the researcher’s portfolio, the build-in research expertise, and the researchers’ mobilization, made by the TERRA TLDBs and the TERRA CEO. Upon demand, the governance structure will rapidly gather a multifaceted team, lead by an appointed responsible researcher, that will comply with the demand. Services and research infrastructures will be made available by the centres and institutions involved, with legal aspects such as protocols, contracts and specific budget (if any) made by these. TERRA involvement will be finished by a short summary report to TERRA DB, a small note to TERRA quarterly on-line Newsletter, and a platform visibility note. Other relevant media releases, such as publications, films and interviews, will be using the TERRA platform channels, such as the TERRA YouTube channel.

The flow chart of policy outputs across TERRA is depicted in Figure 6. This will follow a round scheme from policies and societal needs via the TERRA CEO to the TERRA TLDBs, linking to the researcher’s network, and resulting in tailored advice. All the round pathway will receive feed from the TERRA research and TERRA platform, either experience or data.

There are two other ways to make research outputs useful and applied to land use sustainability. One is to directly reach the end users through the large network of TERRA collaborators, the market and the administration (e.g. a spin-off of early-career researchers). The other is to engage via TERRA in a process of translational research and applied skills where researchers engage together and interactively with society and the public administration to produce desired solutions for the complex problems of sustainability. Approaches from societal agents entering the flow-chart will be often sectorial, as well as the bottom-up approaches from research outputs to society, but many policies will require cross-sectorial translational approaches, with involvement researchers from different TL.

In any case, to accomplish the general strategic objectives of TERRA, including scientific performance, we will strive for contributing to the sustainability of the land use and towards the solution of pressing societal challenges in society, economy, environment and territory. The success of each researcher in achieving such goals will be also the success of TERRA.



Figure 6. Tailored advisory body in TERRA from policy support to policy information.

2. Development and support of research careers

What do post-doctoral researchers need to develop successfully their careers, and how is this linked to TERRA governance and structure? TERRA platform and structure, and the aims described, are important for research careers, either promoting publication via the use of new and wider amounts of data, increasing the critical mass of the ongoing research, using the visibility of the platform and the portfolio to promote their work. Researchers, especially early-career researchers ones, will need:

- a) A highly qualified and challenging research environment for discussion of results and new concepts, yet friendly and cooperative;
- b) A good structure of supervision and of support, able to foster the development of new ideas while conducting them for the best available knowledge in the field;
- c) Good facilities, equipment and experimental possibilities, either in laboratories and in the field, and enough funding to insure the prosecution of the work;
- d) A good network of research-peers and publishing links, and experienced coaching to help publication endeavour, and opportunities to promote he/she research results and visibility.
- e) Early-career researchers also need to gain experience at transmitting their skills, either as teacher or as speakers, e.g. in doctoral and MSc courses, or in Seminars and Talks.
- f) Finally, to gain experience as team leaders and increase their productivity, they benefit from supervising MSc students and PhD students.

TERRA centres present a healthy research-university environment, that will be further incremented by the synergies created by the consortium, including a research network, infrastructures and facilities, fieldwork support, as well as supervision opportunities, promoting a good publication record, supporting open-access costs and project experiences.

In multidisciplinary teams, doctoral students can learn the value of research complementary and listen to new perspectives, within a network, fostering possibilities of joint research. More importantly, researchers will be engaged in doctoral courses and advanced courses, sharing the latest research achievements and increasing the quality of scientific quality. Doctoral students are usually supervised by early-career researchers, the latter benefiting from the latest scientific ideas and experimentation, contributing to foster new researchers. Recruitment of young students of quality is of essence to researchers.

There is a large number of PhD and MSc at the TERRA academic institutions, either institutional (located solely in the mother University), multidisciplinary (several Portuguese institutions) or international, where researchers can contribute to increase the quality of its courses, train to communicate and recruit master and doctoral students.

The more important doctoral courses are the **PhD in Biosciences** of the University of Coimbra; the **PhD in Landscape Architecture and Urban Ecology**, which is a **joint PhD program** that comprises the University of Coimbra, University of Porto and University of Lisbon; the **PhD Program in Climate Change and Sustainable Development Policies**, a **joint initiative** between the Universities of Lisbon and Nova de Lisboa; The **PhD Programme in Sustainable Forest Development** results from the **association between the University of Coimbra and University of Trás-os-Montes and Alto Douro**, with the collaboration and support of various wood and cork industries (Amorim and Navigator company) and institutes linked to energy resources, such as the ICNF (Institute for Nature Conservation and Forests); the PhD program **REASON, Resources, Food and Society in Sustainability Science**, a **joint program** from the Schools of the University of Lisbon oriented to provide human resources with tools to understand and respond to current and future challenges that are posed to sustainability. It recognizes that understanding food systems and acting on the global food system are central instruments for sustainable development, requiring research on the interactions between ecology and socio-economy.

The PhD in Sustainable Forests and Products (CEF) and Migrations Studies (CEG in collaboration with other R&D units from U.Lisboa) are PhD programmes funded by FCT. Territory, Risks and Public Policies (CEG) is a joint-PhD (U.Lisboa, U. Coimbra, U. Aveiro). Single-institutional PhDs include Geography, Tourism, Anthropology, and Intercultural Relations from the University of Lisbon. The PhD in Agriculture, Forest and Natural Resources, Environmental Engineering, Biology, Food Technology, Landscape Architecture (CEF and LEAF), have been recently merged under the name of **PhD on Sustainable Land Use**. They contribute to continuously feeding fresh ideas and approaches for research. The **PhD program River Restoration and Management** (CEF) funded by FCT is a **joint international program** between the Instituto Superior de Agronomia, the Instituto Superior Técnico, the University of Natural Resources and Life Sciences, Vienna, Austria, the Universidad Politecnica de Madrid and the Universidade de Bahia, Brazil. FLUVIO aims the development and the application of scientific knowledge of environmental sciences, ecology, engineering and urbanism to management and restoration of the fluvial ecosystems, at different spatial scales, from the microhabitat to the river reaches and the drainage basin. Thus, it aims to contribute to the sustainable development of human societies and the conservation of natural resources. The **EnviHealth&Co** is a doctoral program entirely devoted to Environmental Health funded by FCT, promoted and conducted by ISAMB. EnviHealth&Co fully adopts the concept of knowledge triangle (linking education, research/innovation and business) and is developed in, and together with, non-academic (industrial and commercial) settings.

A PGCT Postgraduate Course in Science and Technology Management and Policy provides qualified training and skills for the development of management activities in the scientific and technological system (CFE). And three International MSc also contribute to recruitment, the **Master in Applied Ecology** (IMAE), CFE is a **joint degree** offered by the University of Coimbra and the University of Kiel (Germany) with the collaboration of four other Universities where students can develop their thesis project (University of East Anglia - UK, University of São Paulo - Brazil, Federal University of Rio Grande do Sul - Brasil, and University of Saskatchewan - Canada), training specialists to carry out a variety of environmental projects in the area of applied ecology all over the world and is designed to attract students worldwide.

The Erasmus Mundus **Master Degree on Mediterranean Forestry and Natural Resources**, (MEDFOR) (<https://www.medfor.eu/>) providing a new generation of foresters with new scientific knowledge to address effectively topics, needs and threats that are specific to Mediterranean forestry to develop a) new policy frameworks and economic instruments that may contribute to the sustainable use of renewable biological resources for industrial purposes, while ensuring biodiversity and environmental protection, b) new adaptive management strategies based on the understanding of forest ecosystem functions and processes, under a changing environment and c) a new paradigm in addressing forest hazards (e.g. fires, pests). It is coordinated by CEF and it involves 6 other universities in Portugal (Portuguese Catholic University), Spain (University of Lleida and University of Valladolid), Italy (University of Padua and University of Tuscia) and Turkey (Karadeniz Technical University) and a world-wide network of associated partners and stakeholders. The **International Master of the Sciences in Viticulture and Enology** (<https://www.vinifera-euomaster.eu/>)

- Vinifera is organised by a consortium of 15 Universities and Graduate Schools named “EMaVE Consortium” from the countries producing quality wine in Europe: France, Germany, Italy, Portugal and Spain. The Consortium also enrolls 15 Associated Partners around the World, like in USA, South Africa, New Zealand, Australia, Brazil, Tunisia, etc. The Vinifera Master Program was recognized by the European Commission under the label “Success Story” (in 2017).

D. International visibility and funding capacity

1. Installed research capacity in TERRA

The centres composing TERRA are a stronghold of research and innovation and have built a network across and beyond Europe, and Portuguese-speaking countries, including:

Table 3. Research project indicators from TERRA centres in the last 5 years. Approximate values.

