The BiodivERsA strategic research and innovation agenda (2016-2020)

Biodiversity: a natural heritage, and a fundamental asset for Nature-based solutions tackling pressing societal challenges

Towards better coordination of national and local research programmes within mainland Europe, ORs and OCTs to increase the excellence and impact of research on biodiversity and Nature-based solutions

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Foreword

One of the greatest challenges of our time is the conservation, restoration, and sustainable use of biodiversity to reinforce its resistance and resilience to global change pressures. Furthermore, such actions will ensure that biodiversity will keep providing the necessary basis for human well-being and equity, economic growth and jobs. Although human societies and activities depend on biodiversity and the many ecosystem services it delivers, attempts to balance the use of nature against its capacity to face global change and deliver ecosystem services, both now and in the future, have largely failed over the past few decades. **In complement to approaches already applied, new paths must be explored and promoted to reinforce the synergies between biodiversity, human societies and economies**. Europe has to meet this challenge, fully recognizing that biodiversity is both a natural heritage to be conserved for future generations and a fundamental asset that provides the basis for transitioning towards a sustainable social and economic system, both on the European mainland and in the EU overseas. In this context, the priority for research is not only to quantify and understand the status and trends of biodiversity and ecosystem service delivery and act as a warning device; but also to propose solutions for overcoming these.

Against this backdrop, nature-based solutions can support European efforts by offering a holistic approach to address major challenges such as climate and water regulation, and urbanization, while at the same time promoting the sustainable management of ecosystems. **By turning biodiversity into a source for green growth and sustainable development, nature-based solutions can transform environmental and societal challenges into innovation opportunities** and can support the simultaneous achievement of environmental, societal and economic policy objectives. However, more research is needed to investigate the relationship between biodiversity and Nature-based solutions, and explore methods for developing, deploying and monitoring Nature-based solutions. A greater understanding of how to effectively assess potential benefits of the implemented solutions, and evaluate their possible drawbacks is also needed.

The challenge for research programmers and funders is therefore to promote 'research supporting solutions' in complement to 'research raising the alarm'. This requires deep changes in the way we perform research, with reinforced relationships between scientists and research stakeholders, deeper collaborations between disciplines, enhanced international collaborations, and better policy relevance of research. Profound changes in the way research programmers and funders design, implement and evaluate their research programmes, and increased support for cross-sectoral and cross-border research, are also vital.

Box : an overview of BiodivERsA

BiodivERsA was created in 2005 as an ERA-net supported by the European Commission. It now brings together 32 partners from 21 European countries plus one associated country, including 6 ORs and OCTs, to achieve 3 main priorities:

- **Promote cooperation and collaboration among national and local research programmers and funders and the European Commission toward joint programming and program alignment**. The promotion of more effective paths for achieving biodiversity conservation, restoration and sustainable use, and for the development and assessment of Nature-based

solutions are challenges that often cannot be addressed by individual countries. BiodivERsA spurs the coordination of European research around a common vision, shared objectives and joint activities.

- **Increase science-society/policy interfacing throughout the whole research process.** BiodivERsA recognizes the limitations of the linear model of research, and therefore has, since 2005, promoted the stakeholder model of research. Increasing research impact thus requires an innovative approach to research programming. While always promoting scientific excellence, BiodivERsA has developed novel approaches to encourage and facilitate stakeholder engagement, from research inception to everyday research activities and knowledge brokerage and transfer.
- **Promote research and innovation for the benefit of society, economy and human well-being, and biodiversity.** The work carried out by BiodivERsA aims to address pressing environmental, societal and economic issues. In particular, it seeks to promote a sustainable future in mainland Europe as well as the ORs and OCTs, through the protection and sustainable use of biodiversity and ecosystem services and the development of Nature-based solutions.

BiodivERsA main activities and achievements include:

(i) a regular mapping of the research landscape by analysis publications, research collaboration networks, funding sources and amounts, research infrastructures, and research priorities for local, national and international organisations. BiodivERsA has also developed and online database which currently references over 8000 funded projects);

(ii) foresight activities (to assess future research needs and trends, and to evaluate the framing of emerging approaches such as Nature-based solutions);

(iii) research programming, which has already led BiodivERsA partners to address 7 research topics through joint programming over 2008-2015;

(iv) joint research funding, through 6 joint calls amounting to approximately 150 Million Euros (over 80 M€ in cash);

(v) program alignment activities, a young scientist scheme, and a research-business mobility scheme (currently underway);

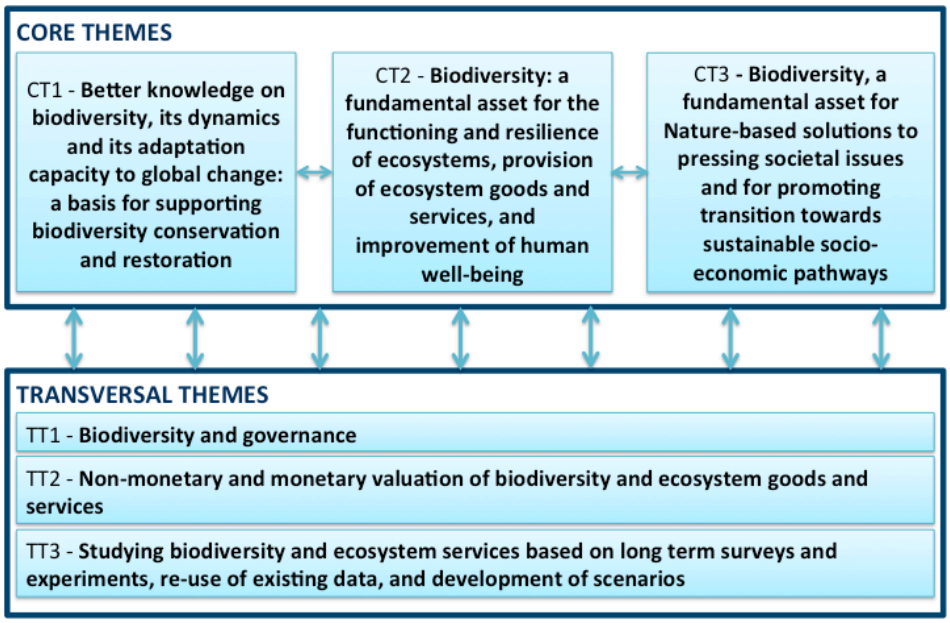
(vi) knowledge brokerage and transfer activities, including science-meets-society and biodiversity@business workshops, and the production of policy briefs for European and national policy makers; and

(vii) the implementation of an innovative and effective approach to stakeholder engagement throughout the whole research process.

The adoption of its strategic research and innovation agenda is an important step forward for BiodivERsA. The objectives of the strategic research and innovation agenda are (1) to frame the research domain to be jointly addressed by BiodivERsA members, (2) to present the common vision and shared objectives of BiodivERsA members, and (3) to identify broad research priorities that will guide BiodivERsA activities over the coming years. With this strategic research and innovation agenda, BiodivERsA partners share a vision of Europe becoming a global leader in conserving, restoring and managing biodiversity, and developing Nature-based solutions that contribute to its economy, with the support of a solid knowledge basis. The strategic research and innovation agenda will typically be updated every 5 years. In complement, a BiodivERsA implementation plan will be

established to detail the activities (e.g. joint calls and alignment of national programmes; mobility schemes and young scientist schemes; activities to cover the research and innovation interface; knowledge brokerage and transfer activities to reinforce the impact of the funded research; activities to evaluate achievements...) to take place. An update of the implementation plan is foreseen to take place every two years, or as required.

The strategic research and innovation agenda has been fed by a range of mapping and foresight activities, based on advice obtained from the BiodivERsA Advisory Board (composed of top scientists and key stakeholders with different backgrounds), as well as numerous researchers, research organisations, and stakeholders through an open consultation process. The strategic research and innovation agenda identifies three core themes (CT) and associated knowledge needs, which is completed by three transversal themes, dealing with general issues that are relevant to all the core themes (see figure).



In addition, BiodivERsA recognizes the need to deal with trans-sectoral issues: **liaising with other European initiatives (in particular Joint Programming Initiatives, JPIs, covering related challenges) and key international initiatives can help in tackling common challenges,** and this strategic research and innovation agenda clearly identifies the need to engage in these types of activities.

BiodivERsA has now the stature of a JPI[1], and will further generate **knowledge and tools to support decision-making and international policies and initiatives** such as Biodiversity 2020, the green pillar of the CAP, the Aichi targets, the CDB, the UN Sustainable Development Goals, and the Intergovernmental Panel on Biodiversity and Ecosystem services (IPBES). It will also promote research and innovation related to biodiversity and Nature-based solutions to support state-of-the-art approaches to conserving, restoring and sustainably managing biodiversity (i.e. both the

[1] Hunter A., Hernani J.T., Giry C., Danielsen K. & Antoniou L. (2016) Evaluation of joint programming to address grand societal challenges. Final Report of the Expert Group, European Commission, 90 pp.

European natural heritage and natural capital it represents) and promoting innovation and the European leadership for the development and deployment of Nature-based solutions.

We sincerely thank all the BiodivERsA partners, scientists, policy makers and stakeholders who have contributed to the development of this strategic research and innovation agenda, which is a milestone for the build up of **a 'European Research Area' on biodiversity and Nature-based solutions**.

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Content

List of acronyms

ABS – Access and Benefit Sharing
CBD – Convention on Biological Diversity
CESAB – Centre for the Synthesis and Analysis of Biodiversity
CT - Core Theme
DGs – Directorates General
DG ENV – Directorate General Environment
DG RTD – Directorate General Research and Innovation
ERA – European Research Area
EU – European Union
GBIF - Global Biodiversity Information Facility
IPBES – Intergovernmental Platform for Biodiversity and Ecosystem services
IPCC – Intergovernmental Platform for Climate Change
JPI – Joint Programming Initiative
KTTOs – Knowledge and Technology Transfer Organisations
NBS – Nature-Based Solutions
OCTA – Overseas Countries and Territories Association
ORs and OCTs – Overseas Regions and Outermost Countries and Territories
REDD – Reducing Emissions from Deforestation and Forest Degradation
SDG – Sustainable Development Goals
sDiv – Synthesis Centre for Biodiversity Sciences
SRIA – Strategic Research and Innovation Agenda
TT – Transversal Theme

1. Introduction

a. Context

Biodiversity and ecosystem services, and the vital benefits they bring to human societies (see Box 1), underpin economic growth, security, and poverty alleviation –thus fostering equity and social justice- and are our life insurance. They are fundamental topics of enormous importance, which affect a broad range of policy areas[2]. It is increasingly recognised that biodiversity is essential for the delivery of ecosystem services[3], which are as much an environmental issue as an economic, food-security, energy-security and political one.

Box #1: definitions

- Biodiversity is defined as "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems" (United Nations Convention on Biological Diversity 1992): *e.g., genetic diversity of crop plants, invertebrate species diversity, functional diversity of fish communities, diversity of natural and managed ecosystems in a landscape*
- Biodiversity conservation refers to the protection of biodiversity but also includes biodiversity restoration and the sustainable management and use of biodiversity. Conserving biodiversity means ensuring that the arrays of ecosystems are maintained, and that species, populations, genes, the complex interactions between them and their evolutionary potential, persist into the future[4].
- Ecosystem services are contributions that ecosystems (whether natural or semi-natural) make to human well-being while retaining a clear link to underlying ecosystem functions, processes and structures (OpenNESS, 2014[5]): *e.g., flood protection, harvestable products*
- Ecosystem goods or benefits are direct and indirect outputs from ecosystems that have been turned into material products or experiences while being no longer functionally connected to the systems from which they were derived (OpenNESS, 2014): *e.g., contribution to health and safety*
- Nature-based solutions refer to the sustainable management and use of nature for tackling societal challenges like climate regulation, sustainable urbanization, or sustainable food supply, aiming to simultaneously meet environmental, societal and economic

[2] Rockström J., Steffen W., Noone K., et al. (2009) A safe operating space for humanity. Nature 461: 472-475.

[3] Balvanera P., Siddique I., Dee L., et al. (2014) Current uncertainties and the necessary next steps. Bioscience 64: 49-57.

[4] http://www.wwf.org.au/our_work/saving_the_natural_world/what_is_biodiversity/conserving_biodiversity/

[5] OpenNESS (2014). Policy brief n°1 – Benefits from Ecosystem Services: towards a shared understanding (http://www.openness-project.eu/sites/default/files/OpenNESS_brief_01.pdf)

objectives[6]. Inclusion of the idea of a "solution" in the concept explicitly recognizes that people agree that there is a problem that needs to be solved: *e.g., greening roofs, streets and walls to cool down city areas during summer, capture storm water, abate pollution, and increase human well-being while enhancing biodiversity; conservation and restoration of mangrove forests to provide protection from coastal erosion in the face of severe storms while providing fish nurseries to local human populations; forest protection and reforestation to provide clean water, reduced flood risks and support carbon sequestration*

The loss of biodiversity and degradation of ecosystems are alarming because biodiversity is a common good that should be preserved for the future generations, and because they jeopardize the sustainable provision of ecosystem services, which is now recognized as major scientific and societal challenges (Fig. 1).

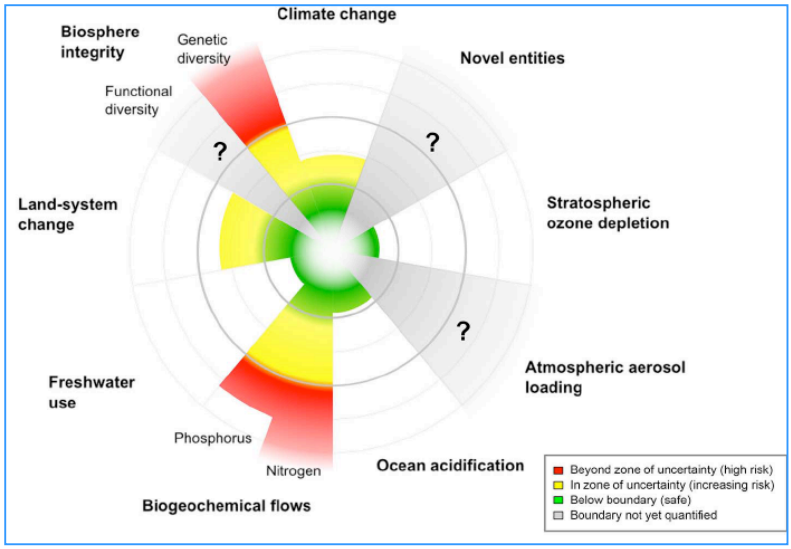

Fig. 1: The current status of the control variables for the 9 main planetary boundaries. The integrity of biodiversity and ecosystems is recognized as one of the 2 boundaries for which pressures from human activities clearly jeopardize the sustainability of the Earth system. From Steffen et al. (2015)[7].

Indigenous species which are part of natural habitats, ecosystems, landscapes, freshwater and marine environments, have inherited genetic properties that have been subjected and adapted to natural selection for over thousands of years during varying environmental regimes. In addition, humans have also selected plant varieties, animal races and microbial strains to better fulfil human needs. Losing species, populations or genotypes and associated functions and functional traits thus means loss of ecosystem adaptability and resilience. This likely also will have huge impacts on human societies, with a welfare loss equivalent to 6-7% of global GDP per annum at the horizon 2050[8]. It

[6] Eggermont H., Balian E., Azevedo J., et al. (2015) Nature-based solutions: new influence for environmental management and research in Europe. GAIA 24: 243 – 248. This paper also provides an overview of related concepts like ecosystem services, green infrastructures, ecosystem-based approaches and ecological engineering – to name a few.

[7] Steffen W., Richardson K., Rockström J., et al. (2015) Planetary boundaries: Guiding human development on a changing planet. Science 347 : DOI: 10.1126/science.1259855.

[8] Sukhdev P., Wittmer H., Schröter-Schlaack C., et al. (2010) The economics of ecosystems and biodiversity: Mainstreaming the economics of nature - A synthesis of the approach, conclusions and recommendations of TEEB. 36 pp.

could also have negative impacts on the labour market because many jobs are directly involved in biodiversity preservation (conservation managers and wardens in natural parks, genetic resource managers, etc.) while many more jobs depend on biodiversity (food and agriculture, biotechnologists, tourism operators, pharmaceutical researchers, etc.) or could be created by biodiversity-based innovation[9]. In this context, the European Commission adopted in 2011 a new strategy to halt the loss of and restore biodiversity and ecosystem services in the EU by 2020, and in 2012 the 7th Environment Action Programme to guide environmental policy was launched too (http://ec.europa.eu/environment/newprg/). It is also promoting Nature-based solutions as a further source of innovation.