PROJECT TYPES (only Portuguese participation)	number	Value k€	Examples
European research projects H2020	63	13 000	B-GOOD (https://b-good-project.eu/) EcoStack (https://www.ecostack-h2020.eu/) HBM4EU (https://www.hbm4eu.eu/) PROMEHS (https://www.promehs.org/) WISE (https://www.oenoviti.com/news/168-rise-vwise-project-granted-by-the-eu.html) MALMON (https://europa.eu/capacity4dev/sites/default/files/media/mangrove_guinea_bissau_desira_2020.pdf) MARS (http://www.mars-project.eu/)
Other competitive research projects Life, Interreg, JPI, Biodiversa, twinning, Eragnet, etc	29	1 300	NEFERTITI (http://nefertiti-h2020.eu/) Poll-Ole-GI (https://www3.ubu.es/poll-ole-gi/pt-pt/), Ecoserve (http://ecoserve-project.eu/), ALTHOUR (http://alhtour.eu/) INMS (http://www.inms.international/) LIFE FLUVIAL (http://www.lifefluvial.eu/es/) Dairy-4-Future (http://dairy4future.eu/) CERES (https://www.ceres-sudoe.eu/projet-es)
National Research projects FCT	188	13 200	FEMINA (https://feminacies.wixsite.com/enversion) SM-COVID 19 (https://sm-covid19.pt/) RIVEAL, https://www.riveal.pt BIOECOSYS, https://www.bioecosys.com/ MODFIRE, https://www.modfire.net/ PESSOAS E FOGO, https://pessoasefogo.wordpress.com/
Other competitive national projects - PRODER 2020, ANI, etc	87	6 200	CULTIVAR (https://icultivar.pt/=) i9Kiwi (https://i9kiwi.pt/) ReNATURE (http://cfe.uc.pt/profile/projects/24), ProCIMA (https://procimacies.wixsite.com/website) OXYREBRAND (https://projects.inia.pt/oxyrebrand/index.php/pt/) STEnCIL (https://stencilablab.wixsite.com/stencil) Tomatinov (https://tomatinov.wordpress.com/)
Total value of consultancies	-	2 300	

- Leadership and/or participation in international research projects and programs;
- Participation and advisory in many fields of applied research, stakeholder and administration support either in Portugal, in Europe or in international organizations;

- c) Dissemination and editing activities related with new and better practices of land use and societal development, and its interactions;
- d) Tool development and dissemination, including platforms for exchange information and data-building, free software models, process-based and others, development of new products, some patented.

Research at TERRA centres is carried out free from political, religious and ideological constraints, while observing the ethical principles of scientific research. TERRA consortium has an outstanding record for harnessing funds from competitive calls (Table 3). About 36 million euros were fund-raised by TERRA in the last 5-year period. Of these, approximately 40% was international funding.

Relevant research projects (examples)

The centres composing TERRA develop research and outreach activities in the framework of research programs, such as H2020, MARIE CURIE, ERC, LIFE, JPI, INTERREG, ERANETs (e.g., BIODIVERSA, FORESTVALUE), national FCT-funded projects (e.g., COMPETE 2020, ANI, PRODER). Funding is provided further by consulting activities to different bodies of public administration, local governments, NGOs and private companies (e.g., Altri, Shell, DuPont). Global funding agencies (e.g., African Union) were instrumental for consolidating several collaboration networks, for training of advanced human resources, and in strengthening knowledge transfer to peers and society. Pivotal examples are CULTIVAR and F4F, strategic regional networks (4 M€ in total) granted to support the agri-food and forest sectors in Centro Region, respectively. Successful spin-offs also contributed to support decision making by national and international authorities (e.g. EU Mission Boards, IPBES, EFSA, IPMA, IUCN).

To illustrate the installed capacity of TERRA the following projects were selected and shortly summarized.

Within the **framework of ReNATURE project (CENTRO2020, <<http://cfe.uc.pt/profile/projects/24>> <http://cfe.uc.pt/profile/projects/24>)**, efforts are being done to preserve agricultural and forest resources of strategic importance for the sustainable development of the Region, in its economic, social and environmental aspects. CFE members from this RG evaluated the provision of ecosystem services in terms of biodiversity conservation and pollination, studied the impacts of introduced pests and diseases affecting agroforestry ecosystems, are characterizing endogenous cultivar varieties with agronomic potential, and are promoting the in situ and ex situ conservation of endogenous natural resources.

The EcoStack project (H2020, <<http://www.ecostack-h2020.eu/>> <http://www.ecostack-h2020.eu/>) is focused in developing ecologically, economically and socially sustainable agricultural production strategies based on the provision of biodiversity services by combining biological inspiration tools for crop protection within and around agricultural fields to increase the sustainability of agri-food systems in Europe.

The **GREEN project (ERC Grant to Paulo Rocha of CFE)** aims to establish a world leading research centre focusing on developing a radically different way to generate clean energy from algae. GREEN will deliver a self-sustainable bioenergy generator, with an output power larger than current state-of-art bioenergy generators. The research team has recently discovered that a population of diatoms, a form of algae, communicate in a cooperative manner and produce long-lasting large magnitude electrical oscillations. The discovery has been made possible through our recent breakthrough – the development of a large area and low impedance transducer to record cooperative communication in cells. The idea is then to harvest the generated electricity from the algae by essentially creating high density electrodes in close contact with cells and conditioning circuitry to store and deliver the generated power. This multidisciplinary research will advance the state-of-the-art by delivering a prototype for a new green self-sustained energy harvester, suitable for power scalability, through realizing technological advances in 1) electrochemical electrodes, 2) cooperative signaling mechanisms in algae and 3) energy harvesting circuits.

Fire-CCI - Essential Climate Variable Fire Disturbance, funded by the European Space Agency Climate Change Initiative Program (ESA Contract No. RFQ/3-14286/15/I-NB, 2014-2018) was focused on several issues relating to fire disturbance including analysis and specification of scientific requirements relating to climate, development and improvement of pre-processing and burned area mapping algorithms, inter-comparison and selection of burned area mapping algorithms, system prototyping and production of burned area datasets, and product validation and accuracy assessment. The CEF team was in charge of the development of a global, daily, burned area mapping algorithm for the Copernicus Programme Sentinel-3 Sea

and Land Surface Temperature Radiometer (SLSTR), which was prototyped with data from the NASA Moderate Resolution Imaging Spectrometer (MODIS). The algorithm developed was tested at global scale and produced global burned area maps with improved spatial and temporal accuracy relatively to the standard NASA product.

HOMED: Holistic Management of Emerging forest pests and Diseases, funded by EU programme Horizon 2020 (contract H2020-SFS-2016/2017 Sustainable Food Security: SFS-10-2017: Research and approaches for emerging diseases and pests in plants and terrestrial livestock) aims to i) improve the understanding of species traits and population demographic features including regulation by native natural enemies; ii) create semi-mechanistic models to predict introduction, establishment and spread of invasive pests and pathogens; iv) develop framework for economic assessment of risk mitigation options; v) Identify key criteria and provide new technological and guide tools for eradication, containment and control of emerging and invasive forest pests and pathogens. The project is structured in 8 work-packages, ISA is involved in WPs 1 to 7 with joint activities with other partners, and is leader of WP5.

ALTERFOR – Alternative models and robust decision-making for future forest management, funded by EU programme Horizon 2020 (contract H2020-ISIB-04b-2015-2 / 676754-2, 2016-2020). The main goal of ALTERFOR was to provide improved and new approaches in forest management that are robust enough to address the challenges of the 21st century. The project focused on the analysis of forest management models (FMMs) at both stand and landscape spatial scales and on the design of methods to facilitate knowledge transfer for alternative FMM adoption by stakeholders. The CEF team was in charge of the design of alternative forest management models (FMMs) that are robust in their capacity to deliver ecosystem services and reduce socio-ecological risks.

ALGAE 2 FUTURE - A2F Consortium: Norwegian-Dutch-Portuguese-Spanish-Belgian-Japanese research. A2F's vision is to lay the foundation for industrial microalgae production in Norway, using natural resources and waste streams from existing production lines within agriculture, aquaculture and process industry. LEAF's participation is the recognition of more than 20 years researching on microalgae in foods. The aim is to explore microalgae (*Chlorella vulgaris*; *Tetraselmis chuii* and *Nannochloropsis gaditana*) potential to be low-carbon-footprint healthy ingredients for future foods.

INMS: Targeted Research for improving understanding of the Global Nitrogen Cycle towards the establishment of an International Nitrogen Management System is a proposal to the Global Environment Facility (GEF) Trust Fund. INMS is a science-policy support process that brings together people, information, approaches, indicators, cost-benefit analysis, regional demonstration, etc as a basis to support governments and others through international nitrogen policy processes. The big message is to count the co-benefits of a joined-up nitrogen approach. By addressing better management across the nitrogen cycle, we can contribute to improving Economy-Wide Nitrogen Use Efficiency, while reducing surplus that would often be wasted as pollution. (<https://www.inms.international/>)

NEFERTITI: Networking European Farms to Enhance Cross Fertilisation and Innovation Uptake through Demonstration is a unique Network (selected under Horizon 2020, Societal Challenge 2, RUR 12-2017 call, grant agreement n°772705.) comprising 32 partners to establish 10 interactive thematic networks and bring together 45 regional clusters (hubs) of demo-farmers and actors involved (advisors, NGOs, industry, education, researchers and policy makers) in 17 countries. NEFERTITI focuses on creating added value from the exchange of knowledge, actors, farmers and technical content between networks in order to inform policies that boost innovation uptake, peer to peer learning, and network connectivity between farming actors across Europe, contributing to a more competitive, sustainable and climate-smart agriculture. (<https://nefertiti-h2020.eu/pt/homept/>).

ALHTOUR (<http://alhtour.eu/>) is a twining project, involving the Universities of Lisbon (including ISAMB), Macerata, Leuven and Maastricht. The project run between 2016 and 2018) and its main aims were to stimulate scientific excellence and develop technological innovation, promoting a health support environment for senior tourists visiting our country. It linked the University of Lisbon with internationally leading research Institutions, through a knowledge transfer process, resulting in the creation of the HEALx Living Lab, identified as a key driver for territorial development.

The **Human Biomonitoring for Europe (HBM4EU)** (<https://www.hbm4eu.eu/>) represents a joint effort of 30 countries to produce comparable data on human exposure to chemicals. It addresses the need for data, on EU level, on aggregate exposure to single or combined chemical substances. HBM4EU's aims to i) provide better evidence on actual exposure to chemicals and resulting health effects, through advanced human biomonitoring, within a collaborative and articulated global strategy; ii) communicate with policy maker to assure that results are exploited to the design of new chemical policies and evaluation of existing measures, supporting the definition of evidence-based environmental policy making. By 2022, it is expected to provide a direct contribution to the improvement of health and well-being of citizens, with special emphasis on vulnerable groups.

The **HBSC** study (<http://www.hbsc.org/>) is an international alliance of researchers that collaborate on the cross-national survey of school students: Health Behaviour in School-aged Children (HBSC). The HBSC collects data every four years on 11-, 13- and 15-year-old boys' and girls' health and well-being, social environments and health behaviours. These years mark a period of increased autonomy that can influence how their health and health-related behaviours develop. The research venture dates back to 1982 and in 1983 it was adopted by the WHO Regional Office for Europe as a collaborative study. ISAMB researchers only take part in the project since 1994.

eMOTIONAL Cities: Mapping the cities through the senses of those who make them is a ~5.000.000€ project funded by the H2020-SC1-BHC-2018-2020 (Better Health and care, economic growth and sustainable health systems), Research and Innovation Action. The overall aim of this project is to provide robust scientific evidence on how the natural and built urban environment shapes the neural system underlying human cognitive and emotional processing, with a perspective that also incorporates age, gender and vulnerable groups' specificities. Furthermore, it has the goal to map such neurobiological reactivity through time and space as the urban landscape changes. Grasping the spatial cognition of the citizens' behaviour and decisions while interacting with their real-life surroundings will be a breakthrough, as it will foster more inclusive urban design resulting in better individual health and well-being.

SECOA – Solutions for Environmental Contrasts in Coastal Areas, with a total budget € 7.8 M, FP7-ENVIRONMENT, Grant agreement ID: 244251. The project examined the competition among metropolitan areas highlighted the essential importance of natural and cultural resources. The project considers the effects of human mobility on urban settlement growth and restructuring in coastal areas where (i) environment is more fragile and space limited, (ii) every phenomenon is more concentrated and (iii) effects on natural and cultural environment are more acute. Problems are multiplied since the climate change affecting environmental parameters - as sea levels - augments risks of flooding, propagation of pollutants, dislocation of a great number of settlers. Controlling and reducing unwanted consequences is contributing to growing conflicts among stakeholders. The project outcomes include (i) elaboration of an analysis methodology, (ii) creating tools for appropriate policies, (iii) scenario building, (iv) dissemination–exploitation of results for users' needs. The project studied 8 metropolitan areas of global importance and 8 of local importance in European and Asian countries (Belgium, Portugal, Italy, Sweden, United Kingdom, Israel, India, and Vietnam, <https://cordis.europa.eu/project/id/244251>).

Nunataryuk – Permafrost thaw and the changing Arctic coast, EU Horizon 2020, BG-2017-1, with a total budget of € 11.5 M. The project examines human activity in the Arctic along permafrost coasts, that have become one of the most dynamic ecosystems on Earth. Permafrost thaw is exposing these coasts to rapid change, threatening the rich biodiversity, putting pressure on communities and contributing to the vulnerability of the global climate system. NUNATARYUK will determine the impacts of thawing coastal and subsea permafrost on the global climate, and will develop targeted and co-designed adaptation and mitigation strategies for the Arctic coastal population. NUNATARYUK will be guided by a Stakeholders' Forum of representatives from Arctic coastal communities and indigenous societies, creating a legacy of collaborative community involvement and a mechanism for developing and applying innovative evidence-based interventions to enable the sustainable development of the Arctic, <https://cordis.europa.eu/project/id/773421>

Science networking

IMISCOE-International Migration, Integration and Social Cohesion is Europe's largest network of scholars in the area of migration and integration, involving 39 member institutes and over 500 scholars from

all over Europe. The network pays particular attention to comparative research, publications, organization of events, PhD training and awards and communication in the field. IMISCOE supports more than 30 research clusters and organizes the IMISCOE annual conference (<https://www.imiscoe.org/>).

EuropaBON “Europa Biodiversity Observation Network: integrating data streams to support policy” funded by H2020 (EU 3.5.2). EuropaBON aims to bridge this gap by designing an EU-wide framework for monitoring biodiversity and ecosystem services. EuropaBON harnesses the power of modelling essential variables to integrate different reporting streams, data sources, and monitoring schemes. These essential variables provide consistent knowledge about multiple dimensions of biodiversity change across space and time. They can then be analyzed and synthesized to support decision-making at different spatial scales, from the sub-national to the European scale, through the production of indicators and scenarios. (<https://cordis.europa.eu/project/id/101003553>)

The **Portuguese Polar Program PROPOLAR**– that promotes and manages access of national researchers to both Polar regions, supporting a total of 60 projects, 121 researchers and 5 flights to Antarctica in 2013-17. PROPOLAR is responsible for the annual call for Polar research projects, freights an aircraft connecting Chile to Antarctica and is responsible for transporting over 100 international scientists and staff to/from the field each year. The PERMANTAR network of Antarctic Peninsula permafrost observatories (<http://permantar.weebly.com>) is the national contribution to the Global Terrestrial Network for Permafrost (<https://gtnp.arcticportal.org>), part of the Global Climate Observing System (GCOS/WMO) and the International Permafrost Association. CEG implemented and maintains since 2007 several permafrost observatories (boreholes, meteorological stations and permafrost deformation sites) from the South Shetlands to the Antarctic Peninsula and the Palmer Archipelago. These sites are maintained by CEG researchers and IGOT students, which conduct field research every austral summer

COST ACTIONS are one of the most important feature of nowadays science networking. TERRA centres have been involved in more than 50 COST actions in the last 5 years, a few relevant ones being: ConservePlants - COST Action CA18201: An integrated approach to conservation of threatened plants for the 21st Century. STReSS - COST Action FP1106: Studying Tree Responses to extreme Events: a SynthesiS. Alien CSI - COST Action CA17122: Increasing understanding of alien species through citizen science. KEYSOM - COST Action ES1406 - Soil fauna: key to soil organic matter dynamics and modelling. EUdaphobase - COST Action CA18237- European Soil-Biology Data Warehouse for Soil Protection. DarkDivNet Global network to explore “dark biodiversity” patterns, coordinated by University of Tartu. NetBiome-CSA network: Strengthening European research cooperation for smart and sustainable management of tropical and subtropical biodiversity in outermost regions and overseas countries and territories. FA1303 Sustainable control of grapevine trunk diseases. FA1307 Super-B Sustainable pollination in Europe. FA1308 DairyCare. FP 1303 Performance of bio-based building materials. FP1202 Sharing data and meta-data on the importance of marginal populations for forest in Europe. FP1203 European Non-wood Forest Products network. FPS-FP1006 Forest, their products and services: Bringing new functions to wood through surface modification.

TERRA has also been involved in Marie Curie networking, notably: Marie Curie ITN – INTEGRIM: INITIAL TRAINING NETWORK INTEGRIM - INTEGRATION AND INTERNATIONAL MIGRATION: PATHWAYS AND INTEGRATION POLICIES, – Contract number 316796, <http://www.integrim.eu/>; Marie Curie IF – MigRural: Return mobilities to rural Portugal: an assessment of the production to place-Contract number 794030, <https://cordis.europa.eu/project/id/794030/es>; Marie Curie – MEDCHANGe: Mediterranean changing relationships: global change, networks and border openings, Contract number: – 61263, https://ec.europa.eu/knowledge4policy/projects-activities/medchange-mediterranean-changing-relationships-global-change-networks-border_en; Marie Curie – SharingSpace: intercultural cities and collective space –Contract number: 318932, <https://cordis.europa.eu/project/id/318932>.

Facilities and scientific structures supporting research

All centres have excellent facilities for research development, with laboratories fully equipped, but also field equipment. The high quality research environment and facilities of CEG include a specialized library, vast map and photo archives, physical geography laboratory and the recent GEOMODLAB, a laboratory for spatial modelling and remote sensing.

CFE is the curator of Plant Collection of the Herbarium of Coimbra. LEAF and CEF are linked to the ISA Herbarium, a plant collection also extremely rich in tropical flora. LEAF and CEF are linked to the Botanical Garden of Ajuda. CFE has the Vice-presidency of the Science Museum of the University of Coimbra. LEAF (Dalila Espirito Santo) is the Portuguese Delegate for the European Botanic Gardens Consortium <http://www.botanicgardens.eu/>,

The Nutrient Network Portugal, a coordinated research network that comprises more than 130 grasslands sites worldwide, spreads over five continents. Two long-term facilities, an outdoor channel mesocosm, and one indoor ecohydraulic flume, support research on freshwater ecosystems. TERRA has many greenhouse facilities and controlled chambers to mimic environmental conditions.

CEF Field Network provides a unique infrastructure to support ecosystem data acquisition and to conduct research of innovative empirical and process based natural ecosystem models to project ecological indicators in scenarios of climate change. It includes i) two facilities in cork oak woodlands equipped with eddy covariance instruments for carbon and water flux measurements and sensors for meteorological measurements and soil moisture; ii) two fertirrigation experimental sites in stone pine stands equipped with meteorological and soil moisture sensors, iii) an experimental site in a cork oak stand to examine the effects of shrub invasion on the functioning of cork oak and iv) sets of permanent plots in eucalypt, umbrella pine, cork oak and maritime pine stands to support the development of growth and yield models. An international infrastructure network includes a permanent set of 38 planting sites within REINFFORCE (RÉseau INFrastructure de recherche pour le suivi et l'adaptation des FORêts au Changement climatiqUE).