Clearly, it seems necessary to bring and maintain the human demand for resources and services at levels consistent with the biophysical constraints of their supply at the same scale of demand. Still, such an approach could be viewed as largely utilitarian, and difficult to reconcile with non-utilitarian approaches to biodiversity conservation. As clearly exemplified by Mace[10], the framing and purpose for nature conservation have shifted over the past years (Fig. 2). Biodiversity thinking prioritized wilderness until the 1960s (i.e. 'nature for itself'), and focused on strategies to reverse threat to species and habitats from humans ('nature despite people') in the 1970s-80s. It then appeared that the best endeavours of conservation were failing[11], but that the amount of goods and benefits that people obtain from nature cannot be ignored. Biodiversity thinking and research thus moved away from species towards communities and ecosystem services ('nature for people') after the 90s, while the concept of ecosystem services was promoted by the work on the Millennium Ecosystem Assessment[12]. In the recent years, emphasis has moved from a potentially overly utilitarian perspective to a more nuanced one recognizing two-way relationships between people and nature ('people and nature'). This more balanced perspective has been integrated in the Conceptual Framework of the Intergovernmental Platform for Biodiversity and Ecosystem Services (IPBES)[13] highlighting commonalities between diverse value sets, and seeking to facilitate cross-disciplinary and cross-cultural understanding. It is also embedded in the notion of Nature-based solutions (Box 1). In this maturity phase, a main objective is to promote sustainable and resilient interactions between human societies and biodiversity, based on a solid knowledge ground built in particular by ecology, resource economics and social sciences.

Importantly, these different views on biodiversity issues coexist today (Fig. 2), being promoted by different actors and leading to tensions and conflicts. Identifying potential synergies and minimizing trade-offs between this pluralism of views and motives will be crucial to overcome the current ecological crisis. Similarly, systems integration —holistic approaches to integrating various

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[9] Jurado E., Rayment M., Bonneau M., et al. (2012) The EU biodiversity objectives and the labour market : benefits and identification of skill gaps in the current workforce. 342 pp.
Bénard S. & Verilhac Y. (2010) Rapport du comité de filière biodiversité et services écosystémiques. MEDDE

[10] Mace G.M. (2015) Whose conservation? Science 345: 1558-1559.

[11] Hindmarch, C. & Pienkowski, M. (2000) Land management: The hidden costs. British Ecological Society, Blackwell Science, Oxford.

[12] Reid W.V., Mooney H.A., Cropper A. et al. (2005) Ecosystems and Human Well-being: Synthesis. Millennium Ecosystem Assessment. Island Press, Washington DC. 140 pp.

[13] Diaz S., Demissew S., Carabias J., et al. (2015) The IPBES Conceptual Framework — connecting nature and people. Curr. Opinion Env. Sustainability 14: 1–16.

components of coupled human and natural systems (spatial, but also temporal)— will be critical to understand social, economic and environmental interconnections and to propose sustainable solutions to the most pressing issues. Such approaches are clearly embodied in the 2030 Agenda for Sustainable Development identifying sustainable development goals (SDGs)[14].

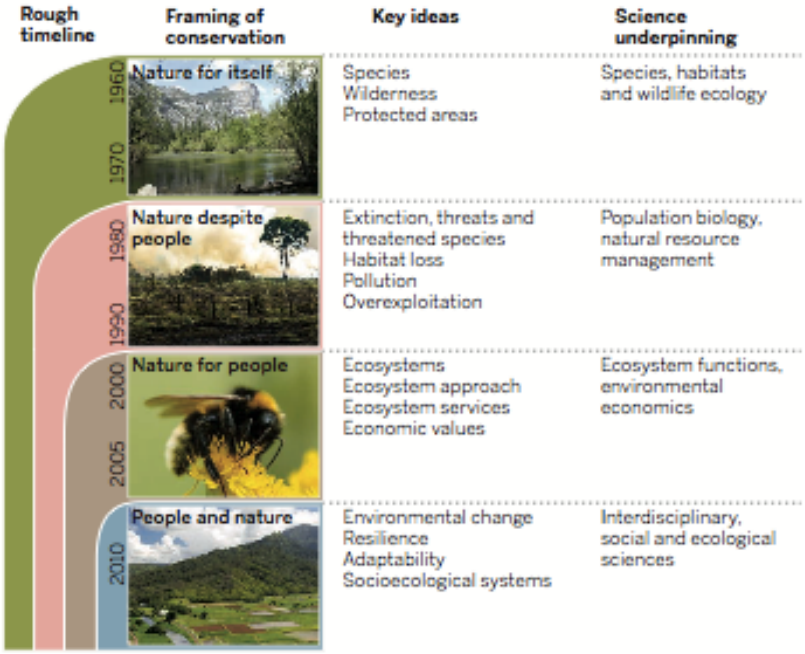

Fig. 2: Views on biodiversity and its relations with humans have strongly evolved over the past 50 years. However, none of the framings has been eclipsed by the emerging ones. This explains the multiple framings in use today, which have different echoes from different stakeholders and different parts of the research community. From Mace et al. (2015).

Although systems integration has already led to fundamental discoveries and practical applications, further efforts are needed to incorporate more human and natural components simultaneously, quantify spillover systems and feedbacks, integrate multiple spatial and temporal scales, cross disciplinary barriers, develop new tools, engage stakeholders from diverse backgrounds, and translate findings into policy and practice. Such efforts can help address important knowledge gaps, link seemingly unconnected challenges, and inform policy and management decisions[15]. In doing so, research on biodiversity and Nature-based solutions would have to maintain and reinforce its academic excellence, while also recognising that it is part of the so-called post-normal science[16], in which socio-economic stakes are high and decisions are pressing.

b. How can biodiversity help tackling major societal challenges in Europe, promoting innovation and a transition towards improved sustainability and well-being for European societies?

A knowledge-based approach to tackle the pressing issues related to biodiversity requires new thinking and a coordinated effort among several sub-disciplines from biology and ecology, earth

[14] United Nations (2015) Transforming our world: the 2030 agenda for sustainable development, 41 pp.

[15] Liu J., Mooney H., Hull V. et al. (2015) Systems integration for global sustainability. Science 347 (6225)

[16] It characterises a methodology of inquiry adequate when 'facts are uncertain, values in dispute, stakes high and decisions urgent' (Funtowicz S.O. & Ravetz J.R. (1991) A new scientific methodology for global environmental issues. In: Ecological economics: the science and management of sustainability. (Costanza R. Ed.) New York, Columbia University Press, pp. 137–152).

sciences, and various social sciences, including economics. It also requires simultaneous investigation of the links and feedbacks between genetic, taxonomic/phylogenetic, and functional dimensions of biodiversity; as well as their dynamics in a global change context to better preserve this common good for future generations.

In addition, a better understanding of the role of biodiversity for the delivery of ecosystem services and of the resistance/resilience of (socio)-ecological systems in a global change world is crucial to achieve this ambitious target (i.e. highlighting the lesser known values of biodiversity supporting human-well being, including health and cultural values). The latter is also the basis for developing and successfully deploying a range of Nature-based solutions (Fig. 3) that use nature for tackling societal challenges whilst simultaneously protecting biodiversity and improving sustainable livelihoods. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions. They also transform environmental and societal challenges into innovation opportunities by turning natural capital into a source for green growth and sustainable development.

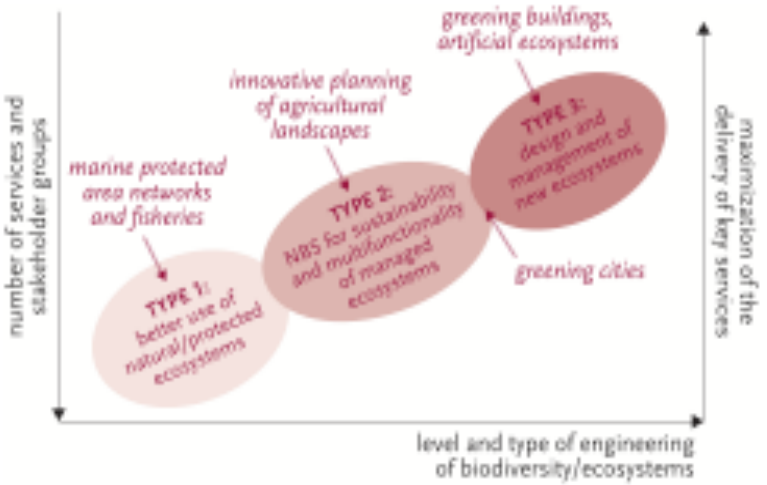

Fig. 3: Schematic representation of the range of nature-based solutions approaches that exist. The different approaches were identified during a BiodivERsA workshop gathering scientists, stakeholders and policy makers. Three main types of Nature-based solutions are defined, differing in the level of engineering or management applied to biodiversity and ecosystems (X-axis), and in the number of services to be delivered, the number of stakeholder groups targeted, and the likely level of maximization of the delivery of targeted services (Y-axis). Some examples of Nature-based solutions are located in this schematic representation. From Eggermont et al. (2015).

This should create new, high quality jobs, because a good number of generally higher skilled, knowledge intensive jobs will be needed to carry out the research, develop innovative Nature-based solutions and deploy them, and carry out surveys and policy work associated to Nature-based solutions deployment. Promoting Nature-based solutions could also encourage skilled manual workers in sectors like agriculture, forestry and fisheries to name a few, thus securing the sustainability of jobs in these declining sectors while attracting young people[17]. This could contribute to the EU's poverty reduction, geographical diversification and smart specialisation.

[17] Maes J & S. Jacobs (2015). Nature-Based Solutions for Europe's Sustainable Development. Conserv. Letters DOI: 10.1111/conl.12216

c. Main issues to be considered by programmers of research on biodiversity and Nature-based solutions

The main issues to be considered for programming and funding research on biodiversity and Nature-based solutions are at least fourfold:

- In order to be effective and inclusive, **biodiversity research needs to take into account a multitude of criteria and stakeholder perspectives**. In particular, biodiversity issues are often at the cross-roads of numerous political and socio-economic interests, which requires to account for sectors such as environment but also agriculture and fisheries, mining, energy, health etc. and promote a cross-sectoral approach towards the conservation and sustainable management and use of biodiversity
- **Biodiversity research** relies on disciplinary communities of high excellence which have to be supported per se, but also **requires various forms of collaboration (multidisciplinary, interdisciplinary and trans-disciplinary)** often implying risks and barriers for scientists
- Biodiversity research is undergoing a shift to a novel type of innovation actions based on a **systemic approach to solve problems** and promote a more resource efficient, greener and competitive economy, in particular by providing the knowledge needed for co-designing, co-developing and co-implementing innovative Nature-based solutions, testing them in real-world conditions through demonstration activities and securing their market uptake
- Promoting **adequate and rapid knowledge brokerage and transfer from research activities** is increasingly needed in this context to ensure effective uptake for economic development, environment protection and societal benefits. It require tools and skills to formulate and channel stakeholders' knowledge and to translate research outputs into societal or market value (i.e. quick translation of new findings into concrete recommendations for environmental policies and for promoting innovation)

d. The BiodivERsA vision for reinforcing Research and Innovation on biodiversity and Nature-based solutions in Europe

Following this philosophy, **BiodivERsA promotes relevant knowledge generation** and continuous engagement of policy makers and other stakeholder, and **allows scientists to act as honest brokers of policy alternatives** (sensu Pielke[18]). A main entry point is that, until now, synergies between biodiversity and human activities (i.e. the human-nature nexus) have often not been properly explored and exploited, due to legislative, financial and even motivational hurdles. This has hampered innovative application of (and limited our knowledge about), e.g., promoting and using nature in landscape and urban planning, and more generally, successful deployment of nature-based solutions to tackle grand societal challenges (see further). Biodiversity and ecosystem services research has thus to reinforce its links to a range of key stakeholders and policy makers, going beyond the traditional niches. This requires the development of a science-society and a science-policy dialogue during the whole research process, from the co-design of this SRIA to the implementation of joint activities and key actions in order to enhance the relevance and impact of research results. **BiodivERsA will benefit from the experience and practices of European Outermost**

[18] Pielke R.A. (2007) The honest broker. Making sense of science in policy and politics. Cambridge University Press. 188 pp.

Regions (ORs) and Overseas Countries and Territories (OCTs) where biodiversity and sustainable development are strongly interdependent and science-society interactions are tight and diverse, as illustrated by the outcomes of the projects funded by the 2010 Era-Net NetBiome Joint Call. ORs and OCTs account for a major part of Europe's total biodiversity, with a particular high rate of endemic species. They host unique ecosystems with specific issues and stakes, but also largely untapped biological resources that could prove strategic for Europe. Although they developed original and innovative approaches with potential added value to reach European Union goals on biodiversity (Box 3), their integration into the European Research Area (ERA) is still insufficient and ought to be enhanced and improved.

In addition, biodiversity issues cross national borders (e.g., invasive species; valuation of biodiversity and ecosystem services; cross location impacts) and sectors (e.g., links between biodiversity and the Common Agricultural Policy, the Common Fisheries Policy, the EU's Trade Policy, etc.). Therefore, even if significant R&D investments exist in this area at the European and even more so at local and national levels in this area, resources cannot, as is often the case today, be allocated independently through a fragmented approach and without a European-scale strategy. Moreover, biodiversity issues are not restricted to mainland Europe. Indeed, integrating research to better address biodiversity, ecosystem services and Nature-based solutions issues within Europe cannot ignore specific issues for overseas territories and regions linked to European countries. Finally, effective coordination and promotion of transnational research in Europe has to be strategically developed in the wider context of the international research landscape. This includes considering the research needs of a range of biodiversity-related Multi-lateral Agreements like the Convention on Biological Diversity (CBD), and interacting with key international initiatives (in particular Belmont Forum, Future Earth and Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)).

In this overall context, the BiodivERsA partners have agreed on a common vision of the main objectives and outcomes of BiodivERsA acting as a major European initiative for joint programming on biodiversity and Nature-based solutions (Box 2).

Box #2: BiodivERsA vision for 2016-2020

Ultimate impact/Outcomes (BiodivERsA contributing to a beyond 5 year time frame)

* Knowledge is reinforced for conserving, restoring, managing and using biodiversity and ecosystems in a way that reinforces their resistance and resilience to global change pressures and maximizes the synergies between economy (jobs/growth), society (culture and well-being) and environment
* Europe is recognized as exemplary for the way it conserves and manages biodiversity and as a global leader for Nature-based solutions supporting its sustainable economy

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Goal of BiodivERsA (indicators of success for BiodivERsA)

* Generate relevant knowledge and scientific underpinning to better conserve, restore and manage biodiversity and to develop and deploy innovative Nature-based solutions tackling key societal challenges and improving human well being

* Increase the coordination between organisations in charge of knowledge generation while promoting the development of new paths for biodiversity conservation and management, and Nature-based solutions across Europe
* Promote an efficient liaison between science & society (including policy), and research & innovation, throughout the whole research process
* Increase the profile of European science and innovation on biodiversity and Nature based solutions, including at the global scale

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Roles of BiodivERsA (guiding BiodivERsA activities)

* Among European countries, among ORs and OCTs, and among mainland and overseas, research programmers and funders properly coordinate their activities, resources and agendas, support capacity building and efficiently develop the ERA on biodiversity and Nature-based solutions through ambitious joint activities
* Scientists from relevant disciplines and stakeholders from a range of sectors are mobilized and efficiently collaborate to improve the knowledge basis needed to conserve and manage biodiversity and develop and deploy Nature-based solutions

2. Methodology used for the development of the BiodivERsA SRIA and implementation plan

a. Importance of the development of the SRIA and implementation plan in the BiodivERsA activities cycle

During the last decade, BiodivERsA has developed a range of complementary activities covering the whole Joint Programming activities cycle (Figure 4).

This document presents the BiodivERsA SRIA that will guide the choice and implementation of the activities of the BiodivERsA members for the next Joint Programming activities cycle. The SRIA should foster the impact of European research and innovation by **(i) raising the efficiency of European policies for biodiversity preservation by avoiding the drawbacks of policy silos, (ii) responding to the increased demand for ecosystem services while operating European societies and economy within environmental limits, and (iii) informing the development of Nature-based solutions to tackle major societal challenges**. The SRIA will be updated typically every 5 years.