In fact, **the established long term monitoring field network, that TERRA centres hold, in forest and other ecosystems, both terrestrial and freshwater, should be proposed as a RI**, and be extremely valuable in its essence for Earth survey, both for linking to other European similar databases (most of it already in course) as also for Portugal. The TERRA platform data repository will promote such a database. Thus not only an extremely important field datasets can be digitally transformed but also open-access to the community. Information concerning environmental alerts produced by TERRA researchers can also exist in the platform, some in a real time basis, such as rural fires maps, invasion risk maps and river ecological quality.

TERRA will support and promote dynamics to collect, provide, share and (re) use scientific data in an interoperable context with infrastructures or programs dedicated (or related) to the observation of earth and space such as AIR Centre.

Table 4. Achievement indicators of TERRA centres in the last 5 years (sum/average of the 5 centres)

Bibliometric indicators (sum or average for centres)	Units	Values
Total number of WoS papers (and in total)	sum	3238 (6446)
Total number of citations (and in total)	sum	>50 000 (>120 000)
H index median	average	8.9
H index 75 percentile	average	14.3
H index maximum value	average	45
Highly cited papers	sum	40
Editing positions journals and special issues editors	sum	146
Number of programs and projects evaluated in Portugal and abroad	sum	613
PhD thesis finished	sum	91
Non-Portuguese admitted in PhD programmes %	average	18.8
Number of Master thesis concluded	sum	343
Non-Portuguese admitted in MSc programmes %	average	11.6

Bibliometric achievements

TERRA achievements in publication, dissemination and knowledge transmission are shown in Table 4. Over 6000 peer-review were published of which more than 3000 in the last 5 years, with more than 50000 citations. In the last five years, TERRA counts 40 highly cited papers in the last 5 years, the highest h index is 54 (45 is

the average of maximum values), and more than 140 positions as Editors in Chief, Associate Editors or Editors of Special Issues.

2. A decade of opportunities

The Earth seems to be at the brink of a 6th extinction⁴ and we can observe many ecosystems collapsing, e.g. reef corals. The development of ecosystems that differ significantly from those found pre-historically will occur over large areas of the world and there is a growing need for researchers to play an influential role in the reconciliation of human activities with land use in anthropogenic biomes⁵.

TERRA will endeavor to **support researchers develop and promote their skills** and to participate in key strategic positions in national and international organizations and networks. There should be **an effort to give young researchers the conditions needed**, facilities, advanced technologies, enlightened supervision, but also individual liberty to pursue their concepts and ideas. TERRA will also promote **nurturing and development of international partnerships and advanced training networks**, raising the international visibility and profile of its researchers. **TERRA will focus on a selective expansion of international networks** in Europe, North and Latin America, as well as in Portuguese-speaking African countries.

These objectives are essentially similar to PERIN's, the Europe Research and Innovation Network, which arises in a context of national priority to promote R&D, innovation and digital transformation activities, assumed in the framework of public policies and its effective insertion in the European context, and to reinforce the Portuguese participation in EU Horizon

The PERIN network monitors the preparation, promotion and implementation of the European Union Research and Innovation Framework Programmes Horizon, with a special emphasis in the field of higher education and post-secondary training, (including the ERASMUS National Agency + Education and Training). It also coordinates the preparation of the Portuguese Presidency of the Council of the European Union in the field of science, technology and higher education. A wide structure of experts and contact points was created to support PERIN <https://perin.pt/>.

TERRA will link to the PERIN structure i) to promote the success in H2020 calls for TERRA members in its topics of interest; ii) to Network of Research and Innovation Promotion Centers within the scope of European Programmes, to be promoted in national Science, Technology and Higher Education institutions, including universities and polytechnic institutes, research units, among others. PERIN will be particularly useful in Horizon calls and through programs of Pillar 1, Excellence Science, via the European Council, the Marie Skłodowska-Curie Actions and the Roadmap of Infrastructures.

With the synergies gathered in TERRA, we hope to contribute to increase our presence in European programs, notably focusing in the following PERIN Missions and Partnerships:

Mission 1: Adaptation to climate changes and society transformation (TL1 and 2);

Mission 3: Healthy oceans, seas, coastal and inland waters (TL 1 and 2);

Mission 4: Climate neutral and smart cities (TL5)

Mission 5: Food and Soil health (TL2 and 3)

Partnership Area 2: Advancing key digital and enabling technologies and their use, including but not limited to novel technologies such as Artificial Intelligence and quantum technologies (especially TL1, 2 and 5)

Partnership Area 5: Sustainable, inclusive and circular bio-based solutions (especially TL3)

⁴ Kolbert, E (2014). *The Sixth Extinction: An Unnatural History* (2014) Henry Holt and Company. New-York.

⁵ Hobbs, Higgs and Harris (2009) *Novel Ecosystems, implications for conservation and restoration. Trends in Ecology and Evolution*, 24:599-605

Partnership Area 8: Innovative and R&D intensive small and medium-sized enterprises (especially TL 1, 2 and 3)

PERIN Missions spark innovation across disciplines and sectors, and is a bottom-up approach with multiple solutions, have a strong impact and visibility, bring Europe closer to citizens, widening participation and spreading excellence. **Translational science is at the core of such plans**, when societal demands create hubs of stakeholders, policy makers and researchers, working together for better and more innovative solutions, whose applications should be Earth-friendly, sustainable at the long course. The Missions should engage citizens in co-designing, co-creating, co-implementing and co-assessing such solutions. As in the Netflix series' Mandalorian moto, "This is the way".

E. Funding for TERRA

1. TERRA in a nutshell

The growing impacts of human activities on the biotic and abiotic environment has increased the pressure on natural ecosystems at local to global scales, threatening biodiversity, ecosystem functioning and the provision of critical ecosystem services. Reconciling human development with the safeguard of the natural ecosystems that support humanity is the most pressing need of our times and calls for truly systemic approaches. The Associate Laboratory for Sustainable Land Use and Ecosystem Services (TERRA) brings together ca. 400 researchers from five leading research centres to attain such multidisciplinary dimension required to promote more sustainable land uses, healthier inclusive societies, and healthier and resilient ecosystems.

The intertwined and highly complementary expertise of these research centres, i.e., Forest Research Centre (CEF/ISA-UL); Centre for Functional Ecology (CFE/FCTUC-UC); Centre of Geographical Studies (CEG/IGOT-UL); Linking Landscape, Environment, Agriculture and Food (LEAF/ISA-UL); and Environmental Health Institute (ISAMB/AIDFM-UL), creates the perfect conditions for effective synergies where the total is much more than the sum of the parts.

The action of TERRA will strongly hinge upon the concerted action of five transversal thematic lines: 1) Natural Capital and Sustainable Ecosystem Services; 2) Sustainable agriculture, forestry and fisheries; 3) Products Processing and Circular Economy; 4) Society and Environmental Health; and 5) Socioecological systems, planning and policies. Such thematic lines are highly complementary, cross-sectorial, and inclusive, covering all levels of anthropogenic pressures, spatial scales, levels of biological organization, and perspectives on environmental problems and solutions. TERRA members will continue delivering and strengthen their critical support to public policies contributing for a more sustainable land use. The contribution of TERRA will be specifically articulated through the establishment of multidisciplinary teams with a mission-oriented approach, targeting specific societal challenges and providing quick tailored advice to public and private sectors, both upon request, and by actively engaging scientists, stakeholders and policy-makers in knowledge co-creation.

TERRA researchers are already routinely involved in numerous National Research & Innovation Agendas including leading roles in: AgroFood, Forests and Biodiversity; Climatic Change, Urban Science and Future Cities; Circular Economy; Tourism Recreation and Hospitality; Health, Clinic Research and Translation Agendas. Members of TERRA have been actively contributing towards the definition and implementation of public policies, for example by providing tailored support for the National Platform for Disaster Risk Reduction; Network of Municipalities for Local Adaptation to Climate Change; Institute for Nature Conservation and Forests; Institute of Housing and Urban Renewal; High Commissioner for Migrations; Commission for Citizenship and Gender Equality; Portuguese Polar Program; Commission for Coordination and Regional Development of Lisbon and Tagus Valley; Centro Regional Coordination and Development Commission; Portuguese National Health Plan; National Mental Health Program; National Water Council; Regional Water Council of Tejo and of Algarve; National Forest Council; National Education Council; National Irrigation Council; National Economic Council; Economic and Food Safety Authority; and the Foundation for Science and Technology. Accordingly, the centres that integrate TERRA also have a strong interaction with the National Roadmap of Research Infrastructures (RIs) of Strategic Relevance, being involved in five: (C4G- The Collaboratory for Geosciences, PORBIOTA- Portuguese E-Infrastructure for

Information and Research on Biodiversity; PRISC- Portuguese Research Infrastructure of Scientific Collections; GenomePT- National Facility for Genome Sequencing and Analysis; ROSSIO- Social Sciences, Arts and Humanities) and also in the coordination of the Environment RIs.

At the international level, TERRA members also have a relevant track-record integrating, developing, evaluating and implementing several European and Global policy mechanisms, such as the EC Mission Board for Adaptation to Climate Change; European Green Deal; EU 2030 Biodiversity strategy; From Farm to Fork initiative; EU Scientific Forum on Invasive Alien Species; Common Agricultural Policy; Paris Agreement; European Food Security Agency; International Platform for Biodiversity and Ecosystem Services; International Union for Conservation of Nature; World Health Organization; and the UNESCO Chair on Biodiversity Safeguard for Sustainable Development. As a result of their international activity, members of TERRA integrate or coordinate over 30 European research networks (e.g. EUFRIN, HBM4EU, MarTERA ERANET, WINETWORK, FarmDemo, SCAR AKIS, Skan NETWork, AGRINATURA, PERMANTAR, BIODESERT, ECOSERVE, EPOS, DarkDivNet), and have strong ties with the economic sector (e.g. ALTRI, Amorim, Delta, EDIA, Jerónimo Martins, The Navigator Company, Águas de Portugal, Shell Thiogro, PETROBRÁS, DuPont). Such relevance is further reflected in the participation of TERRA on four Collaborative Laboratories (Circular Economy CECOLAB, Colab4Food, VINES&WINES, and ForestWISE), five Centres of Competences (Cork-Oak and Cork; Climate Change for the Agroforest sector; Aromatic, Medicinal and Spice Plants; Apiculture and Biodiversity; Maritime Pine), and 3 successful spinoffs (Fitolab, David Picard, Cooking Lab), fostering effective knowledge transfer between academic and the private sectors.

The governance of the consortium will be based on a light, efficient and inclusive structure, promoting transparent and decentralized decisions, and assuming a very strong commitment to attract talented researchers and provide them with permanent research contracts. TERRA research outputs and participation in policy advice and planning will be streamlined and showcased in a fully dedicated online platform that will also compile, organize, curate and share tailored information and data, fully embodying open science best practices.

Overall, the members of TERRA, in the last 5 years, have attracted over 36M€ in competitive funding (including national, public, private and European funding, e.g. ERC) and consultancies, published more than 3000 ISI papers that attracted >57000 citations, participate in about 150 editorial boards of international journals and special issues, and support 15 PhD programs. The establishment of TERRA will further capitalize on this demonstrated potential by strengthening multidisciplinary collaboration networks within and beyond the Associate Laboratory. Such an environment will continue to foster high-quality research that matters to people and the Planet, promoting effective translational knowledge co-creation with relevant stakeholders and policy makers, targeting sustainable land use, the conservation of biodiversity and ecosystem services, and more inclusive societies and human well-being.

2. Main research lines serving public policies and needs

To mainstream the research across Thematic Lines that will be used by TERRA to support public policies and societal needs, we have organized a group of research topics considered more significant.

Thematic Line 1 - Natural Capital and Sustainable Ecosystem Services

TL 1 will be focused on exploring links between biodiversity, ecological resilience, and nature's contributions to people well-being, with the goal to provide a clear mechanistic understanding of current threats to biodiversity in terrestrial, freshwater and marine environments, their impacts on ecosystem functioning and resilience, and effective ways to mitigate and reverse those impacts, including developing the sustainable use of ecosystem services: Specific goals include:

- **Quantification of biodiversity and its indicators** by collecting, curating and publishing data on species diversity and distribution, access, preserve and study scientific collections, fully integrated in the scope of current research infrastructures (e.g., PORBIOTA and PRISC), in line with the Thematic Agenda on Biodiversity, and giving full support to national and international entities in this area (ICNF, IPBES, IUCN).

- **Evaluating regulating and supporting ecosystem services, towards the preservation of agricultural and forest resources** of strategic importance for the sustainable development of Portugal, in its economic, social and environmental aspects, integrated in established research networks (e.g., CULTIVAR, F4F) and in connection with policy agencies and local, regional and national stakeholders.
- **Protecting and conserving protected areas in straight collaboration with the UNESCO World Network of Biosphere Reserves and the Man and Biosphere Programme and its action plan for Portugal 2018-2025**, by developing local strategies of sustainable development based on endogenous resources and mapping and valuing of ecosystem services coupled with knowledge transfer and capacity building.
- **Development of management plans of water resources, soil and nutrients** for sustainable environments comprising nature and climate based solutions, and protection of the natural systems against biotic and abiotic agents, such as invasive species and fire, in straight collaboration with the Public Administration and the private sector.

Thematic Line 2 - Sustainable agriculture, forestry and fisheries

TL2 will be focused on developing innovative community-based approaches for ecosystem management planning that may increase the efficiency and the effectiveness of food, wood, fibre and wildlife materials harvest scheduling while addressing ecological sustainability and intergenerational societal needs and demands, under scenarios of global change. Specific goals include:

- Development of **process-based dynamic ecosystem models** to project and predict indicators for the full range of ecosystem services under climate change, and to support the **design of landscapes** integrating productive areas and other land uses and natural systems.
- Development of **spatial optimization approaches and decision systems** that may provide information about the trade-offs between economic products and ecological services to support collaborative and community-based landscape-level management planning.
- **Ecoforestry and ecofarming**, development of nature-based solutions, including organic farming, for conciliating plant production and ecosystem management, and interchanging services, especially of regulation.
- **Sustainable ways to implement plant protection and invasive species control**, pushing forward integrated pest management to an ecosystem-based approach, and reducing the use of pesticides.
- Development of **precision forestry and precision agriculture** tools and management systems, including irrigation and nutrient supply, with emphasis in ways to increase production efficiency while decreasing environmental impacts in **water and soils**.
- Implementing **the blue-green infrastructure** across agricultural and forest landscapes, considering maximum benefits of regulatory services, such as rural-fire and climate resilience, water recharge, nutrient filtering and sediment trapping, and the hands-on solutions for its technical implementation, involving stakeholders.

Thematic Line 3 Sustainable products and circular economy

TL3 will research to deliver solutions and innovation towards sustainability of land-derived products' processing in support of national and European policies towards the competitiveness of a circular bioeconomy for the agrifood sector, while developing eco-efficient and zero-waste strategies. Specific goals include:

- Development of optimal procedures for improved use of resources, materials and energy based on 4.0 digital tools
- Development of quantitative assessment methodologies to measure the economic, social and environmental sustainability impact of processing practices
- Development of industrial technologies and closed-loop manufacturing systems.
- Development of innovative products to connect economic, health and environmental gains

Thematic Line 4 Society and environmental health

Focused on supporting policy decision that promotes an integrated and synergic perspective and action on human and planetary health⁶. Human health conditions and well-being state are dependent of the sustainability of natural resources. This is lined with the main hallmark of the United Nations Sustainable Development Agenda 2030. This strategic orientation includes the following dimensions of concern:

- **Healthy diets.** The EU Farm to Fork Strategy for a fair, healthy and environmentally friendly food system, positions nutrition and healthy diets as a key focus of international cooperation. **Diets as a key driver of nutritional status, but also to the social determinants of nutrition** and aims to facilitate better connection between research and decision-making by strengthening the dialogue in a way that is useful for policy development and programming.
- **Epidemiological surveillance.** Information, including bioinformatic and machine learning techniques, on the development and progression of non-communicable diseases, with particular focus on respiratory and metabolic diseases, linked to the identification of environmental, occupational exposures as well as lifestyle factors.
- **Social determinants of health and health equity.** Evidence-based knowledge about multiple determinants of health, combining environmental factors to inform and shape effective and equity-based health policies.
- **Environmental health communication.** An observatory of beliefs and attitudes of the Portuguese population about environmental health, allowing an effective communication, acknowledging that the information about perceptions attitudes and behavioural intentions related to environmental and human health are key determinants of human health, human wellbeing and planetary health.

From Thematic Line 5 – Socioecological systems, planning and policies

This thematic line will address climate change impacts on society, and adaptation and disaster risk management, intertwined with societal and cultural dimensions in space and place, examining opportunities for changing entrenched resource-intensive patterns of contemporary society, while addressing strategies, policies and governance structures to achieve sustainable cities and regions. Specific goals include:

- **Mapping and modeling regional climate change threats** and providing support to climate driven hazard impacts and disaster risk assessment, including floods, landslides, soil erosion, drought, forest fires, invasive species.
- **Examining, monitoring and evaluating territorial public policies and sectoral policies with territorial relevance to sustainable development**, that may inform strategies and planning of sustainable and resilient cities and regions (nature-based solutions, city greening, sustainable land-use, accessibility, just cities, rural depopulation and land abandonment, land use dynamics at the rural-urban interface) in the context of the EU Cohesion policy.

3. Public and stakeholder engagement in TERRA

Institutions related to nature conservation and natural capital, agriculture and forests, agrifood, social and economic geography and human health will be the main receivers of policy briefs and cooperation, together with management units at local, district, regional and national levels. Also major Land stakeholders should be interested in the Laboratory TERRA.

Within the scope of this proposal, we have explained the TERRA concept and organization, and invited these key institutions to grant the TERRA Laboratory proposal with a Letter of Support. We have given special attention to the **national public administration institutions**.

⁶ Santos O, Virgolino A, Santos RR, Costa J, Rodrigues A, Vaz-Carneiro A. Environmental health: An overview on the evolution of the concept and its definitions. In: Nriagu J, editor. Encyclopedia of Environmental Health. 2nd ed. Elsevier; 2019. p. 466–74.

All contacted institutions responded positively, and their Letters of Support that can be consulted at the following link: <https://www.isa.ulisboa.pt/cef/cef/laboratorio-associado-terra/>

Among these, we have the more relevant institutions for management and policies for landscape, nature conservation, agriculture and forests, territory, and health, corresponding to the first ten institutions in the list. These institutions will have a permanent seat in the TERRA Steering Committee.

From numbers 11 to 20, we have local and regional administration, companies and stakeholders association. This is just an example of the societal reach that TERRA can have due to its trademark in societal support activities with all types of companies of different size and role. From 21 to 23, we have examples of collaborative labs supporting TERRA. A variable number of these structures (the list not exhaustive) will be invited to participate in the TERRA Steering Committee. The composition of TERRA SC for these fluctuating members will be defined at the beginning of each mandate of TERRA' governance structure.