Based on this SRIA, a BiodivERsA implementation plan will be elaborated to define priority activities (e.g. joint calls and alignment of national programmes; mobility schemes and young scientist schemes; activities to cover the research and innovation interface; knowledge brokerage and transfer activities to reinforce the impact of the funded research; activities to evaluate achievements; etc.). The implementation plan will be updated as needed - at least every 2 years - as the activities of BiodivERsA advance.

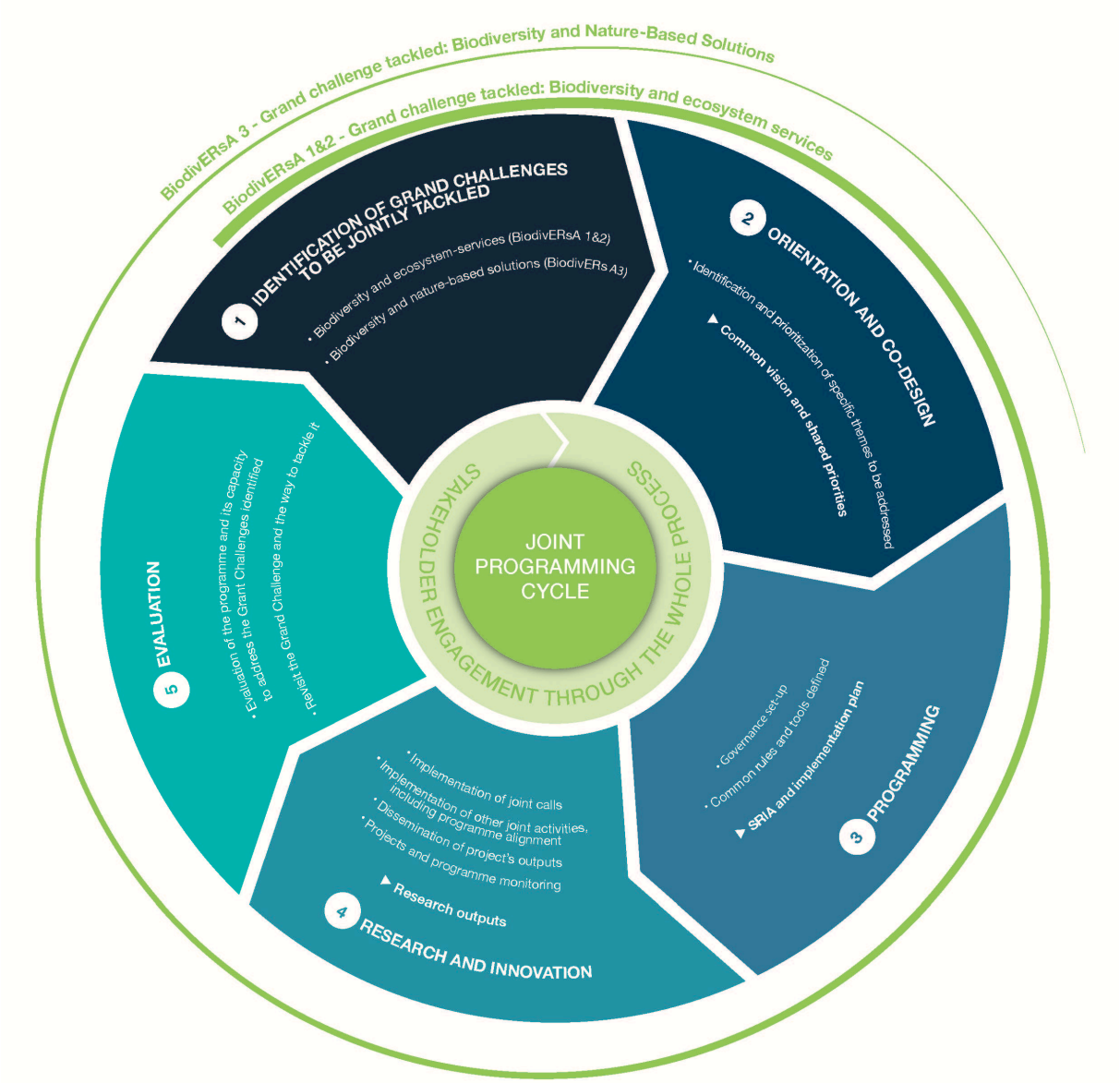

Fig. 4: The development of the SRIA is a key activity part of the joint programming cycle, which structures the BiodivERsA approach. The present SRIA is developed after the 2010-2015 period, which allowed BiodivERsA to develop a first round of activities covering the whole Joint Programming activities cycle. This led to revisiting the grand challenge addressed by BiodivERsA, with updated core and transversal themes, through a new SRIA. This will then lead BiodivERsA partners to adjust/complement their priority activities and topics, through an implementation plan that will be developed based on the updated SRIA.

A wide range of stakeholders (see below) have been mobilised to develop both the SRIA and the implementation plan.

b. Overall approach used to develop the BiodivERsA SRIA and implementation plan

An appropriate process was used to develop the BiodivERsA SRIA and the first associated implementation plan in order to ensure their relevance for a broad range of stakeholders, their credibility and their legitimacy. The process was designed for:

- identifying the strengths and weaknesses of research for this domain in Europe ;

- building on priorities and strategies that exist at international, national and local levels ;
- accounting for the scientific forefronts and technological/infrastructure potential ;
- accounting for stakeholder needs, considering a broad range of stakeholders and efficiently addressing cross-sectoral issues ;
- going beyond the linear model of research and promoting the multi-stakeholder model of research ;
- linking local, national, European – and, when relevant, international – policies and programmes to prepare an ambitious joint programming plan.

Fig. 5: Multi-stakeholder involvement approach used for developing the BiodivERsA SRIA. Note that a parallel approach was used for the mainland and overseas actors to properly account for overseas specific assets and challenges regarding biodiversity.

This was achieved by a multi-stakeholder involvement approach (Figure 5). As presented in the following sections, we took into account the results from a range of mapping and foresight activities, as well as inputs from researchers/research organisations and research infrastructure managers, policy makers (including different relevant DGs from the European Commission, the European Parliament, and relevant national Ministries and local governments), many stakeholders including businesses, different joint programming initiatives, and different international initiatives.

c. Results from mapping and foresight activities

During the last years, BiodivERsA has conducted a range of mapping activities to better characterize the landscape of research on biodiversity and ecosystem services in Europe.

Concerning the size of the research community, an analysis based on the information available in the BiodivERsA database (www.biodiversa.org/8) indicated that over 5000 laboratories/teams from 21 European countries are represented in the database. Although this analysis remains rough, it shows the importance of the research community working on biodiversity and the ecosystem services depending on biodiversity. This is consistent with a comprehensive analysis of the scientists working at least partly on biodiversity and associated ecosystem services performed in France: the total number of French scientists working in the domain was over 4,000, which represents over 1,500 full time researchers[19]. For Spain, according to the Project database of MINECO, the number of researchers on terrestrial and aquatic biodiversity is ca. 3,650. Furthermore, the scientific community working on biodiversity is increasingly active. At the global level, the number of papers on biodiversity published in international, peer-reviewed journals has increased markedly over the last 15 years, being similar to the number of papers produced by research on climate and climate effects (Figure 6). All these elements demonstrate that there is a large and active research community focusing on biodiversity. This also explains the high level of the research community mobilization in response to BiodivERsA calls: more than 200 proposals in response to the first (open) BiodivERsA call in 2008, and 128 proposals in response to the 2015 call focused on 2 topics!

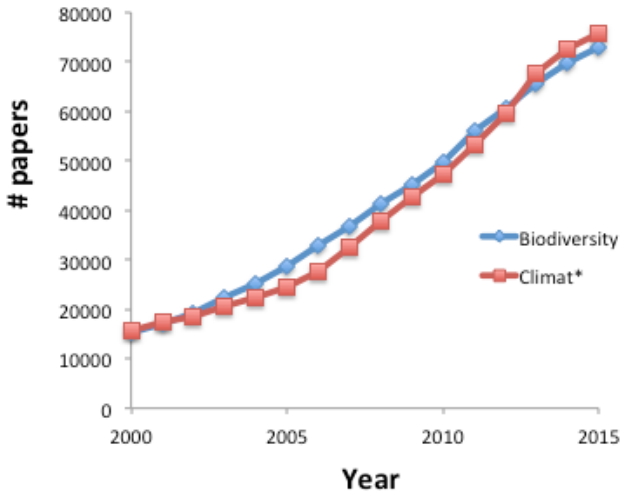

Fig. 6: Temporal variation in the total (global scale) number of papers published in international, peer-reviewed journals on biodiversity (blue) and climate (red) since 2000. Search with the Web of Science database using a keyword profile (Appendix 1) and the keyword climat* to target biodiversity research and research on climate and on the effects of climate/climate change, respectively.

Concerning the type of research funded, a recent analysis of the ecological literature over the 1981-2010 period reported that ecology has mostly remained species-oriented, while ecosystem and

[19] Chaveriat C., Ghitalla F., Pelegrin F., et al. (2011). La base de données nationale des acteurs, structures et projets de recherche sur la biodiversité: présentation et analyse du paysage de la recherche. Rapport FRB, Série Expertise et synthèse, 2011, 36 pages. Available at: http://www.fondationbiodiversite.fr/publications/rapports-et-expertises

community studies together comprise a quarter of ecological research[20]. However, over the same period, a growing proportion of problem-solving studies was observed (from 9% in the 1980s to 20% in the 2000s) which may indicate a major transition operating in ecological science. Changes in the type of biodiversity research performed can hardly be characterized in real time by analyses based on published papers and focused on ecological research only, due to the time lag generated by the research work itself and then the publication process, and due to the possible importance of other disciplines. In order to have a better view on possible ongoing changes in the type of research performed during the last years, a semantic analysis of the abstracts from thousands of research projects funded at the European, national or local level and referenced in the BiodivERsA database was performed. Such analysis can capture even very recent research trends (i.e. including the topics of research projects just starting). This demonstrated obvious changes in the type of research funded across Europe during the 2004-2011 period (Figure 7).

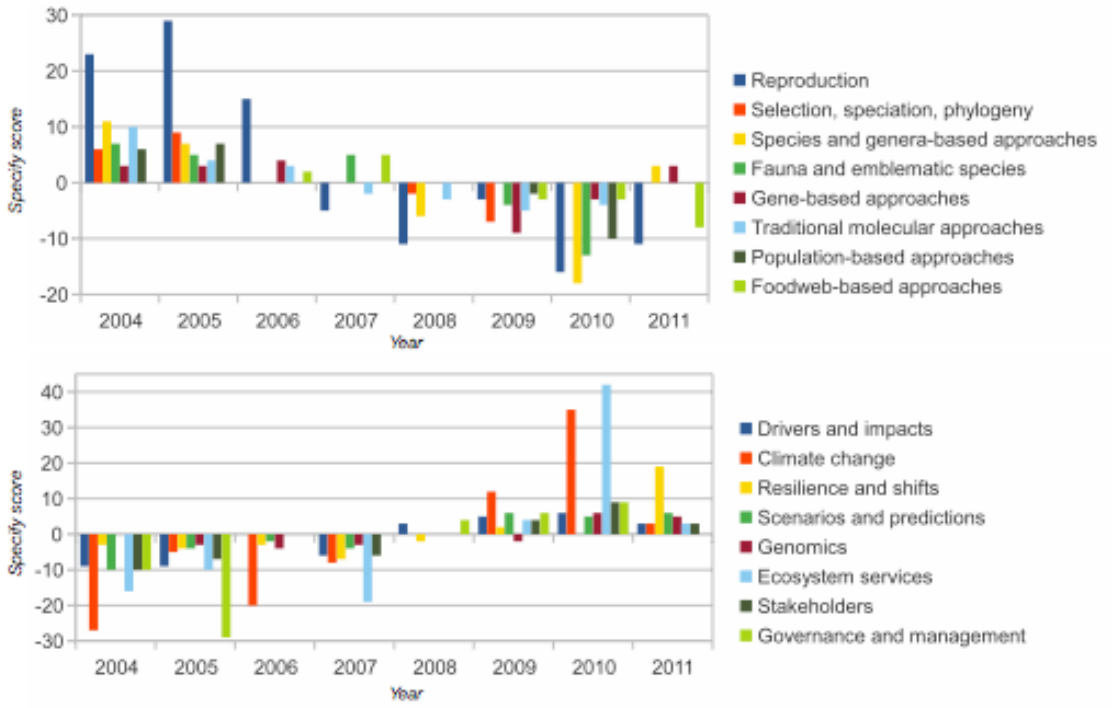

Fig. 7: A semantic analysis of the abstracts of 4159 projects included in the BiodivERsA database (i.e. research projects funded at the European, national or local level on a competitive basis) highlighted clear temporal trends in the type of funded research. These trends are presented here through the variations in the values of specificity scores for (Top) 8 major groups of words that were decreasingly used and (Bottom) 8 major groups of words that were increasingly used over the 2008-2011 period. From Gambette et al. (2014).

On average, focus has shifted from research on organism and population levels (taxa, populations, emblematic species, phylogeny, individual genes) and their conservation, to larger organisation levels (biological communities and ecosystems, landscapes, socio-ecological systems, (meta)genomes) and forecasts and scenarios of future biodiversity. Emphasis also changed from acquiring basic knowledge on taxa and their dynamics to analyses of biodiversity protection costs and benefits and stakeholder's views[21]. The observed trends (Figure 7) are consistent with both the results of the

[20] Carmel Y., Kent R., Bar-Massada A., et al. (2013) Trends in ecological research during the last three decades – A systematic review. PLOS ONE 8: e59813.

[21] Gambette P., Eggermont H. & Le Roux X. (2014) Temporal and geographical trends in the type of biodiversity research funded on a competitive basis in European countries. BiodivERsA report, 33pp.

Millennium Ecosystem Assessment and shifts in research policies to better address integrative and trans-sectoral issues (like fisheries, agriculture, etc.), but not with the goals set by the EU regarding the halt of biodiversity loss. These trends demonstrate how quickly research on biodiversity and ecosystem services evolves, likely through 'internal' forces due to new and renewed topics addressed by the research community and through the orientations given by research programmers and funders. In this context, local, national and European research managers have to clearly define the balance to be maintained between the different aspects of biodiversity research, and to carefully monitor this balance, so that biodiversity research support is based on an explicit, long-term and strategic approach.

Concerning the level of research funding, the analysis of the funding amounts and sources for 605 research programmes from 25 agencies of 17 European countries and from the EC demonstrated that (Figure 8)[22]:

- Biodiversity research funding in Europe is largely dependent on national (and local) funders; the contribution of the EC and the joined contribution of national programmers and funders to biodiversity research over the 2005-2011 period was estimated to be 19% vs 81%, respectively.
- After a period of increased funding (2005 to 2009), a strong decrease of funding level (-37.7%) was observed from 2010 to 2011.

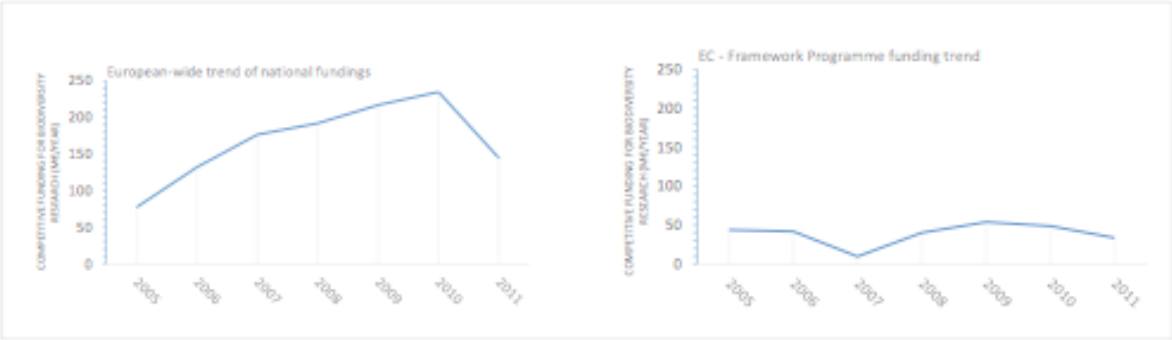

Fig. 8: Temporal evolution of the annual competitive funding for biodiversity research. Data were aggregated for 14 major national agencies studied from 11 countries and for main schemes of EC-FP/H2020, as assessed from the BiodivERsA database. After Eggermont et al. (2013).