Finally, 24 is the European Forest Institute, an international organization dedicated to forest research. It is set as an example because many other international institutions with whom TERRA researchers work with, could be listed and send letters of support. These will be invited to the workshops and brainstorm meetings that TERRA will organize to debate relevant topics, as well as be part of TERRA research networking.

1. DGAV–Direção-Geral de Alimentação e Veterinária <http://www.dgv.min-agricultura.pt/portal/page/portal/DGV>
2. INIAV –Instituto Nacional de Investigação Agrária e Veterinária
3. IPMA– Instituto Português do Mar e da Atmosfera, <http://www.ipma.pt/pt/ndex.html>
4. DGADR – Direcção-Geral de Agricultura e Desenvolvimento Rural – <https://www.dgadr.gov.pt/>
5. DGS - Direcção Geral da Saúde, <https://www.dgs.pt/>
6. DGT Direcção Geral do Território – <https://www.dgterritorio.gov.pt/>
7. ICNF – Instituto de Conservação da Natureza, <https://www.icnf.pt/>
8. Gabinete de Políticas, Planeamento e Administração Administração Geral, <https://www.gpp.pt/index.php/>
9. APA- Agência Portuguesa do Ambiente, <https://www.apa.pt/>
10. Instituto Nacional de Investigação Agrária e Veterinária, <http://www.iniaiv.pt/>
11. AML – Área Metropolitana de Lisboa – <https://www.aml.pt/ndex.php>
12. CCDRLVT – Comissão de Coordenação e Desenvolvimento regional de Lisboa e Vale do Tejo – <http://www.ccdr-lvt.pt/pt/a-ccdr/vt/7281.htm>
13. ANIMAFORUM – Associação para o Desenvolvimento da Agro-Indústria – <https://agrocluster.pt/agrocluster/>
14. Centro Operativo Tecnológico Hortofrutícola Nacional – Centro de Competências (COTHN-CC) – <https://www.cothn.pt/>
15. Portugal Foods – Associação Integrar – Intervenção de Excelência no Sector Agro-Alimentar – <https://www.portugalfoods.org/>
16. TagusValley – Parque Tecnológico do Vale do Tejo – <https://tagusvalley.pt/>
17. The Navigator Company – <http://en.thenavigatorcompany.com/>
18. AGIF – Agência para a Gestão Integrada de Fogos Rurais. – <https://agif.pt/pt>
19. RAIZ – Instituto de Investigação da Floresta e Papel – <http://raiz-iifp.pt/>
20. InovCluster – Associação do Cluster Agro-Industrial do Centro – <https://www.inovcluster.pt/>
21. Colab4Food – Laboratório Colaborativo – <https://colab4food.com/>
22. C4G – Colaboratório para as Geociências – <https://www.c4g-pt.eu/>
23. ForestWise – Associação para o Laboratório Colaborativo para a Gestão Integrada da Floresta e do Fogo, <http://www.forestwise.pt/pt/institution/>
24. EFI – European Forest Institute - <https://efi.int/>

4. Funding

During the last 5 years, the research centers of TERRA have fund-raised 33500 k€, of which 13 million are still on projects in progress, for the following years (Table 5). About 2200 k € have been obtained via consultancies.

We will assume that the centres that constitute TERRA will continue to have the same scientific performance and capacity for fund-raising, and that the existence of the Laboratory will promote a synergy and a cooperation between researchers, that will result in more funding, of 3% increment per year. This value does not consider that research and funding will decrease due to retirement in the present corps of researchers, because it will be substituted. On total, we expect to have a budget of about 80 million euros for the next 10 years. A supplementary budget resulting from consultancies should be added.

Table 5. Research funding in the last 5 years and further until 2030, in €

PROJECT TYPES	Total 5 years	Remaining budget	2021	2022	2023	2024	2025	2021-30
European research projects H2020 and HORIZON	12 909 173	7 888 253	2 659 290	2 739 068	2 821 240	2 905 878	2 993 054	30 485 785
Other competitive research projects – Life, Interreg, JPI, twinning, Eranet...	1 245 573	530 571	256 588	264 286	273 214	280 381	288 792	2 941 494
National Research project FCT	13 126 433	3 459 176	2 704 045	2 785 176	2 868 722	2 954 783	3 043 427	30 998 848
Other competitive national projects - PRODER 2020, ANI, etc	6 124 920	1 151 195	1 261 734	1 299 586	1 338 573	1 378 730	1 420 92	14 464 361
Consultancy contribution	2 284 668	-	2 200 000	2 200 000	2 200 000	2 200 000	2 200 000	2 200 000
TOTAL	33 406 099	13 029 191	6 881 657	7 088 116	7 300 1749	7 519 772	6 467 365	78 890 478

The centres involved belong to research universities. It is not foreseeable that the institutional budget used for teaching activities and salaries of the academic careers and other administrative staff, will be used to supplement research because it is already too adjusted to the existing necessities. In all centres, research budgets come from research project funds; and the amount of applied contracts has noticeably decreased in the last decade, even if the same number of studies occur.

A very important effort was developed in the last years by the institutions to absorb long-term researchers, by opening fixed or permanent positions to whom they could apply (Table 6). Several positions will be open until end of year 2020 to potentially absorb the very-long-term researchers, sometimes with 20 years of activity of various nature. With the TERRA proposal, we intend to increase this installed research capacity, with 24 researchers. The budget record from the last years will benefit from these 24 high level researchers contracted by the complementary funds to the Laboratory, and they will also cooperate to obtain research funding.

The centres involved belong to research universities. However, it is not foreseeable that the budget for teaching activities and salaries of the academic careers and administrative staff will supplement the budget obtained outside of the institution's budget. In all centres, research budgets come from research project funds; and the amount of applied contracts has noticeably decreased in the last decade, even if the same number of studies occur.

Table 6. Research employment indicators from TERRA

INDICATORS	
Total number of integrated researchers in TERRA	403
Total number of permanent non-academic researchers including technical positions	30
Number of core CV	40
Ongoing fixed term contracts and various types of scholarships	233
Research contracts in the last 5 years	60
GOAL of TERRA for NEW permanent research positions	24

There is a **strong commitment** of all TERRA management institutions to create permanent contracts for these 24 researchers, on a 5-year horizon. These will be seven research positions and two technical positions at the Instituto Superior de Agronomia, six research positions and two technical positions at the University of Coimbra, four research positions at the Instituto de Geografia e Ordenamento do Território and three research positions at the Instituto de Saúde Ambiental.

Selected PhD researchers must have an excellent international research record and a strong potential to develop new and innovative research aligned with TERRA main goals. They are expected to work in a multidisciplinary team and in a collaborative way. They will lead research on their specific fields, interact with TL members, publish in high impact-factor journals, bid and obtain research funds at international level and foremost be able to develop high social impact research supporting public policies and actors in analysing, monitoring, evaluating and informing public policies targeting the sustainability of socioecological systems. A strong focus on the demonstration of scientific independence will be given, measured by scientific competence, novelty and international recognition, by experience in supervision, and by the competitive research funds attracted.

The distribution of these researchers and research technicians will be made along the TERRA TLs’ topics of research indicated above, and according to the institution needs. The following is a prevision.

TERRA CEO will be a Senior researcher with experience in research group management. He/she should have a good publication tracking record, a good science networking, and have been subjected to different research environments along his/her professional life. He/she should be able to do excellent scientific writing and to show leadership skills (#1).

Data science is an inter-disciplinary field that uses scientific methods, statistics, processes, algorithms and systems to extract knowledge and insights from many structural and unstructured data. Data science is related to data mining, machine learning and big data. The TERRA platform and its databases is a perfect environment for data scientists. These researchers will be fluent in data management, and therefore will be in charge of the platform, conceiving the structure, supervising the technicians that will introduce data, and more importantly, screening and insuring its quality. At the same time, they develop their own research along lines of spatial optimization and landscape eco-designs (#2 and 3).

Some important areas of work depend on the existence of knowledgeable field and laboratory technicians, able to install experiments, to collect and process biological data, to analysing and summarize it, so there will be two positions for research technicians at ISA (#4 and 5). Among possible areas in need of research technicians, there is the wine and winery group, including wine production and technology, and the plant protection group, including vectors of diseases, insect pests and all the methodologies for collecting and studying these.

One or two researchers will be considered for research on sustainable production, for example, the implementation of nature-based solutions and practices, such as organic farming, the study of precision forestry and precision agriculture, the development of soil conservation techniques and water conservation and reuse (# 6). Considering the goal to continue to invest in protection of natural systems against invasive species and to work on climate change scenarios to pursue alternatives to current land use practices towards sustainable environments, one or two positions will be open (#7). At least two research positions are proposed for developing eco-efficient and zero-waste strategies (# 8 and 9).

The research to increase the efficiency and the effectiveness of forest and agriculture ecosystem management planning and policy analysis to meet the increasing demand of economic goods while safeguarding ecological values, under global climate and market change scenarios, will require two new contracts (#16 and 17).

Attending to the multidisciplinary nature of the Laboratory, researchers will work in close collaboration between centres and in topics of common interest, notably nutrition and environmental determinants of diets and diet quality (#18), and environmental constrains of human mental health and non-communicable diseases (#19). Human resources with extensive and solid experience in health promotion, science communication, and machine learning will be selected. In addition, a contract (#20) for a researcher skillful in using data from environment and exploring connections between such data and environmental health at TERRA platform. This researcher will be a focal point for research collaborations using the full potential at the Laboratory.

For TL5, it is essential to attract and retain four highly qualified researchers that will be integrated in a multidisciplinary team aiming at expanding new strategic areas of research with a strong focus on policy analysis and recommendations within TERRA Laboratory. Among the strategic research areas, climate change impacts on society deserves a special attention. One research contract (#21) will be open to examine in-depth climate change threats and to prepare for climate driven hazard impacts, including floods, landslides, soil erosion, drought, forest fires, invasive species.

Another contract (#22) will be open to address the disaster risk assessment at several scales through mapping and prediction based on innovative modelling of the intersection between hazard, exposure and vulnerability. Strategies of knowledge transfer towards disaster risk reduction are also in the scope of this research contract.

Considering the goals of sustainable development, a research contract (#23) is devoted to the advancement to monitoring and evaluating territorial public policies and sectoral policies with territorial relevance, to produce new impact indicators aiming at inform planning of sustainable and resilient cities (nature-based solutions, city greening, sustainable land-use, accessibility, just cities). The research stream is aligned with and will contribute to the implementation of the National Program for Spatial Planning Policy and the development of the Spatial Planning and Urbanism Observatory. This researcher will be also enrolled in the development of TERRA platform.

Considering the problems of less developed areas in Portugal, where different and complex socio-economic dynamics operate in conjunction to create “wicked problems”, one research contract (#24) will address a variegated set of research topics, such as de-population, ageing, well-being, services of general interest, rural development, land-use change in peri-urban areas, sustainable tourism, and local and regional governance structures and their interaction with the national and international levels. This researcher will contribute to the study and impact analysis of European Structural and Investment Funds and to support national and sub-national development policy bodies in the country, focusing on sustainable development.



The researchers that have joined forces in the TERRA consortium collectively present an excellent record of activities in all the science fields addressed, and have strong liaisons with the administration, the stakeholders and other researchers working in the same areas, at national and international levels. However, TERRA bring synergy to the group, by the dimension of the visibility it provides, by the scale factor potentiating collaboration through data and idea sharing, and by the funding for research contracts that it represents.

Boosted by a traditional distance in cause-effect between research and its applications, and the consciousness that humanity cannot continue to go “business as usual” when dealing with the (mis)use of natural resources, also after many initiatives slowing down or providing weak results, Europe is pushing the environmental research into stakeholder-engaged and citizen-driven initiatives. This provides a challenge to researchers, and the need for a new attitude, that may be a window of opportunity for researchers but especially for the sustainable use of the land and the conservation of natural resources for the generations that follow.

Group synergy means strength, and with it comes more responsibility, and an inflated capacity to provide services to society, for supporting policy needs and to improve the way we manage the Land in our territory and beyond, taking also care of the human populations. TERRA believes that we can make a difference, and that at the end of the road, there will be a better future, if we all try, together.

ANNEX: COORDINATORS OF THEMATIC LINES AND TL MANAGEMENT BOARDS

LT 1 - Natural Capital and Sustainable Ecosystem Services

Helena Freitas (Coordinator). Received her PhD in Ecology from the University of Coimbra (1993), and did postdoctoral studies at Stanford University (1994/96). Full Professor of Biodiversity and Ecology at the Dept. Life Sciences of the UC since 2003 and holds the UNESCO Chair in Biodiversity and Conservation for Sustainable Development since 2014. Vice-Dean of the UC (2011/2015). Coordinator of the Centre for Functional Ecology, member of the EU Horizon Europe Mission Board for Climate Change Adaptation, including Societal Transformation and Focal Point for Portugal in IPBES. Areas of expertise include: Ecology; Mediterranean Ecosystems; Management of exotic and invasive species; Nature Conservation, Biodiversity; Tolerance to Stress and Bioremediation; Environmental policy. She coordinated national and international projects and consortia, including the Millennium Ecosystem Assessment. Supervised or co-supervised 35 PhDs. She is the author of more than 300 ISI publications (h = 52).

César Capinha. PhD in Environmental Sciences (University of Évora, 2012), and postdoc at the University of Porto (2017-2019), University of Lisbon (2016-2017), and the Zoological Research Museum Alexander Koenig (2013-2017). He is currently an FCT researcher [equiv. to Assistant Professor] at the Centre for Geographical Studies and a member of the Research Group “Assessment and Management of Hazards and Environmental Risk” (RISKam). He has published over 50 articles in ISI journals (h=19; c.1950 citations). He is a principal investigator (n=2) or nuclear researcher (n=10) in national and international projects related to biogeographical change, biological invasions and predictive modelling. Has supervised 5 MSc Students, 5 PhD students and 3 post-doc researchers. Contributing author for the upcoming IPBES assessment of invasive alien species and their control. External expert for European, Swiss and Czech R&I Agencies and Associate Editor of the international journal Diversity and Distributions.

M. Teresa Ferreira has a biologist background (1981), a post-graduation in Freshwater Ecology (1984), and a PhD (1992) and a Habilitation (2000) in Forest Engineering and Natural Resources Management. Works on freshwater ecology and management, ecological quality, fish habitat requirements and riparian ecology. Responsible for a MSc in Management and Conservation of Natural Resources and a PhD on River Restoration and Management. Supervised 37 MSc thesis and 19 PhD thesis concluded. Developed research activities in 56 national and European competitive projects, and involved in an identical number of applied studies. Scopus hindex 38. Published over 200 peer-reviewed papers and presented over 400 oral communications. Editor and evaluator of projects and institutions. Deeply involved in WFD implementation in Portugal, Member of the Science Council for the FCT, Advisor for public water management affairs and a Member to the National Water Council and the Tagus River Basin Council.

João Loureiro. PhD in Biology from the University of Aveiro (2007), João Loureiro is currently an Associate Professor in the Department of Life Sciences, University of Coimbra, and PI of the research line, Biodiversity, Conservation and Ecosystem Services of the Centre for Functional Ecology (CFE-UC). Together with Sílvia Castro, he coordinates the FLOWer Lab, whose objectives are to study plant diversification, pollination as an ecosystem service fundamental to the sustainability of agroecosystems, plant reproductive biology, ecology and in and ex situ conservation of threatened species, and valuing of endogenous genetic resources. Author of more than 100 scientific publications (92 ISI articles; index h = 29), advisor of several students of the 2nd (16 completed) and 3rd cycle (3 completed and 8 in progress) and Post-Docs (5 completed, 2 in progress). PI of 4 projects, team member of 22 projects, coordinator of the Intermunicipal Plan for Adaptation to Climate Change of CIM-RC.

LT 2 - Sustainable agriculture, forestry and fisheries

Margarida Tomé (Coordinator) Full Professor at ISA, coordinates the research line of CEF ForChange (Forest ecosystem management under global change). The research focuses on forest resources inventory and monitoring and forest growth modelling under a scenario of global change. She coordinated and / or participated in several national and international research projects, as well as consultancy projects, recently coordinating the Program of Recovery of Coastal Forests and Regional Forest plans from Centro Litoral, Centro Interior and Algarve. She has more than 100 publications in international journals with references (h-index of 30), is co-editor of Springer’s series “Managing Forest Ecosystems” and one of the Editor-in-Chief of Forest Ecology and Management. She is vice-chair of the IUFRO task force “Resilient Planted Forests

Serving Society & Bioeconomy”, was coordinator of IUFRO Division 4.0, member of EFI Scientific Advisory Board and President of the European Institute of Cultivated Forests.

José Luís Zêzere is Full Professor of Physical Geography at the IGOT-ULisboa, specializing in applied geomorphology, landslide hazard assessment and risk analysis. He is Vice-President of the CERG—European Centre on Geomorphological Hazards, Council of Europe, and Head of RISKam—Research Group Environmental Hazard and Risk Assessment and Management within the CEG. He was the Principal investigator of 8 Research Projects, including the FCT funded project “DISASTER - GIS database on hydro-geomorphologic disasters in Portugal: a tool for environmental management and emergency planning”. He coordinated 26 Contact projects related to Spatial Planning and Hazard and Risk Assessment and Management, including the team responsible for the Risks and Civil Protection for regional master plans and intermunicipal plans for climate change adaptation. He coordinates the reassessing of wildfire susceptibility and hazard in mainland Portugal an ongoing project for the ICNF.

JGC Borges is Associate Professor at the School of Agriculture (ISA), ULisbon and coordinator of its Forest Research Centre. Has a Ph.D. in Forest Science from the U. Minnesota. Visiting Professor in 5 universities in America in the period 1996-2019 and coordinator of the EMJMD Mediterranean Forestry and Natural Resources Management involving 6 other universities in Europe. His coordination activities attracted an annual average of about .5 million euros in 1998-2020, from EU and Portuguese programs and the Forest Industry. Co-author of over 100 peer reviewed publications. Participation in over 20 evaluation panels in several international organizations and over 10 editorial boards of WoS forestry journals. Co-author of 4 international policy briefs targeting European forestry, of the Mediterranean forestry research agenda 2010-2020 and of several reports to support Portuguese forest policy, namely its fiscal policy, as well as the development of regional plans and forest legislation.

Carlos Lopes is an Associate Professor at Instituto Superior de Agronomia/ULisboa, with the teaching activity centered on the area of Viticulture. He has a Degree in Agricultural Engineering (Évora Univ.), a Master of Sciences in Plant Production and a PhD and Habilitation in Agronomic Engineering (ISA/Lisbon Univ.). His research activity, funded by national and international research projects, has been centered in applied research performed in close collaboration with growers and focused on sustainable vineyard management practices (deficit irrigation, cover cropping, adaptations to climate change and precision viticulture). He has been responsible for many consulting services provided to several wine estates. Within the research unit LEAF he has coordinate the thematic line “Sustainable grape & wine production” and he is the Director of the Master in Viticulture and Oenology. He has an h-index of 21 (Scopus).