This is consistent with the results of an analysis of the importance of biodiversity within the "Environment" theme of the 7th framework programme[23] showing that, although overall funding allocated to this theme was roughly constant over the 2007-2010 period, the part of the budget allocated to projects addressing at least partly one or several biodiversity issue(s) significantly decreased, from 23.6% in 2007 to 17.9% in 2010. All these features of biodiversity research funding

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www.biodiversa.org/700/download

[22] Eggermont H., Le Roux X., Heughebaert A., et al. (2013) The BiodivERsA database: analysis of the competitive funding landscape for research on biodiversity and ecosystem services in Europe. BiodivERsA report, 33 pp. www.biodiversa.org/563/download.

[23] Matei S., Henckel L., Gauthier C.A. et al. (2011) Biodiversity within the "Environment" theme of the 7th Framework Programme (2007-2010): funding amounts, success rates, temporal trends & comparisons between countries. FRB report, 2011, 32 pp.
http://www.fondationbiodiversite.fr/images/documents/Rapports_Etudes/Rapport_valeurs_02.pdf

demonstrate (i) the need to reinforce synergies between the national/local and European levels to adequately integrate research across Europe, and (ii) the need for a renewed, long-term strategy for research programming and funding in the domain.

Concerning the level of internationalisation of research, an analysis of research collaboration networks was made based on affiliations of publications' authors[24]. For instance, over the 2003-2013 period, Europeans published 121,000 scientific papers on biodiversity in international peer-reviewed journals, mainly through intra-Europe research networks (Figure 9). Co-publications with North American researchers represented 17% of the publications, whereas co-publications with researchers from other continents were much more marginal (8%, 5.6% and 4.6% with Asia, Latin America and the Caribbean and Africa, respectively).

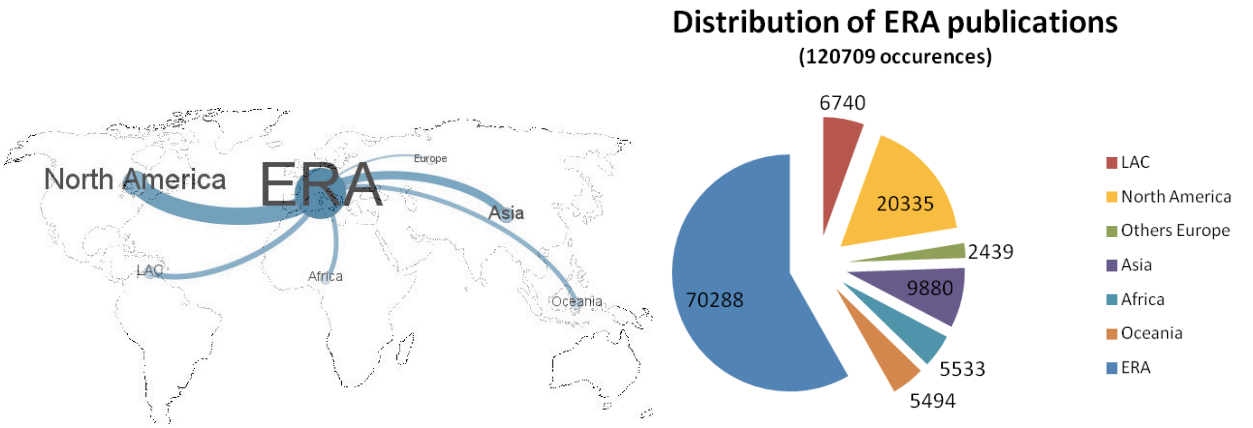

Fig. 9: Main inter-continental collaborations for European research on biodiversity. The category "Others Europe" refers to Andorra, Armenia, Georgia, Kazakhstan, Monaco, Russia, Tajikistan, Ukraine and Uzbekistan. The lines in the map (Left) represent the level of collaboration between the ERA and another continent, based on the 121,000 publications on biodiversity generated in the ERA during the 2003-2013 period. The pie (Right) provides the values of co-publication between the ERA and other continents and within ERA. Result of a mapping activity performed in collaboration by ALCUENET and BiodivERsA (Loirat et al. 2016).

The mapping results also identified that research collaboration on biodiversity between the ERA and some continents, like the LAC region, was promoted faster than research collaboration on other domains, suggesting that research policy incentives at the European and national levels to promote the internationalisation of European research on biodiversity have concrete outcomes. This requires a clear strategy regarding the level and scope of internationalisation to be targeted by research programmers and funders. Within this context, BiodivERsA has increased its capacity to strengthen international cooperation with the participation of European overseas partners in Indian Ocean, Pacific, Caribbean and Atlantic that have close links with their neighbouring countries. They could act as active frontiers of Europe and contribute to propose avenues to overcome barriers that exist in funding mechanisms, notably for effective international research cooperation.

Concerning specific foresight activities, BiodivERsA has organized such activities as needed. In particular, in June 2014, a BiodivERsA foresight exercise was implemented on Nature-Based Solutions

[24] Loirat J., Dangles O. & Le Roux X. (2016) Mapping the collaboration between Europe and Latin America/Caribbean for research on biodiversity. ALCUE NET- BiodivERsA report, 23 pp. http://www.biodiversa.org/899/download; Dangles O., Loirat J., Freour C. et al. (2016). Research on biodiversity and climate change at a distance: collaboration networks between Europe and Latin America and the Caribbean. PLoS ONE 11: e0157441. Doi: 10.1371/ journal.pone.0157441

as the concept was rising in the research policy agenda, calling for new knowledge but also for further framing. BiodivERsA gathered a wide range of actors (scientists, stakeholders, policy-makers) to discuss about this emerging concept. This foresight exercise was very successful and contributed to the framing of the concept of Nature-Based Solutions[25]. It also helped identifying knowledge gaps and research needs and formulating research recommendations related to this new concept[26]. The outputs of this exercise were very valuable for the development of the SRIA and the discussion on future BiodivERsA activities and priorities. In addition, analyses of the gaps and priorities for European research on biodiversity and ecosystem services have been conducted[27], which has been taken into account when developing this SRIA.

d. Inputs from academic and non academic stakeholders

The BiodivERsA Advisory Board members, i.e. 6 internationally renowned scientists spanning a range of scientific disciplines, and 12 stakeholders from 6 broad categories relevant for the domain (Economic and industrial activities; European policy-making; Habitats, species and nature conservation; Relations with the public; Socio-political activities; and Wild and domestic genetic resources) (see Appendix 2) have worked on the development of this SRIA, from inception to finalization. This is consistent with the model promoted by BiodivERsA for research programming. Many BiodivERsA partners also mobilised their scientific and/or stakeholders boards to feed the SRIA and implementation plan. In addition, an online questionnaire organised around the three core themes and three transversal themes of the SRIA was used to consult research organisations and scientific societies, as well as a broad range of stakeholders. The summary of the responses has been used to amend the SRIA and to feed the implementation plan.

e. Inputs from policy-makers

This SRIA has benefited from inputs of a range of policy-makers: those involved in BiodivERsA (Ministries from 7 countries, and 3 local governments); DGR RTD and DG Env from the European Commission and OCTA, that are all part of the BiodivERsA Advisory Board; the European Parliament intergroup on 'Climate Change, Biodiversity and sustainable development'; the Committee of the regions of the European Union; and a range of other policy-makers during the large scale consultation process (mainly national Ministries, local governments, and other DGs from the European Commission).

[25] Eggermont et al. (2015) id.

[26] Balian E., Eggermont H. & Le Roux X. (2014) Outputs of the Strategic Foresight workshop "Nature-Based Solutions in a BiodivERsA context". BiodivERsA report, 45 pp. (http://biodiversa.org/672)

[27] Balian E. (2016) An analysis of the gaps and priorities for European research on biodiversity and ecosystem services. Internal BiodivERsA report (Milestone MS3.2); Balian E., Eggermont H. & Le Roux X. (2014) EU biodiversity research gaps and priorities, and foresight views. Internal BiodivERsA report.

f. Inputs from the screening of research infrastructures

BiodivERsA is mapping the landscape of research infrastructures for biodiversity and Nature-based solutions[28]. This screening exercise allows identification of opportunities offered by existing research infrastructures as well as gaps and possible barriers for an efficient use of research infrastructures by the research community over Europe. This analysis helped BiodivERsA in considering possible actions and strategies to increase interactions and develop complementarities and synergies with the existing research infrastructures, e.g., exploring how BiodivERsA could promote the use of research infrastructures in its activities and how research infrastructures can offer better possibilities to BiodivERsA-funded projects to develop even better pan-European research.

g. Inputs from activities analysing how BiodivERsA can reinforce the research-innovation interface

BiodivERsA is developing a number of activities to better bridge the gap between biodiversity research and innovation, and to better mobilize the private sector. The aim is not to focus on innovation per se (coordination and promotion of research will remain the core BiodivERsA activities), but to further promote the co-design and implementation of biodiversity and nature-based solutions research with the private sector, including businesses, and the transfer of relevant knowledge and technology from funded research projects towards organisations working on demonstration projects in support of innovation. The composition of the BiodivERsA Advisory board (which includes members from industry and private organisations) contributes to reaching this goal. BiodivERsA is now considering a range of activities to bridge the gap between research and innovation, including the mapping and accessibility of Knowledge and Technology Transfer Organisations, networking activities, the production of support tools, and the support to capacity-building opportunities for the engagement of private sector organisations by BiodivERsA-funded researchers. The aim is to support the cascading of funded research in the different steps of the research-innovation chain, and more generally to enhance research-innovation interactions throughout the whole research process, since the link between research and innovation is not unidirectional[29].
In addition, BiodivERsA will further explore possible cooperation with the future European platform linking research on biodiversity and nature-based solutions to private sector stakeholders, and with the Business@Biodiversity platform (see Table 1 below).

h. Inputs from national and local research programmers and funders

Concerning the priorities of national programmers and funders, an analysis of institutional biodiversity research strategies and priorities of BiodivERsA's partners was performed, through the screening of local and national research strategies and/or foresight documents. This exercise allowed

[28] Pugnaire F.I., Le Roux X., Morales G. et al. (2013) Infrastructures for biodiversity research in Europe: a critical overview of available facilities, and ways to better integrate them in BiodivERsA programmes. BiodivERsA report, 35 pp.
[29] Organisation for Economic Co-operation and Development - OCDE (1997) Oslo Manual. Proposed guidelines for collecting and interpreting technological innovation, 2nd Edition.

outlining shared priorities among partners[30]. This exercise was complemented by an analysis of key European and international strategies and policy documents, contributing to identify at a larger scale research needs, gaps and priorities[31]. This allows to place partners priorities and strategies in a broader framework and to link them with European and when relevant international agendas. The outputs of these two exercises were of major importance for the development of the SRIA and implementation plan as it contributed to the direct identification of research priorities that BiodivERsA partners recognize as shared priorities.

Box #3: Specificities and specific needs for research on biodiversity and ecosystem services research in the overseas: the view of ORs and OCTs[32,33]

The European Overseas territories comprise 9 Outermost Regions (ORs) and 25 Overseas Territories and Countries (OCTs). The ORs are part of three European Union (EU) Member States (France, Spain and Portugal) and are integral part of EU. The OCTs are associated to EU and constitutionally depend on Denmark, France, the Netherland and the United Kingdom.
The overseas specific features (their marine and terrestrial biodiversity is exceptional; their environments are particularly vulnerable to the impacts of climate change, natural hazards and pressures of human activities; and their biodiversity is fundamental to their economic development) framed their biodiversity and ecosystem services research landscape in an original way. Bottom-up and solution-oriented approaches are fundamental for the research developed locally. Because BiodivERsA now includes partners from ORs and OCTs, these partners played a key role for identifying the specificities and specific research needs of ORs and OCTs during the development of this SRIA.

Natural and geographical situation
(Sub)tropical ORs and OCTs host a high and distinctive biological diversity with a high level of endemism distributed in 3 different oceans and the Caribbean sea. It composes a world-wide network with a wide range of geoclimatic characteristics and drivers and with high ecosystem diversity over short distance, which offers an opportunity for scientific approaches at various hierarchy of scales, providing robust trends and fundamental insight into mechanism shaping biodiversity and ecosystem services. ORs and OCTs are generally isolated and small, have limited resources, and are highly exposed to climate change impacts, natural hazard and pressures of human activities. The magnitude of these pressures and the diversity of situations of potential conflicts is more important than for many locations in continental Europe. This puts ORs and OCTs at the forefront for testing innovative strategies to cope with those pressures and to mitigate their impacts.

[30] Balian E., Eggermont H. & Le Roux X. (2014) EU biodiversity research gaps and priorities, and foresight views. BiodivERsA report, 26 pp.
[31] Balian E., Le Roux X. & Lemaître F. (2013) International and European Biodiversity policy and research strategies: an overview of priority research thematics for biodiversity research. BiodivERsA report, 12 pp.
[32] Netbiome network (2012) Synthesis of meeting and recommendations from the Net-Biome roundtable discussion on "Motivated" science on biodiversity management and use in support of Overseas sustainable development. NetBiome Era-Net, 16th February 2012
[33] Netbiome network (2016). Management of European Overseas (sub)tropical biodiversity in support to sustainable development : policy recommendations and priorities for research cooperation. NetBiome-CSA report, 34 p.

Socio-economic context:
Biodiversity is a fundamental asset for their socio-economic development and human well-being. Many economic activities (fisheries, farming, ecotourism...) are linked to the status of biodiversity, and changes that affect this status have major impact of local economies and development capacities status. The diversity of nature-society interactions, the role and importance of local culture and practices, as well as the high level of interactions between and within the various levels of society allow for a more holistic approach to biodiversity research and to stakeholder involvement into research. This leads to the early involvement of stakeholders into co-design processes that take into account both academic and empirical (including traditional) knowledge. Applied research and collaborations with SMEs (farmers, biotech companies...) are among the main schemes supported by local governments. The bio-economy concept and the Nature based solutions approaches are in the alignment of ORs and OCTs interest to fund research, which meets local needs and could create local economic impact locally, notably through innovation.

International cooperation opportunities:
Sub(tropical) ORs and OCTs encompass 5 biodiversity hotspots and share similarities with other hotspots located in tropical and subtropical areas, which make them attractive partners for international research cooperation. Thus, ORs and OCTs have developed long term cooperation with their surrounding geographical areas, thanks to the research capacities and infrastructures they host and the cultural duality. However, for several reasons (distances, isolation, deficiency of resources and critical mass, access to facilities and information), both cooperation and coordination of research activities, between the ORs and OCTs themselves and between them and continental EU, are still to be strengthened. Furthermore, continuous reinforcement of the links between research teams in ORs and OCTs and in mainland Europe will be key to further promote a European Research Area that is open to international collaboration.

i. Inputs from the analysis of the European and international initiatives that may be engaged

Links with JPIs and other European initiatives: In order to address cross sectoral issues, reinforce the impact of BiodivERsA-funded research, and properly build the European Research Area on biodiversity and Nature-based solutions, BiodivERsA has evaluated the missions and strategies of a number of European initiatives and programmes, in particular relevant Joint Programming Initiatives, JPIs (Table 1).

Table 1: Synthesis of (Top) the main JPIs and (Bottom) other European programmes or initiatives that BiodivERsA has engaged with or has identified as potentially important to engage. The expected added value of collaborations and possible joint activities are indicated. Green: ongoing collaborations; blue: ongoing discussions/framing activities; brown: still to be explored.

JOINT PROGRAMMING INITIATIVES			
INITIATIVE	**JOINT RESEARCH PRIORITIES**	**ADDED VALUE OF A COLLABORATION**	**POTENTIAL JOINT ACTIVITIES**
JPI CLIMATE	Effects and impact of climate change on biodiversity and ESS Trade-offs and synergies among	Climate and biodiversity are closely interlinked Complementary skills and	Joint activities, including calls on climate change effects on biodiversity,

	climate change and other global change policies	membership that could benefit from joint activities	feedbacks on climate, climate services, and trade-offs between climate, biodiversity and other policies
JPI Cultural Heritage	Landscape heritage (e.g. traditional agricultural landscapes)	Close links between cultural landscapes and biodiversity; biocultural diversity Opportunity to focus more on humanities and other knowledge systems, such as local ecological knowledge	To be discussed
JPI FACCE	Food supply, biodiversity and ESS Climate change, agriculture and biodiversity	Scientific interests overlap; Successful on-going cooperation with JPI FACCE (1 joint call launched in 2014);	Common activities for the follow-up of funded projects ; Promotion of the funded projects outputs; Future joint activities
JPI 'Healthy Diet for a Healthy Life'	Biodiversity & Health (biodiversity/ecosystem services as the basis of human health) ?	Opportunity to emphasize the role of biodiversity in health is often neglected, but high in research and policy agenda (see One Health Initiative) Biodiversity & Health identified by BiodivERsA as an important topic	To be discussed
JPI OCEANS	Climate change & ecosystem dynamics Deep-sea & marine biodiversity Effects of Acidification and Warming on Marine Ecosystems	Scientific interests overlap Complementary skills and membership that could benefit from joint activities	Joint activities, including calls on common priorities for research on marine biodiversity and ecosystems?
JPI URBAN	Urban ecosystem services (nature based solutions and greening cities)	Urban ecology & Nature-based solutions are high on research and policy agendas Opportunities for close collaboration with social sciences	Joint activities, including calls on urban biodiversity and Nature-based solutions in urban/peri-urban areas?
JPI WATER	Sustainable aquatic ecosystems & ESS Reconnecting socio-economic and ecological issues in the water cycle	Shared interest for research on aquatic ecosystems and ecosystem services (Theme #1 of JPI SRIA) Complementary skills and membership that could benefit from joint activities	Joint activities/calls, on, e.g., the dynamics, conservation and restoration of biodiversity and ecosystem services, with a particular focus on degraded water bodies and aquatic ecosystems

OTHER EUROPEAN INITIATIVES			
INITIATIVE	**MAIN OBJECTIVES**	**ADDED VALUE OF A COLLABORATION**	**POTENTIAL JOINT ACTIVITIES**

EKLIPSE - European Support mechanism on biodiversity and Ecosystem services	Promotion of Science-society / science-policy interface on biodiversity and ecosystem services ; assessments in response to EC queries	Both initiatives could complement each other (BiodivERsA could feed EKLIPSE with the results of its mapping exercises, policy briefs, etc. while EKLIPSE could promote dissemination of the results of BiodivERsA-funded projects and could benefit BiodivERsA through its assessments)	Feed EKLIPSE assessments with knowledge generated by BiodivERsA funded projects Joint workshops to promote the science-society / science-policy interfacing
Multi-dialogue platform on Nature-based solutions	Reinforce science-society interactions, innovation and market uptake for Nature Based solutions	BiodivERsA could help the platform by mapping and programming research on Nature-based solutions; the platform could help BiodivERsA by identifying knowledge gaps and needs for stakeholders on Nature-based solutions	Mapping activities on Nature-based solutions research and needs of stakeholders ; direct link with CT3 of BiodivERsA SRIA
OPPLA	Resource platform on Nature-based solutions	BiodivERsA could reinforce the resources available for OPPLA (funded-projects and their products…) ; OPPLA could promote dissemination of the results of BiodivERsA-funded research	Feed the OPPLA platform with knowledge generated through BiodivERsA, with good practices and tools (e.g. BiodivERsA SHE)
Life Programme	Programme funding conservation projects (interests on invasive species, restoration, green and blue infrastructures, etc.)	Life could promote further impact of BiodivERsA-funded research for biodiversity conservation BiodivERsA could reinforce the knowledge basis for Life	Joint workshops and other joint activities; direct link with CT1 of BiodivERsA SRIA
Norface	Initiatve that launches research programmes with active contribution of the social sciences disciplines	Both North Face and BiodivERsA have interest in promoting inter- and trans-disciplinary research	Joint actions to further promote inter- and trans-disciplinary research in research on biodiversity and Nature-based solutions
European initiatives linked to GEO-BON (EU-BON, ERA Planet)	Initiatives strengthening the ERA on Earth (including or focusing on biodiversity) Observation in coherence with the European participation to GEO	Common interest in reinforcing infrastructures for long term monitoring of biodiversity and ecosystems	Joint workshops and activities to consolidate the European counterpart of GEO-BON and use of data by research
The EU Business @ Biodiversity Platform	An EU-level forum for sustained and strategic dialogue about the links between business and biodiversity	Both initiatives could complement each other (BiodivERsA could feed EU B@B with achievements and ongoing activities (of BiodivERsA or funded projects) while EU B@B could help BiodivERsA	Joint actions to promote the links between biodiversity research and innovation, and the mobilization of business

		strengthening the link between research and innovation	

A concrete and successful joint approach has been implemented with FACCE-JPI, through joint foresight workshops which led to the co-design and launching a joint call in 2013. Interactions already exist or may be developed with the JPIs Climate, Water, Oceans and Urban, which were identified as particularly relevant to BiodivERsA.

Regarding the link between research and innovation, BiodivERsA has evaluated the possible added value of engaging with the future 'multistakeholder dialogue platform on Nature-based solutions', with a direct link with CT3 (Table 1), and more generally with the European B@B platform. Regarding the link between research and biodiversity conservation, BiodivERsA may engage with the Life programme to bridge the gap between research and conservation actions, with a direct link with CT1. In addition, collaboration with the OPPLA platform and EKLIPSE project could be fruitful and complement BiodivERsA's activities to promote the dissemination of knowledge derived from funded projects, while allowing these projects to benefit from BiodivERsA resources and skills (Table 1).

Links with international initiatives: Because many research issues addressed by BiodivERsA are overarching and exceed a sole European problem, because the deployment of Nature-based solutions - and marketable Nature-based solutions - requires a global approach, and because one cannot promote the excellence of European science disregarding its international dimension, engaging with key international initiatives is also part of this SRIA. BiodivERsA thus has assessed the possible added value of developing partnerships with major international initiatives (Table 2).

Table 2: Synthesis of the main international initiatives that BiodivERsA has engaged with or has identified as potentially important to engage. The expected added value of collaborations and possible joint activities are indicated. Green: ongoing collaborations; blue: first contacts/activities already made; brown: to be explored.

INTERNATIONAL INITIATIVES			
INITIATIVE	**MAIN ACTIVITIES**	**ADDED VALUE OF A COOPERATION**	**POTENTIAL JOINT ACTIVITIES**
Belmont Forum	Network of major research funders across the globe that promotes international research on all environmental issues	For issues of common interest, BiodivERsA could promote the European participation in Belmont Forum calls, while the Belmont Forum could help BiodivERsA promote international dimension of the European research on biodiversity and Nature-based solutions	Mapping of international collaboration on biodiversity and Nature-based solutions ; Co-design and implementation of joint calls on common research priorities (e.g., ongoing work on 'scenarios of biodiversity and ecosystem services')
Future Earth	Network of research organisation that promotes environmental research	BiodivERsA could account for priorities identified by Future Earth and benefit from Future Earth and its Knowledge-	Further explore possible joint activities and the added value of a collaboration

		Action Network on natural asset[34]) for internationalisation of research; Future Earth could benefit from BiodivERsA capacity to mobilize and support European research on biodiversity and Nature-based solutions, and its skills for stakeholder engagement	
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services Performs regional, global, topical and methodological assessments	BiodivERsA could feed some assessments performed by IPBES with the outputs of BiodivERsA-funded research (increased impact of research) and could benefit from the knowledge gaps identified by IPBES	BiodivERsA is participating to the IPBES plenary sessions as an official observer IPBES outputs were used for this SRIA, and BiodivERsA has fed the IPBES assessment for ECA

Regarding research programming, BiodivERsA considers that the Belmont Forum and Future Earth may be particularly important to engage (Table 2). The Belmont Forum has already been viewed as a key initiative to engage, because it is an 'international counterpart' of BiodivERsA, although covering the broad scope of environmental research. BiodivERsA has begun to collaborate with the Belmont Forum, which could lead to the co-design and launching of a joint call soon. Future Earth is a new, not fully established programme, but one of its 8 focal challenges is to « Safeguard the terrestrial, freshwater and marine natural assets underpinning human well-being by understanding relationships between biodiversity, ecosystem functioning and services, and developing effective valuation and governance approaches». BiodivERsA thus plans to further evaluate the expected added value of a collaboration with this initiative.

Last but not least, BiodivERsA has already decided to promote a strong collaboration with the IPBES, both by feeding IPBES assessments with syntheses of relevant knowledge generated by BiodivERsA-funded projects, and by taking into account the unknowns and knowledge gaps identified during IPBES activities (Table 2).

3. Core themes and transversal themes

As explained above, BiodivERsA aims to fund and promote pan-European research and innovation on biodiversity and Nature-based solutions. The funded research and associated activities should be scientifically excellent, challenge-driven and have high societal relevance. From a research programming and funding perspective, this translates to a set of **core themes** suitable for the design

[34] http://www.futureearth.org/knowledge-action-networks

and implementation of joint calls, program alignment, mobility schemes, networking and matchmaking sessions and other joint activities. The core research themes should:

- Be mission-oriented, with high expected societal impact
- Be ground-breaking for science
- Be of urgency for policy and management at the European and international levels
- Be comprehensive for building the overall BiodivERsA strategy, and complementary for promoting synergies between sectors, actors and policies

The core themes are complemented by **transversal themes** dealing with general issues that are relevant to all the core themes. The BiodivERsA approach with core and transversal themes is to lead to more integrative, co-produced knowledge that can help tackling major challenges, without compromising the sharpness of disciplinary science.

The IPBES conceptual framework can be used to present how the 3 major core themes of this SRIA cover nicely the perspectives of conservation, sustainable use of biodiversity, and benefits to human well-being and sustainable development (Figure 10). Figure 10 also highlights the central role that (1) institutions, governance systems and decision-making, and (2) non-monetary and monetary valuation of biodiversity and ecosystem services play in this context. It also underlines the need (3) to support backward- and forward-looking analysis and decision-making; these three issues are the backbones of the 3 transversal themes of this SRIA.

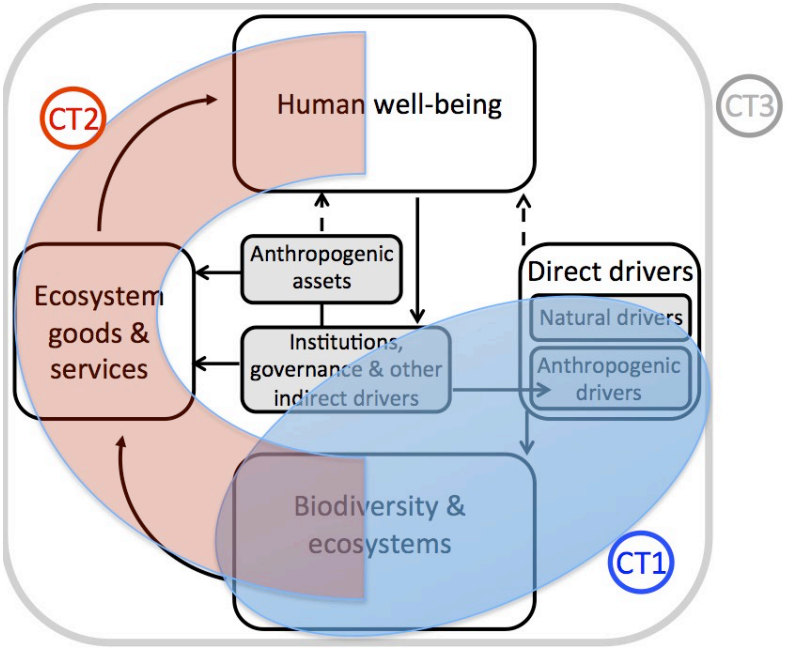

Fig. 10: Location of the 3 BiodivERsA core themes on the IPBES Conceptual Framework (a simplified version of the framework was used). From Diaz et al. (2015)

Besides the central role of the three aforementioned aspects, the IPBES conceptual framework also recognizes the importance of respectfully acknowledging the contribution of indigenous and local ecological knowledge in understanding human-nature relationships as well as in providing insights for

sustainable management of biodiversity and ecosystem services[35]. Local ecological knowledge is understood as those practices, beliefs and knowledge that is context-specific, transmitted orally or through imitation and experiences, adaptive to change, and shared through collective memory[36]. This knowledge system is thus also considered as a source of knowledge for addressing the 3 transversal themes of this SRIA.

For each theme, a short rationale is presented, major knowledge needs are identified, and expected socio-economic impacts are highlighted, based on the mapping and foresight activities and the various inputs (from BiodivERsA or other initiatives, in particular NetBiome[37]) presented in section 2.

CORE THEME #CT1: Better knowledge on biodiversity, its dynamics and its adaptation capacity to global change: a basis for supporting biodiversity conservation and restoration

Rationale

During the elaboration of this SRIA, stakeholders' and scientists' inputs showed that there are contrasted views on the importance of, and paths to, biodiversity conservation but that this is still a grand challenge of our time for different categories of stakeholders and policy makers, while being a major scientific forefront for the research community[38]. The need to fight biodiversity loss is present in political agendas, from the international to European and national/local levels. In particular, to address the continued loss of biodiversity, many governments agreed on common goals, i.e. the Aichi targets defined within the CBD and agreed in 2010[39]. These 20 targets identify 5 major issues:

- addressing the causes of biodiversity loss
- decreasing the pressures on biodiversity
- safeguarding species, genetic and ecosystem diversity
- enhancing the benefits to all from biodiversity
- promoting participatory planning, knowledge management and capacity building

The 17 UN Sustainable Development Goals[40] adopted in 2015 include two goals directly addressing these issues (i.e. Goal 15 referring to the need to halt biodiversity loss on land; and Goal 14 « Conserve and sustainably use the oceans, seas and marine resources »). The European Union also seeks to preserve biodiversity: the EU Biodiversity Strategy to 2020 adopted in 2011 reflects the commitments taken by the EU within the CBD. In the EU, biodiversity is protected by several initiatives, including the birds and habitats Directives, the establishment of the EU-wide Natura 2000 network of protected areas, the Wildlife Trade Legislation, and the invasive alien species Regulation.

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[35] Tengö M. et al. (2014) Connecting Diverse Knowledge Systems for Enhanced Ecosystem Governance: The Multiple Evidence Base Approach. Ambio 43: 579-591; DOI: 10.1007/s13280-014-0501-3;

a. *Díaz et al. (2015) A Rosetta Stone for Nature's Benefits to People. PLOS Biology 13:1*

[36] Berkes, F. (2008) Sacred ecology. New York: Routledge;

J. Mistry, in International Encyclopedia of Human Geography, R. Kitchin, N. Thrift, Eds. (Elsevier, 2009), vol. 5, pp. 371–376

[37] Netbiome network (2012) id. Netbiome network (2016) id.

[38] See the conclusions from the 27th ICCB congress hold in August 2015; see also Sutherland W.J. et al. (2016) A horizon scan of global conservation issues for 2016. TREE 31: 44-53.

[39] Convention on Biological Diversity (2010) Strategic Plan for Biodiversity 2011-2020, including Aichi Biodiversity Targets (Annex to decision X/2). https://www.cbd.int/decision/cop/?id=12268.

[40] United Nations (2015) id.

These initiatives translate into national and local policies and laws. However, even though the mid-term review of the EU Biodiversity Strategy in 2015 demonstrated progress in some areas, the overall progress was insufficient for attaining the targets. The review thus highlighted the need for much greater effort, and for a better, science-based post hoc evaluation of policies' impact.

In parallel, the scientific community has largely renewed the perspectives on biodiversity conservation, highlighting the human dimension of biodiversity conservation approaches[41] and identifying the different roots, challenges, and consequences associated to different conservation strategies and ethics[42]. This is calling for research exploring different paths to conserve biodiversity (Figure 11). In addition, literature reviews on biodiversity conservation[43] and the on-going IPBES assessment for Europe and Central Asia are confirming that information on biodiversity trends is biased towards some taxonomic groups and some environments, and that important dimensions of biodiversity (e.g., genetic and functional diversity) still remain to be properly studied.

Fig. 11: Different rationales and paths for biodiversity conservation exist. They are associated to different challenges and consequences for humans and non humans (after Sarrazin and Lecomte, 2016). This calls for a renewed research effort for clarifying and possibly seeking to expand the scope of choice available to policy-makers, ultimately integrating scientific knowledge with stakeholders concerns in the form of alternative possible courses of action.

Knowledge needs

[41] Mace (2015) id.

[42] Sarrazin F. & Lecomte J. (2016) Evolution in the Anthropocene. Science 351: 922-923.

[43] Velasco D. et al. (2015) Biodiversity conservation research challenges in the 21st century: a review of publishing trends in 2000 and 2011. Env. Sci. Policy 54: 90-96.