José Paulo Sousa PhD in Ecology (2003). Associate professor at the Univ. Coimbra, develops research on soil ecology and ecotoxicology studying changes of invertebrate diversity (using taxonomic and trait-based approaches) to assess changes in soil processes and associated ecosystem service provision due to land-use changes, pesticide use and extreme climatic events in agricultural systems in Mediterranean and tropical areas. Current interests include assessing landscape resilience towards habitat change and pesticide use on biodiversity and service provision, especially pollination and pest control. Since 2009 he is a collaborator the EFSA (European Food Safety Authority) Scientific Panel for Pesticides. Since 2014 is the head of ASAE panel for Pesticides and GMOs. He also provides consulting for the Shell, paper industry, German and Brazilian EPA. Publications: 20 books/book chapters and 186 papers in indexed journals (Scopus h =36). He supervises(ed) or co-supervises(ed) 24 PhDs and 64 MSc students.

LT 3 - Products Processing and Circular Economy

Isabel Sousa (Coordinator), PhD in Food Science/Nottingham University UK, associate professor with habilitation at ISA/ ULisboa (2001). Former head of the Research Group G3-Food & Feed from the LEAF (Linking Landscape Environment Agriculture & Food). Actual Head of LEAF research centre FCT/MCTES. Pioneered Food Texture and Rheology studies in Portugal, set up Food Rheology and Cereal Technology Labs to support research. Focused in sustainability/efficiency, involved in projects with the Industry, mainly in boosting Innovation through product development e.g. using functional ingredients, upcycling by-products and underexplored food sources, into plantbased staple foods, with strong impact on consumer’s well-being. More than 80 ISI publications and several book chapters in Applied Food Rheology and Functional Foods. International Expert evaluator (since 2005) for: i) EC and Research Executive Agency (REA); ii) the Eurostar program of the Eureka Secretariat; and iii) the Danish IFD.

José Carlos Rodrigues is a Researcher at CEF/ForEco. PhD in Forestry Engineering (1998) ISA/UTL, Habilitation on the applications of NIR in Agro-Forestry, IICT (2007). Coordinator of the Forestry and Wood Technology Centre (IICT, 2007-2015). Main research interests are the development of high-throughput phenotyping tools based on FTIR and NIR spectroscopy in combination with chemometrics, for the characterization of important agriculture commodities and especially for wood of relevant industrial species like maritime pine and eucalypts. Also developed a semi- micro chemical quantification of wood based on analytical pyrolysis. Published 65 publications in peer reviewed journals. h-index: 24 (ISI Web of Science/Publons; citations: 2854); 25 (Scopus, citations:3003).

Jorge Manuel Pataca Leal Canhoto has a PhD in Plant Physiology by Univ. Coimbra (1995). Assistant Professor with habilitation at Department of Life Sciences of the Univ. Coimbra and researcher at the Centre for Functional Ecology. Actual director of the Plant Biodiversity and Plant Biotechnology MSc. and leads the Plant Biotechnology Group of the Centre for Functional Ecology. Co-editor of the Springer journals *In Vitro Cell & Dev Biology* and *Forestry Research*. Chair of the Division of Plant Biotechnology and Genetic Resources of the ISHS. Recent collaboration with the FAO in publications related with the area of Plant Genetic Resources.

LT 4 - Society and Environmental Health

Antonio Vaz Carneiro (Coordinator). With 40 years of professional experience in Portugal and the US, António Vaz Carneiro is a Medical Doctor holding specialist degrees in Internal Medicine, Nephrology and Clinical Pharmacology. He is also a Full Professor at the Faculty of Medicine, University of Lisbon (FMUL) where he directs the Institute for Environmental Health, the Center for Evidence Based Medicine, the Institute of Preventive Medicine and Public Health, and the Institute for Higher Education, having several other educational and scientific responsibilities in the FMUL. Prof. Vaz Carneiro is the Head of Cochrane Portugal and of the Scientific Council of the Institute for Evidence Based Health (ISBE). He is a Clinical Researcher with special interest in the areas of secondary research (systematic reviews and meta-analyses), methodologies of translation of knowledge into practice, overutilization of health resources, applications of Artificial intelligence in Medicine and research in Precision Medicine.

Anabela Raymundo PhD in Food Engineering at ISA/ULisboa. Assistant Professor with Habilitation. Main research areas: functional properties of macromolecules - proteins and polysaccharides; development of new food products; evaluation of the rheological behavior of different food matrices and relations with the structural composition. Main work focused on the use of poorly exploited food sources (e.g., microalgae biomass and food industry by-products) for the development of high added value products. Participates in several national and international research projects, highlighting the establishment of a close relationship with the industry. ISA representative at PortugalFoods, CoLab4Food and EABA. Co-chair of the Agro Network - interdisciplinary structure at the University of Lisbon. Participation in the working groups for the redefinition of RIS 3 – Lisbon. Regular participation in project evaluation panels in the food and innovation area for ANI/MCTES. h-index of 26 (Scopus).

António Lopes is Associate Professor at IGOT-ULisboa and researcher at CEG (Zephyrus research group coordinator). Holds a PhD in Physical Geography since 2003. Member of the “F3 - Food Farm and Forestry” and the Tropical College -ULisboa; Scientific Associations: International Society of Biometeorology -ISB and International Association of Urban Climate – IAUC. Topic Editor of *Atmosphere/MDPI*; section editor of *Finisterra*. Research topics: Urban Climate Changes; Thermal Comfort and Health; Atmospheric Pollution; Micro-meteorology Modelling; Thermal Remote Sensing. In the last 30 years, was involved in national and international projects, among them: “SECOA - Solutions for Environmental Contrasts in Coastal Areas”; “URBKLM – Climate and Urban Sustainability Perception of Comfort and climatic Risks”; “National Plan for Territorial Development of Mozambique”; Climate Change Lisbon Metropolitan Adaptation Plan; “The Cape Verde Natural Hazards and Risk Profile of Cape Verde”-UNPD.

Andreia Costa, PhD, Ms Public Health, Training Epidemiology (ECDC), Coordinator Professor, Research Group coordinator “Environment, Family and Society” at ISAMB. Directorate-General for Health (DGS) consultant and WHO consultant for Ageing and Social Inequalities. Professor since 2004 with experience in health policies, working in public health as head of the Division of Health Statistics (2007-2009) and head of the Division of Programs Monitoring (2012-2013) of the DGS, and working in European Joint Actions, European Joint Action on Chronic Diseases and Promoting Healthy Ageing Across the Life Cycle, Joint Action

on Nutrition and Physical Activity and Joint Action Advantage. Between 2014-2018 Director of the Directorate of Disease Prevention and Health Promotion DGS. National and International Focal point for different subjects as Non-Communicable Diseases. Part of several international working groups namely Health Systems Performance Assessment to European Commission.

LT 5 - Socioecological systems, planning and policies

Mário Vale (Coordinator) is a Full Professor at IGOT-ULisboa. He holds a PhD in Human Geography from the University of Lisbon. He was a Fulbright Visiting Scholar at the Department of Geography of UCLA (University of California Los Angeles) in 2013. He is currently Director of the Centre of Geographical Studies -University of Lisbon. Research topics are on innovation and urban and regional economic dynamics, with special emphasis on European peripheral regions. His research has been underpinned by national and international research projects (4th, 5th and 6th Framework Programs, integrated actions, ESPON and FCT). His part of the coordination team that produced the technical studies for the first PNPT. He has collaborated on the preparation and evaluation of Structural Funds Programs (Observatory of QREN, CCDRLVT) and on the elaboration of the spatial plans in the LMA. He was Vice-President of the Regional Studies Association (RSA) (2008-2011) and is currently member of the Board of the RSA Europe.

JMC Pereira is a Full Professor at the School of Agriculture (ISA), ULisbon and member of the Lisbon Academy of Sciences. Has an undergraduate degree in Forestry from ISA, ULisboa, a Master of Landscape Architecture and a Ph.D. in Renewable Natural Resources Studies, both from the U. Arizona. His WoS record lists 120 publications, 5442 citations, and an h-index=38 and is the author or co-author of four WoS Highly Cited papers; His research was cited in the IPCC Assessment Reports 4 and 5. He leads the Forest Ecology research group at and is a collaborator of the Center for Statistics and Applications (ULisbon), and of the Laboratory for Environmental Satellite Applications, UFRJ, Brazil. He is a member of the editorial boards of journals, Fire, Forests, and Land. In 2004-2005, coordinated the technical report underlying the National Plan for Forest Protection Against Wildfires (2004-2005), and in 2017 helped draft legislation on fire research and revitalization of fire-affected areas.

Paulo Jorge Nogueira, MSc. in Probabilities and Statistics, and PhD. in International Health (Health and Development Policies), currently Researcher Assistant and Invited Assistant Professor for Biostatistics at the Faculty of Medicine of the UL. Lead several important projects namely the HEWS Project (Health Early Warning System using Satellite technology) for the European Space Agency and the ICARUS/ICARO Project first European Heat Surveillance system in Europe). 2010-2018 Head of Health Statistics and of Director of Health information (DGS). Several functions at ECDC, National focal Point for Training, for Epidemiology, for surveillance, Member of the Advisory Board of Eurosurveillance; Chair of the ECDC EPIET/One Fellowship Program, Chair of National Focal Points Forum. Member of the European Experts on Health Information (EGHI) and Ministry of Health LEAR in the European Commission Funding & Tenders Platform. For WHO performed several missions as a Health Expert.