Assessment of this core theme through mapping and foresight actually led to identify the following research needs:

- **Better characterization of all biodiversity dimensions and their trends in Europe, and propose and assess relevant indicators of biodiversity and ecosystem status**: new tools (including metagenomics) make it easier to characterize biodiversity at the different organisation levels (functional, genetic and taxonomic) in all compartments. Efforts are particularly needed for the less known organism groups (like microbial or arthropod diversity), compartments (like soils or deep seas) and dimensions (like functional diversity), as well as the identification of endangered species, biodiversity-rich areas and hotspots that remain uncharacterized in some parts of continental Europe and OCTs and ORs, which has major implications for conservation and sustainable management decisions. This is particularly needed to determine what constitutes a "favourable ecological condition" and "good conservation status", better guide conservation strategies and management, and provide new opportunities for innovation. For instance, bio-prospection of new genes, functions and natural substances harboured by aquatic and terrestrial organisms – including microorganisms - can offer great economic opportunities. In addition, we still need to define operational metrics, e.g., of genetic, functional and cultural diversity; of evolutionary potential; and of interaction level within communities and ecosystems. Regarding cultural diversity, yet, there is a need to explore how local ecological knowledge can contribute to activities that improve the biodiversity status in Europe.
- **Characterize the threats to biodiversity and genetic resources in a global change context**: this includes the effects of climate change, land use change, overexploitation, pollution, (re)emerging pathogens, and biological invasions. It requires downscaling climate models to adequate levels, for which small regions, islands and archipelagos provide excellent case-studies (e.g ORs/OCTs). A particular attention should be paid to potential impacts of synthetic biology, and of pollutants including new/emerging ones like endocrine disrupters, microplastics and engineered nanoparticules, which have been argued as one pressing issue for the fate of biological diversity in the future[44]. Long-term, cumulative effects on ecological communities and specific taxonomic groups are not yet well understood and deserve further attention. Research identifying phase-shift thresholds of direct and indirect stressors is urgently needed, in particular to guide decisions over limits to extractive activities, such as fishing or logging. Specific threats to animal breeds and plant varieties should also be better understood to guide efficient strategies to conserve and manage genetic resources. Moreover, knowledge is needed on the effects of multiple stressors and extreme events. It is also essential to better include social sciences in the field of biodiversity management to understand the roots of our interactions with non-humans and how social factors (beliefs, value systems, culture, markets, policy, demographics) evolve and determine decision making process and choices for nature conservation and sustainable exploitation. Including social sciences in the field of biodiversity conservation is a prerequisite to achieve the first Aichi Strategic Goal (address the underlying causes of biodiversity loss) and promote co-learning processes and collective action.
- **Role of adaptation in a global change context.** Climate, land use, ecosystems, infrastructures, and human societies are all being transformed simultaneously. On-going research has

[44] Sutherland et al. (2016) id.

developed a basic understanding of the potential consequences of these concurrent changes, but important uncertainties persist, especially at geographical and time scales relevant to adaptation processes and adoption and use of options for limiting impacts and seizing opportunities. Research should better characterize the sources of flexibility and transformability for species, populations, ecosystems and socio-ecosystems, in the face of global change. This should include studies on phenotypic plasticity, evolution, migration, reshuffling of biological assemblages, and the dynamics of strategies, knowledge and practices, as well as the relative roles of these different flexibility sources at a range of spatial and temporal scales. Research should also study how local communities and indigenous people in Europe pursue to adapt to environmental changes by exploring holistic solutions able to increase their response capacity and resilience to a broad range of perturbations.[45]In particular it should also study how attempts to create new management and governance strategies of biodiversity and ecosystem services in the face of global change should build on the local ecological knowledge of indigenous and local communities[46]. All these studies could be used to propose indicators of adaptation potential. This research is also needed to develop scenarios of biodiversity (see TT3) and a new generation of integrated tools for providing quality-controlled, usable information for near-term decisions with long-term implications.

- **Exploring new paths for conservation and inform conservation policies:** While biodiversity conservation strategies have been successful for some taxonomic groups or in some areas, many traditional methods for conserving biodiversity have not fully met expectations or have proven to be insufficient to tackle all drivers of biodiversity loss. New solutions to tackle this challenge are thus needed to complement more traditional approaches. This requires working on the links between the evolutionary trajectories of humans and non-humans, and on the trade-offs and synergies between human well-being and nature over the short and long terms. The question on how to conserve the evolutionary potential and opportunity of all organisms other than-humans beyond the services they provide us needs to be answered. Furthermore, conservation / management approaches based on particular populations, species, or traits still have a key role in biodiversity and genetic resource conservation research and policies, but this can generate unintended changes through extinction cascades, direct and indirect selective pressures, and altered interaction networks. **More holistic approaches such as the conservation of communities and wildness, and system analyses of intervention programmes to find "leverage points" where actions will exert particularly strong improvement of the conservation results, are also needed.** In addition, the conservation community faces new challenges. A major one is climate change. Species distribution areas may change rapidly but in fairly complex ways, and biodiversity in current conserved areas might have to adapt and possibly to be relocated to take into account climate change effect. Through the development of models and scenarios (TT3), researchers can provide guidelines to help conservation area managers, policy makers and other stakeholders to anticipate the effect of climate change. Another major challenge faced by the conservation community is emerging pathogens and invasive species. This requires adapting the way to develop science

[45] Mistry J. & Berardi A. (2016) Bridging indigenous and scientific knowledge: Local ecological knowledge must be placed at the center of environmental governance. Science 10 JUN 2016: pp. 1274-1275

[46] Gomez-Baggethun et al. (2012) Traditional ecological knowledge and community resilience to environmental extremes: A case study in Donana, SW Spain. Global Environmental Change 22: 640-650

and practice conservation. New conservation strategies emerge, like assisted colonization, land sharing versus land sparing, and re-wilding or not re-wilding, which still requires proper knowledge basis and evidence-based assessment. At the same time, new technologies offer working tools like 'ecodrones', mobile-sensing technology[47], and renewed remotely sensed data, whose potential still has to be explored by research. Similarly, citizen science is probably still in its infancy, both in terms of possible research impact and public engagement. Further, **any attempt to create new paths of biodiversity and ecosystem services governance should include the local ecological knowledge,** a knowledge system which is highly endangered in Europe[48] despite its contributions to biodiversity conservation and sustainably management of ecosystem services[49]. There is thus a need for research to keep up with and anticipate all these changes to ultimately improve the science and scientific underpinning of biodiversity conservation and sustainable management.

Expected socio-economic impacts

Research under this core theme will guide alternative ways/innovative strategies for biodiversity conservation as well as for the conservation and management of genetic resources (cf. issues related to governance and institutions that form the basis of TT1). It will inform choice for conservation policy alternatives and will help assessing the success or failure of conservation policies and regulations (e.g. the EU Habitats Directive's Articles 10 and 18) and revisiting them in face of global change. It will also help preventing the establishment of pathogens and invasive alien species, and eradicating or controlling species that have already become established. This will have positive impact on European biodiversity per se, as a common good for future human generations and as a natural capital underlying human well-being and sustainability. Research under this core theme will also help predicting the effects global change effects on biodiversity, an important issue for key sectors like agriculture and fisheries, either directly through changes in species range and metabolic rate, or indirectly via coral bleaching or invasive species. In addition, it will guide regional and international biodiversity discovery initiatives that will contribute to promote innovation in continental Europe, ORs and OCTs through the discovery of new taxa, genes, functions and bioproducts.

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[47] Sutherland W.J., Clout M., Côté I.M. et al. (2010) A horizon scanning of global conservation issues for 2010. TREE 25: 1 -7.

[48] Pardo-de-Santayana, M., Pieroni, A., Puri, R. K. (2010). The ethnobotany of Europe, past and present. In: M. Pardo-de-Santayana et al. (Eds.), The Ethnobotany in the New Europe: people, health and wild plant resources. Berghahn Books, New York, USA, pp. 1–15. Łuczaj, Ł., Pieroni, A., Tardío, J., et al. (2012). Wild food plant use in 21st century Europe: the disappearance of old traditions and the search for new cuisines involving wild edibles. Acta Societatis Botanicorum Poloniae, 81: 359–370. Gomez-Baggethun, E., Mingorrı´a, S., Reyes-Garcia, V., et al. (2010). Traditional ecological knowledge trends in the transition to a market economy: empirical study in Donana natural areas. Conservation Biology 24: 721–729. Hernández-Morcillo, M., Hoberg, J., Oteros-Rozas, E., et al. (2014). Traditional ecological knowledge in Europe: Status quo and insights for the environmental policy agenda. Environ. Science Policy Sustain. Dev. 56 : 3–17.

[49] García-Llorente, M., I. Iniesta-Arandia, B. A. Willaarts, et al. (2015). Biophysical and sociocultural factors underlying spatial trade-offs of ecosystem services in semiarid watersheds. Ecol. Soc. 20: 39. Iniesta-Arandia, I., D. García del Amo, A. P. García-Nieto, et al. (2015). Factors influencing local ecological knowledge maintenance in Mediterranean watersheds: insights for environmental policies. AMBIO 44: 285-296.

CORE THEME #CT2: Biodiversity: a fundamental asset for the functioning and resilience of ecosystems, provision of ecosystem goods and services, and improvement of human well-being

Rationale

The term '**ecosystem services**' was defined in the Millennium Ecosystem Assessment[50] as 'the benefits people obtain from ecosystems', both natural and managed. These services may be categorized as provisional, regulative, cultural or supporting services, also referred to as supporting processes. The first three categories have a direct impact on **human well-being** (i.e. a human experience that includes the basic materials for a good life, freedom of choice and action, health, good social relationships, a sense of cultural identity, and a sense of security), whereas the latter has an indirect impact by supporting provisioning, regulating, and cultural services.

The importance of biodiversity for ecosystem functioning, service delivery and human well-being is increasingly recognised by international policy frameworks (SDGs), international conventions (CBD, e.g. Aichi Targets 14 to 16) and scientific and intergovernmental initiatives (Millennium Ecosystem Assessment, Figure 12; IPCC; IPBES). It is also well reflected in the 2011-2010 EU Biodiversity Strategy (for example, Target 2 that aims to maintain and enhance ecosystems and their services by establishing green infrastructure and restoring degraded ecosystems) and in efforts to mainstream biodiversity across relevant sectors (for example, agriculture, fisheries, tourism) and in national sustainable development and poverty reduction strategies.

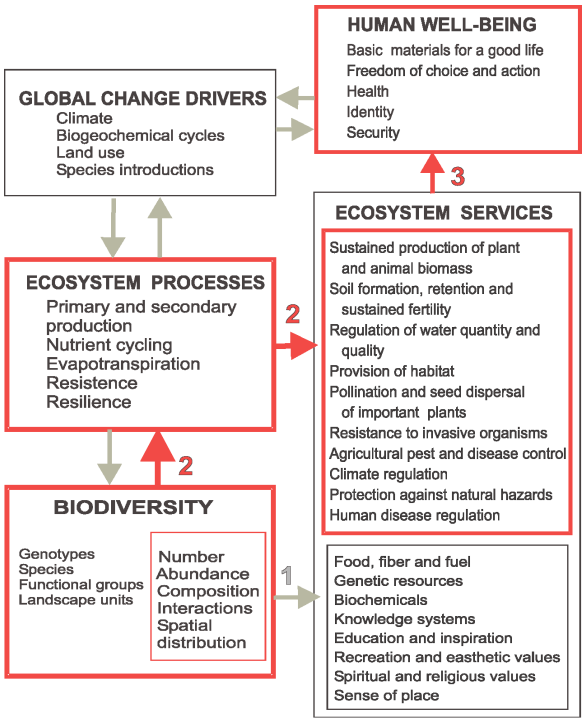

Fig. 12: Biodiversity is both a response variable affected by Global Change drivers and a factor that affects human well-being. From Diaz et al. (2006)[51].

[50] Reid et al. (2005) id.

[51] Diaz S., Fargione J., Chapin F.S., et al. (2006) Biodiversity loss threatens human well-being. PLOS 4(8): e277.

Yet, the wider benefits of biodiversity are not always understood by those concerned with biodiversity conservation. Moreover, the scientific community recognizes that there are still major knowledge gaps in understanding the **causality relationships between single and multiple drivers/pressures and changes in biodiversity (at all relevant levels of biological organization), ecosystem functions and ecosystem services and their societal impacts**. For instance, the recent IPBES assessment on pollinators, pollination and food production[52] highlighted the lack of understanding of combinations and interactions of drivers (i.e., mixtures of pesticides, diseases, climate change…) and their effects on the pollination service. In addition, tropical and subtropical entities of Europe host unique ecosystems such as coral reefs, tropical forests and mangroves providing a range of services that are degraded, which generates negative feedback on global change[53]. While this corresponds to forefront science, meeting the knowledge needs on the importance of biodiversity for ecosystem service delivery and human well-being could spur innovative solutions for sustainable development (link with CT3).

Over the last few decades, numerous studies and experiments have investigated **whether more diverse biological communities would help maintain the provision of ecosystem services**, or specifically **if there is a positive relationship between biodiversity and ecosystem functioning and services**. Most studies have focused on aboveground terrestrial and aquatic ecosystems and have shown, in general, a consensus for – on average - the positive relationship between biodiversity and ecosystem function, stability and resource use efficiency. Yet, several key issues remain unresolved, and some ecosystems remain understudied.

Mainstreaming ecosystem services into policy and decision-making is also dependent on the availability of spatially explicit information **on the state and trends of ecosystems and their services**. In particular, the EU Biodiversity Strategy to 2020 addresses the need to account for ecosystem services through **biophysical mapping and valuation**, which led to the development of the MAES initiative[54]. In addition, in the context of the IPBES, the temporal trends of biodiversity and ecosystem services are currently assessed for Europe and Central Asia[55] and other regions.

Finally, as clearly reflected in the recent State of Knowledge Review on Biodiversity and Health[56], a better understanding of the **links between biodiversity, health and diseases** also presents major opportunities for policy development, and can enhance our understanding of how health-focused measures affect biodiversity, and biodiversity-focused measures affect health. The breadth and

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[52] IPBES (2016) Summary for policy makers of the assessment report of the Intergovernmental Science-Policy Platform for Biodiversity and Ecosystem Services on pollinators, pollination and food production. Potts S.G., Imperatriz-Fonseca V.L., Ngo T. et al., 30 pp. To become available in all languages of the United Nations at: http://www.ipbes.net/work-programme/pollination

[53] Gerdes H. et al. The value of biodiversity and ecosystem services in the EU's Outermost Regions and Overseas Countries and Territories. NetBiome-CSA document, 71 pages.

[54] Erhard M., Teller A., Maes J. et al. (2016) Mapping and Assessment of Ecosystems and their Services (MAES) - 3rd Report. European Commission. 180 pp.

[55] IPBES regional assessment for Europe and Central Asia. www.ipbes.net/work-programme.

[56] WHO and CBD (2015) Connecting Global Priorities: Biodiversity and Human Health: A State of Knowledge Review. ISBN 9789241508537. http://www.who.int/globalchange/publications/biodiversity-human-health/en/

complexity of these relationships, and the socio-economic drivers by which they are influenced, in the context of rapidly shifting global trends, reaffirm the need for an integrative, multidisciplinary and systemic approach to the health of people, livestock, crops and wildlife within the ecosystem context[57]. Loss of biodiversity and natural environments as well as habitat fragmentation threaten the full range of life-supporting services provided by ecosystems at all levels of biodiversity, including species, genetic and ecosystem diversity. The disruption of ecosystem services has direct and indirect implications for public health, which are likely to exacerbate existing health inequities, whether through exposure to environmental hazards or through the loss of livelihoods. For instance, the absence of winter break in diseases and pathogens dynamics in the tropical and subtropical regions of Europe increase the impact on health, which is an asset for scientific investigations. The recently introduced '**One Health'-approach**[58] provides a valuable framework for the development of mutually beneficial policies and interventions at the nexus between health and biodiversity.

Clearly, more research and transdisciplinary approaches are needed to facilitate a **better understanding of the interdependence of biodiversity, ecosystem services and human well-being, to elevate boundaries between disciplines, and to support decision making**.

Knowledge needs

- **Reinforcing the knowledge on causal links (including synergies and trade-offs) between biodiversity, ecosystem functioning, and ecosystem goods and services and human well-being in different sectors (**agriculture, aquaculture & forestry; energy; health, including recreational outdoor activities; etc). This requires analysing how biodiversity relates or contributes to the maintenance and delivery of such services and their resilience to climate change and disturbances. It also requires better knowledge on the cascading effects of direct, indirect and emerging drivers of change, separately and in combination and interaction, on biodiversity, ecosystem function and ecosystem services (at all relevant scales); and provision of methodologies to predict such effects. This includes analysing the importance of breed/variety selection and the utility of locally-adapted genetic resources and species for the delivery of multiple services in agricultural areas and adaptation capacity to climate change, invasive species and pathogens.
- Research on the benefits of biodiversity for public health (e.g. research on the relationship between biodiversity and infectious disease, and how ecosystem change and biodiversity loss may affect the ecology of disease / vector organisms and the dynamics of pathogen-host interactions). Tropical and subtropical ORs and OCTs are particularly relevant locations for studying the impact of climate change on such interactions, since their weather conditions mimic to some extent those expected in mainland Europe following climate change. Research could focus on ecosystem health risks, ecosystem health services, or both.
- **Promoting the science basis to develop and assess innovative, ecosystem service-oriented management approaches** (including participatory initiatives)**, and elaborate common frameworks and tools for the conservation and sustainable management of ecosystem services**. For instance, research is needed to improve the effectiveness of pest management in

[57] Romanelli C., Cooper H.D. & de Souza Dias B.F. (2014) The integration of biodiversity into One Health. Rev. Sci. Tech. Off. Int. Epiz. 33: 487-496.

[58] One Health initiative (www.onehealthinitiative.com)

pesticide-free and pesticide-minimized farming systems to help provide viable alternatives to conventional, high chemical input agricultural systems through innovations in fields including agro-ecology, agro-forestry and natural pest control. More science is also needed to allow for a transition to systems of food production that are based on "ecological intensification"—using land, water, biodiversity and nutrients efficiently and in ways that are regenerative, minimizing negative impacts. Similarly, more research is needed on environmental impacts of renewable energy technologies, as they become a larger portion of our electric supply. Large set of actual and future services should be considered because the relative importance of ecosystem services can change with time and people needs: new services can be considered in response to the societal need for adaptation to global changes, as underlined by the concept of adaptation services[59]. This includes the development of valuation tools (see TT2) that should account for differing policy goals, differing cultural perspectives, and a variety of potentially conflicting community needs. It also includes the development of sound and cost-effective indicators of ecosystem function/resilience, ecosystem service and biodiversity, which capture all the relevant ecological and socio-economic dimensions and are widely applicable. This would, for example, help defining what is a 'good status' of biodiversity and ecosystems to guide good practices, incl. for business.

Expected socio-economic impacts

Exploring possible synergies between biodiversity and ecosystem services and human well-being will pave the way to new practices, new incentives and new policies for reconciling social, economic and environmental interests, and more particularly reconciling production objectives and biodiversity conservation objectives. For instance, this can help the elaboration of new approaches to balancing of the Common Agricultural Policy, and the implementation of One Health approaches. For European overseas, it can contribute to the definition and implementation of development and spatial planning strategies and effective mitigation compensation mechanisms. The knowledge obtained through this CT2 will also be of major importance to guide the development and deployment of Nature-based solutions (CT3).

CORE THEME #CT3: Biodiversity, a fundamental asset for Nature-based solutions to pressing societal issues and for promoting transition towards sustainable socio-economic pathways

Rationale

It is now widely recognized that human activities have reached a level that could result in irreversible and, in some cases, abrupt environmental changes, leading to a state less conducive to human development. All societies and generations face increasing challenges such as climate change, jeopardized food security and water resource provision, or enhanced disaster risk. There is thus a need for a major transition in society to support the aim for a more sustainable future. Nature has tremendous potential to support such a transition through the benefits it provides to human well-being. In this context, **the concept of Nature-based solutions has recently emerged, referring to the**

[59] Lavorel S., Colloff M.J., Mcintyre S. (2015) Ecological mechanisms underpinning climate adaptation services. Global Change Biol. 21: 12-31.

sustainable use of nature in solving environmental and socio-economic challenges. Nature-based solutions go beyond the traditional biodiversity conservation and use principles by inherently integrating societal factors such as human well-being and poverty alleviation, socio-economic development, environment preservation, and governance principles. Inclusion of the idea of a "solution" in the concept explicitly recognizes that people agree that there must be a "problem that needs to be solved". A key feature of Nature-based solutions is that they offer multiple benefits and simultaneously address multiple societal challenges. Urban climate buffers (e.g. stretches of natural vegetation in an urban context to increase flood prevention), for example, show how nature can offer solutions to multiple societal challenges: the creation of such climate buffers supports green employment for development, implementation and maintenance and at the same time offers an attractive environment for company locations; they reduce negative local impacts of a changing climate by giving space for excess rainwater to infiltrate into the soil or by reducing heat island effects; if large enough they allow for urban green spaces and local communities to more easily recover from heat waves or other extreme events; and they support local biodiversity. Although different stakeholders view Nature-based solutions from different perspectives, it seems that **Nature-based solutions have the potential to transform environmental and societal challenges into innovation opportunities**, i.e. by turning natural capital into a source for green growth and sustainable development[60]. Nature-based solutions are thus seen as sustainable measures that simultaneously meet environmental, societal and economic objectives, which should help maintain and enhance natural capital. In any case, Nature-based solutions could play an important role in providing incentives for governments, institutions, business and citizens to develop innovative ways to integrate natural capital in policies and planning, and to maintain or increase biodiversity and human well-being. More generally, Nature-Based Solutions already constitute a significant component of indicators offered by States following the 2015 Paris climate agreement[61].

Despite the benefits of this new concept[62], **innovation with nature and marketable Nature-based solutions uptake strongly depend on a solid knowledge base**, and engagement of relevant networks and stakeholder groups from policy, business and practice. Much knowledge and practical experience already exists and many Nature-based solutions are known or have been developed; yet, they often remain highly under-deployed, with the dominant technocratic paradigms and technical solutions mostly being considered as the only options for tackling societal challenges. Scientists, policy makers, practitioners and other stakeholders need to join forces in order to support the needed systemic transition to a sustainable future in which economic, social and environmental needs are in balance.

Documenting and analysing the possible synergies and trade-offs between multiple ecosystem services and between multiple stakeholders' views, and between ecosystem services and biodiversity, will be at the heart of the identification and implementation of Nature-based solutions. In addition, stakeholders and policy makers must remain aware of the **complexities and uncertainties that surround Nature-based solutions**. Assessing the risks associated with a given

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[60] European Commission. (2015). *Towards an EU Research and Innovation policy agenda for Nature-Based Solutions & Re-Naturing Cities. Final Report of the Horizon2020 Expert Group on 'Nature-Based Solutions and Re-Naturing Cities'*, 70 pp.

[61] Laurans Y., Ruat R., Barthélemy P. (2016) Counting on nature: how government plan to rely on ecosystems for their climate strategies. IDDRI Brief 5/16 April 2016.

[62] Eggermont et al. (2015) id.

Nature-based solution should be compulsory and alternative solutions should be envisaged, looking at the potential impacts through time and space, and accounting for future environmental changes. Otherwise, Nature-Based Solutions could generate problems instead of solutions (e. g., species introduced for pest control can become invasive, if corresponding controls are lacking). Finally, the way the concept will be defined, used to promote research and innovation, and put into practice, will probably influence research in many domains, and ultimately the sustainability of future socio-ecological systems and the fate of biodiversity.

Knowledge needs

- **How can Nature-based solutions offer smart alternatives to technical solutions to tackle major challenges** like restoration of degraded ecosystems, climate change adaptation and mitigation, improved risk management and resilience, and sustainable urbanisation and agriculture. In particular, there is an increasing need of knowledge to inform the development of Nature-based solutions for, e.g., enhancing the insurance value of ecosystems, restoring degraded ecosystems and re-naturalizing environments dominated by humans (e.g. cities[63]), increasing carbon sequestration, and improving the sustainability of the food, fiber or energy production systems. A key issue here is to **evaluate the effectiveness of various** Nature-based solutions **through science-based assessment of their economic, social and environmental benefits** while also addressing the timescale for the delivery of benefits. This requires generating knowledge needed to monitor Nature-based solutions, evaluate their outcome, assess complexities and uncertainties, and guide risk assessments (including the challenges associated to Nature-based solutions implying the introduction of species and creation of new ecosystems). Genericity of knowledge on Nature-based solutions should go beyond case studies.
- **What role does biodiversity play or may play in Nature-based solutions?** A better understanding of the relationships between biodiversity, ecosystem functions and ecosystem services (CT2) is required to develop science-based Nature-based solutions (CT3). Here research should focus more than previously on efficiency and resilience properties of systems. Genetic resources and species and community diversity should be explored as a toolbox for Nature-based solutions, promoting adaptation and sustainability. Indeed genetic diversity and resources offer a great potential to develop nature-based solutions for tackling major societal challenges like climate change regulation and mitigation, and multi-functional and sustainable agriculture and forestry.
- **What role can Nature-based solutions actually play for biodiversity conservation and restoration?** The links between Nature-Based Solutions and biodiversity conservation should not always be taken for granted, but should be systematically analysed. Ethical issues linked to the increasing capacity of humans to transform 'Nature' should be explored. In addition, research should explore to what extent the reactive "conserve/restore to solve current

[63] European Commission. 2015. *Towards an EU Research and Innovation policy agenda for Nature-Based Solutions & Re-Naturing Cities. Final Report of the Horizon2020 Expert Group on 'Nature-Based Solutions and Re-Naturing Cities'*, 70 pp.

problems" approaches should be complemented by more proactive "conserve for future adaptation needs" approaches.

- **What are the synergies and trade-offs associated with Nature-based solutions?** A systemic approach is required when developing research on Nature-based solutions, accounting for multiple stakeholders' views and combining the social, economic and environmental perspectives required to prepare a truly sustainable future. This should help identifying Nature-based solutions that offer maximized synergies, while also analysing the trade-offs inherent to particular Nature-based solutions.
- **Which approaches and governance systems can reinforce the capacity to innovate with Nature-based solutions, to develop and deploy them on large scales, and to overcome (some) trade-offs?** It is important to analyse the drivers, correlates and incentives that could restrict or conversely help the implementation of proposed Nature-based solutions. This includes the analysis of supportive policies and policy frameworks and of the political and social resistance to change at relevant levels. Consistency of different policies and approaches for integrated spatial planning and efficient Nature-based solutions deployment (e.g., integrating Nature-based solutions and green and blue infrastructures) should be assessed. It will also be needed to identify awareness-raising factors for stakeholders, and explore participatory ways of translating and sharing lessons learned on Nature-based solutions.

Expected socio-economic impacts

This research will support the knowledge base that is required to enable a nature-based transition in Europe. It will provide evidence to stakeholders, decision and policy makers, practitioners and public about the multiple benefits, cost-effectiveness and economic viability of nature-based solutions to address societal challenges. This will also increase the awareness that economy and nature are not mutually exclusive, in line with the bio-economy view but adopting a complementary, more systemic approach searching for solutions that reinforce the sustainability of European societies and their activity while preserving European biodiversity and natural capital. This will result in better use of available knowledge for informed decision-making, innovative solutions and more effective deployment and market uptake. This will ultimately promote the European leadership on Nature-based solutions at the international level.

TRANSVERSAL THEME # TT1: Biodiversity and governance

Rationale

As it is increasingly required to tackle ecosystem degradation and biodiversity loss and to develop and deploy nature-based solutions, it is becoming **urgent to identify governance strategies that successfully address these issues and mitigate the impact of non-sustainable human activities**. Although many different governance approaches have been proposed and good practice examples in

Europe exist[64], their effectiveness has rarely been evaluated systematically in term of outcomes, and samples of case studies are often small. This lack of systems analyses, evaluation, and science-based evidence on the effects of different governance strategies has led to polarized debates among conservationists and other stakeholders, wastage of scarce financial resources, and a risk of poorly designed and ineffective programs in situ.

Governance strategies adopted for nature conservation vary widely, embracing community management as well as centrally controlled, state-run protected areas and private property regimes[65]. The Convention on Biological Diversity (CBD) encourages devolution of management responsibilities and has drawn attention to the **importance of adaptive management** (i.e., regular monitoring to enable "learning through doing") to complement protected-area governance. More particularly, for biodiversity and ecosystem services management, processes in which the perceptions and preferences and knowledge of different stakeholders are coherently combined have proven to have effective impacts to promote collective decision and solution-oriented actions.

Moreover, growing recognition of the often hidden values of ecosystem services now supports CBD's recommendation to **use economic or social instruments to promote effective conservation**. Examples include waste-trading schemes, eco-labelling, creation of knowledge networks, and public payment for maintenance of certain ecosystem services, for example through Reduced Emission from Deforestation and environmental Degradation (REDD). However, discussion continues on the relative merits of protective regulation or positive social and economic incentives for conserving biodiversity within and beyond protected areas. Similarly, there is still uncertainty about the potential effectiveness of biodiversity offsetting[66] (i.e. an approach to compensate for habitats and species lost to development in one area, with the creation, enhancement or restoration of habitat in another - resulting in so-called 'no net loss'). To address socio-environmental objectives, it is therefore important to consider a range of processes and socio-economic tools within an envelope of institutional capacities, including a potential role for leadership (typically, in the form of providing knowledge on complex issues) that has recently come to the fore. « Leverage points » should be searched where change in approach/intervention is highly likely to affect the end results strongly.

Similarly, **applying proper governance approaches will be a prerequisite for successful development and deployment of Nature-based solutions at relevant scales and for addressing the needs of different categories of stakeholders**. For instance, without a coordinated approach at the city scale, firms would only design green buildings in a case-by-case approach with a very uncertain effectiveness at city scale. Actually, such an approach, which largely misses out on the objectives of sustainability, increased biodiversity, and effectiveness at relevant scale (here the city and semi-urban fringe), would not fit the Nature-based solutions framing[67]. Adopting adequate governance to properly tackle the issue at city scale is thus of paramount importance.

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[64] EEA (2015) State of nature in the EU: Results from reporting under the nature directives 2007-2012. EEA Technical Report n°2, 173 pp. See also : Management of Natura 2000 sites - Best practice (http://ec.europa.eu/environment/nature/natura2000/management/best_practice_en.htm)

[65] Kenward R.E., Whittingham M.J., Arampatzis S. et al. (2011) Identifying governance strategies that effectively support ecosystem services, resource sustainability and biodiversity. PNAS 108: 5308-5312.

[66] DEFRA (2016) Consultation on biodiversity offsetting in England. Summary of Responses, 37 pp.

[67] Eggermont et al. (2015) id

These approaches should help the elaboration of policies aiming at the right balance between nature conservation and socio-economic development (including land management and spatial planning and the development of economic activities), which is critical in many areas in mainland Europe and in OCTs and ORs, and between biodiversity protection and enhancement (including the application of the ABS framework and rules). Articulating national and European policies, accounting for the local specificities of biodiversity status and development needs, is also needed.

Finally, for governance strategies to be effective, **a cross-sectoral approach will be needed, as well as an integrated approach at spatial level**. For example, EU integration has been found to be a key driving force for changes and synchronization in the governance of natural resources[68]. Similarly, it is more and more acknowledged that full biodiversity governance is unavoidably rooted in the participation of local actors and their problems and knowledge[69].

Knowledge needs

- **Knowledge on and scientific evaluation of the performance of different governance systems in supporting ecosystem services, resource sustainability and biodiversity**. Studies directed at specific regions or natural resources are needed to guide local adaptation strategies, while broader-scale investigations are crucial to plan regional strategies for the use of natural resources. Research should help answer the following questions: Which factors determine governance strategies that foster resilience, sustainable management of biodiversity and an equitable distribution of ecosystem services among social actors? How do local institutional arrangements facilitate awareness raising, social learning and effective management of biodiversity? What are the diversity of interactions between society and ecosystem components and their influence on participation and decision-making? What are the impacts of stakeholder engagement on the efficiency of decision-making for management measures? Especially lessons learnt from failures and less successful cases are relevant in this context.
- Legislation is one of the instruments used in governance, and environmental policy is to an increasing extent being legalized both through national laws and international agreements, also with regards to biodiversity and ecosystem services. **The interplay between national and international development of law should thus be studied more intensely to identify obstacles and opportunities for improved implementation.**
- Research should seek at **developing participatory tools and methods** to incorporate short-term interests within long-term frameworks, improve our capacity to cope with uncertainties, and integrate local and scientific knowledge on biodiversity for collective and adaptive decision-making.
- **Designing and assessing adequate governance systems will be key for the success of Nature-based solutions to be deployed in Europe**. Research is needed on how properly engaging the right actors, recognizing the diversity of institutions (both formal and informal) that could play a role here; and how making Nature-based solutions sustainable through adequate support by stakeholders and citizens. In particular, urbanization creates new

[68] Kluvankova-Oravska T., Chobotova V., Banaszak et al. (2009) From government to governance for biodiversity: The perspective of Central and Eastern European transition countries. Env. Pol. Gov. 19: 186-196.

[69] Sobéron J. & Peterson A.T. (2015) Biodiversity governance: A tower of Babel of scales and cultures. PLoS Biol 13: e1002108.

challenges for biodiversity conservation and Nature-based solutions implementation, and for supportive policy frameworks to mainstream biodiversity and Nature-based solutions in public authorities. More generally, research should inform the development of **policies and governance systems aiming at the right balance between nature protection and socio-economic development** (including land management and the development of economic activities), **and ways to avoid compromises and promote synergies between these**, which is critical in many areas in Europe and in OCTs and ORs. The balance between biodiversity protection and valuation, including the application of the ABS framework and rules, is also relevant here. Research should also evaluate ways to better articulate national and European policies, and account for the specificities of biodiversity status and development needs locally.

- **Ecological and social-anthropological sciences, as multi-stakeholder governance, play a key role in the appropriate implementation of offsets as part of the avoidance/ mitigation/compensation hierarchy**. The use of the mitigation hierarchy is critical in helping to ensure that unnecessary impacts of development on the environment are avoided. Ecological science can help with the process, helping to establish which impacts might be possible to offset, and whether proposed offsets are technically feasible. Ecological knowledge would particularly be needed on implications of offsetting in particular habitats; use of multipliers; timescale required to restore habitats to functioning ecosystems and ensure no net loss; and how to capture spatial mixes of habitats in biodiversity offset design.

Expected socio-economic impacts

Research will help developing empirically justified governance strategies that improve nature conservation schemes and the management of human-altered environments, with benefits for both biodiversity and people. This includes a more coherent spatial planning of sea- and landscapes, accounting for ecological, economic and societal considerations in a global (particularly climate) change context. It will help to identify synergies between global and local values and negotiate trade-offs where the two cannot be reconciled, to distribute the costs and benefits of conservation fairly, and to avoid one-size fits all approaches that neglect local dynamic complexity and heterogeneity. As such, it will provide the knowledge base needed to start investing in building biodiversity assets, by making the economic case and linking biodiversity to agendas that matter (e.g., poverty reduction, social justice, security and climate change). At the local level and in ORs and OCTs, the fewer hierarchical levels of organisation and shorter economic cycles enable innovative governance systems that could accelerate the uptake of results and increase the socio-economic impacts. However this requires significant involvement of local research teams and stakeholders in research projects to ensure local uptake, capacity building and impact.

TRANSVERSAL THEME #TT2: Non-monetary and monetary valuation of biodiversity and ecosystem goods and services

Rationale

The Millennium Ecosystem Assessment gave legitimacy to the concept of ecosystem services, which helps capturing the complex relationships between nature and societies. It generally leads to the idea

that associated costs and benefits are insufficiently integrated in public and private decision-making[70]. Critical global policy demand to advance environmental-economic accounting is also expressed in the Strategic Plan for Biodiversity 2011-2020. For example, Aichi target 2 under this strategic goal commits government to integrate, by 2020, biodiversity values into national and local development and poverty reduction strategies and planning processes, and to incorporate them into national accounting, as appropriate, and reporting systems.

In this context, many experts and stakeholders, from environmental NGOs to private companies and international organisations, have called for the development of **monetary valuation of biodiversity and ecosystem services**, so that societies can eventually put a price on what they value so highly but protect so poorly.

The initial stage of this valuation process is to conduct a check of the natural capital assets within scope of an analysis. This not only provides the foundation as to what elements of ecosystems (including biodiversity) are to be quantified in utilitarian terms, and more importantly provides a clear identification of the natural assets that are depended upon. When put into economic terms, this illustrates to interested parties their dependency upon these assets and the potential risks that are faced should these natural capital assets become degraded and fail to function.

If they may be part of the solution, such monetary valuations also raise numerous questions in theory and practice. The value of some ecosystem services, such as the provision of food, fuel and fiber, can be quantified, but estimates often reflect single services rather than incorporating all services provided by an ecosystem (but see[71]). Moreover, for other services such as mitigation of drought and floods, climate regulation, soil erosion prevention and water filtration, and services provided in the form of recreational, aesthetic or cultural values, it is very difficult to assign a price tag particularly because values vary across national and local boundaries.

In the past years, with the increasing importance of natural capital accounting, research on the monetary valuation of living natural resources and also of biodiversity has shown a significant progress, but **there is not yet an established framework for valuing biological diversity**. The discussion on monetary and non-monetary valuation is currently a hot topic[72], as also exemplified by the proposed IPBES assessment on diverse conceptualization of values for biodiversity and ecosystem services. There is an urgent need for the research community to collaborate with users to ascertain how existing valuation methods are being applied, how well they are operating, and **provide trusted impartial guidance to assist in the selection of the right natural capital assessment and valuation methods based upon user requirements**. The research community should improve the rigour of the models used, and thus the resilience (in terms of environmental considerations) of the decisions that result from their application.

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[70] Hindmarch, C., Harris, J. & Morris, J (2006) Growth and sustainability: integrating ecosystem services into economics. Biologist, 53: 135-142.

[71] Nelson E., Mendoza G., Regetz et al. (2009) Modeling multiple ecosystem services, biodiversity conservation, commodity production, and tradeoffs at landscape scales. Frontiers Ecol. Env. 7: 4-11.

[72] Nijkamp P., Vindigni G. & Nunes P.A.L.D. (2008) Economic valuation of biodiversity: a comparative study. Biodiv. Policy 67: 217-231.

Economists value biodiversity because valuation allows for a direct comparison with economic values of alternative options, a corner stone for any cost-benefit analysis exercise. In addition, the **monetary valuation** of biodiversity allows economists to perform environmental accounting, natural resource assessment, and to carry out benefit assessment. Valuation is also essential in the research of individual consumer behaviour. It indicates the opinion of individual consumers about certain biodiversity management or Nature-based solutions management objectives and identifies individual consumer motivations with respect to biodiversity conservation or Nature-based solutions implementation. Despite some flaws in monetary valuation approaches to biodiversity, there is a clear need to continue with developing rigorous valuation tools in order to cope with complicated trade-offs in environmental policy analysis in the context of sustainable development initiatives and emerging policies which take explicitly account of the variety in the earth's ecosystems.

Non-monetary valuation also has a long tradition in some fields of environmental policy making (e.g., in delineating protected areas), and in the last decade different international initiatives have acknowledged its role in ecosystem services valuation (e.g., the Millennium Ecosystem Assessment, The Economics of Ecosystems and Biodiversity –TEEB– initiative and IPBES). In spite of the growing policy and scientific interest, the non-monetary valuation of ecosystem services does not yet constitute a formalized methodological field. As such, it often applies coarse and arbitrary indicators[73] and produces results whose accuracy and reliability is hard to judge or difficult to operationalize. To increase the applicability of non-monetary valuation, it is necessary to clarify the boundaries and the terminology of the field, and address considerations with regard to the context-specificity of non-monetary techniques[74].

Knowledge needs

- **Knowledge base for developing practical and implementable natural capital accounting tools** (e.g., in companies and banking sector; but also in public sector, e.g., policy makers, cities), a framework for valuing changes in biodiversity, as well as applications for ecological compensation. This should guide assessments at a landscape or seascape scale, focusing on developing methods to reflect cumulative impacts and variations in environmental quality, social needs and value preferences. Research should explore the impact (i.e. the effectiveness or added value) that the valuation of ecosystem services has on sustainable development, including the design and effectiveness of avoidance/mitigation/compensation mechanisms that could be applied in the case of new developments.

- **Improving methodologies and tools to capture different values of ecosystem services and biodiversity** and to describe different conceptualizations of value and of the relationship between biodiversity and human well-being. Research is needed to test and compare existing monetary and non-monetary valuation methods. Indicators beyond monetary estimates should be developed as needed and tested, which can give estimates of the value and attitudes of local communities towards biodiversity. It is also needed to **study valuation**

[73] Seppelt R., Dormann C.F., Eppink F.V. et al. (2011) A quantitative review of ecosystem services studies: approaches, shortcomings and the road ahead. J. Appl Ecol. 48: 630-636

[74] Kelemen E., Garcia-Llorente M., Pataki G. et al. (2014) Non-monetary techniques for the valuation of ecosystem services. OpenNESS Synthesis paper (http://www.openness-project.eu/sites/default/files/SP-Non-monetary-valuation.pdf)

methods for Nature-based solutions that can help assessing their effectiveness in terms of societal, economic and environmental assets.

- **Knowledge on context-specific applicability** (which valuation methods can address which type of biodiversity value).

Expected socio-economic impacts

Research on tools and methodologies for valuation of biodiversity, and biodiversity resources and functions, is instrumental for the development of policies for protection and sustainably management of biodiversity and ecosystem services, and as such, as a contribution to poverty alleviation and to sustainable economy, and for the greater benefit of all life on earth. It will contribute to evaluate the design and effectiveness of available mitigation hierarchy mechanisms and widen their effective application. A sound knowledge base on valuation is also needed to assess and monitor the cost-effectiveness and economic viability of nature-based solutions to meet multiple benefits (environmental, social and economic). More specifically, decision-makers face an increased number of tools and approaches, and research can help critically compare these tools and help science-based choices by policy-makers for adapted and contextualised legislation and regulation.

TRANSVERSAL THEME #TT3: Studying biodiversity and ecosystem services based on long term surveys and experiments, re-use of existing data, and development of scenarios

Rationale

During the last decades, it has been increasingly recognized that one should reinforce three complementary capacities for research on biodiversity and ecosystem services.

Research capacity to study the dynamics of biodiversity and ecosystems over the long term based on adequate monitoring and experimental schemes. Understanding biological diversity in terms of processes by which ecosystems and their components function, be it at community, species, population or genetic levels, is critical to informing sustainable use and safeguarding it. Given that biological diversity is dynamic, continually evolving and changing in response to biotic and fluctuations and other environmental pressures, it is necessary to record in time and space (i.e. benchmark) its status and, subsequently, monitor that status in order to identify changes and assess underlying mechanisms. In this context, recording both biodiversity status and a range of variables acting as proximal and distal drivers for biodiversity changes (land use, climate, exploitation levels, governance systems at stake, …) is of paramount importance.

Research capacity to re-use existing data sets and information from biological collections to perform new research and (meta)-analyses on biodiversity, ecosystem services and Nature-based solutions. To address the major issues societies are currently facing, the biodiversity research community increasingly needs to rely on a broad range of information over large temporal and spatial scales, which often goes beyond the capacity of individual research teams. The huge number of data sets and natural collections generated by previous studies and programmes is often relevant to address these issues, but the information has rarely been put to constructive use and remains

dormant. Studies (meta-analyses and syntheses[75]) based on these existing data sets thus have to be promoted in addition to the classical research projects generating new data through monitoring, experimentation and modelling. This is especially relevant in the context of biodiversity and ecosystem services research, where data produced by these projects are often limited to a specific level of biological organization, and/or limited in space or time. This requires more capacity to rescue, mobilize and exchange biodiversity data through appropriate research infrastructures and programmes. The development of such meta-analyses and syntheses has increased during the last decades at the international level, in particular through the establishment in the USA of the NCEAS[76] and NESCent[77], followed by the establishment of recent counterparts in European countries as sDiv in Germany and CESAB in France[78]. This type of research activity can play a key role in promoting the leadership of a regional research community at the international level. In addition, the wealth of biodiversity data that is held by European research organisations has useful applications beyond the realms of pure biodiversity conservation, and efforts need to be made to identify where missed opportunities exists for **novel application of biodiversity data in processes / mechanisms / decision support that can help inform effective decision making**. This undertaking will demonstrate widest positive impacts that improved biodiversity knowledge can deliver, and will aid in minimising duplication of research effort, help ensure that interested parties are not investing in endeavours to collect environmental data that already exists, and provide a pathway to identifying novel collaborative partnerships that may facilitate the leverage of co-funding of biodiversity data gathering; particularly with parties outside the usual sphere of influence that BiodivERsA has traditionally operated within.

Research capacity to support decision making through the development of scenarios and projections of biodiversity and ecosystem services, human well-being and social equity. In the context of human-induced global environmental changes (climate, invasive alien species, land-use change) research capacity is also needed for scenario development and modelling matching the needs of particular policy or decision contexts. Main gaps in the methods for modelling the impacts of drivers and policy intervention scenarios on biodiversity and ecosystem services were identified during the IPBES Methodological assessment of scenarios and models of biodiversity and ecosystem services[79]. Further, the development of tools that can predict and envision future scenarios of nature-human relationships, which explicitly address the impact of drivers of changes in ecosystem services and human wellbeing are much needed. In contrast to climate change, biodiversity modelling often has so far not achieved the level of maturity necessary to effectively inform policy-making, which creates a barrier to mainstreaming biodiversity in other areas of global concern.

Knowledge needs

[75] Gurevitch J., Curtis P.S. & Jones M.H. (2001) Meta-analysis in ecology. Advances in Ecological Research. 32: 199–247 ; Stewart G. (2010) Meta-analysis in applied ecology. Biol. Lett. 6: 78–81.

[76] National Center for Ecological Analysis & Synthesis (https://www.nceas.ucsb.edu)

[77] The National Evolutionary Synthesis Center (https://nescent.org)

[78] Specht A. (2016) Synthesis Centres: their relevance to and importance in the anthropocene, in: « Terrestrial Ecosystem Research Infrastructures: Challenges, New developments and Perspectives », A. Chabbi and H. Loescher (eds) CRC.

[79] IPBES (2015) IPBES Methodological assessment of scenarios and models of biodiversity and ecosystem services

- **Long term monitoring and experiments:**
    - Participate -with other relevant initiatives- to a coherent strategy at the European level for supporting infrastructures and initiatives that generate datasets on the long term dynamics of biodiversity and ecosystems in response to global change factors, This will require to reinforce existing ones, and improve their use for research. This requires development of monitoring protocols (including Essential Biodiversity Variables[80]) on temporal and spatial scales relevant to ecological thresholds, also informing local and regional-scale management. This also requires to explore further the use of a range of sites of potential interest, including those of the regional and national parks, Biosphere Reserves, and natural and mix World Heritage sites in Europe.
    - More specifically, better use long-term data series to assess the causality of biodiversity and ecosystem services changes;
    - Develop science-based indicators of biodiversity change, including changes in people's attitude towards biodiversity, and establish biodiversity indicators specific to local contexts and needs;
    - Knowledge base for early warning systems;
    - Reinforce research infrastructures allowing long-term surveys and experimentations on biodiversity and ecosystem services, and data archiving and access.
- **Synthesis and meta-analysis using existing data:**
    - Work on the ontology of biodiversity data (pre-requisite for syntheses and meta-analyses);
    - Promote meta-analyses compiling long-term series of biodiversity data and data on direct and indirect drivers;
    - Reinforce research infrastructures allowing better (re)use of existing data (for example open data infrastructures like the Global Biodiversity Information Facility, GBIF, and synthesis centres as sDiv and CESAB)
- **Improving modelling and the development of scenarios** of the impacts of drivers and policy interventions on biodiversity and ecosystem services. In particular, the following issues should be addressed:
    - System-level approaches to link direct and indirect drivers, nature, quality of life and nature's benefit to people, by addressing relevant processes and temporal and spatial scales and accounting for feedbacks;
    - Models explicitly linking ecosystem services and benefits to people. For instance, it is required to develop models and scenarios for optimizing extraction from multiple trophic levels, e.g., for developing more sustainable fisheries;
    - Models anticipating and providing early warning of ecological breakpoints and regime shift. For instance, research should help answering when do climatic and socio-economic factors combine to amplify the impacts of climate extremes and induce cascading harm on biodiversity and ecosystems, and are there 'tipping points' at which social or natural systems might fail to recover from shocks;

[80] Pereira H.M., Ferrier, S et al. (2013) Essential Biodiversity Variables. Science 339 : 277-278

- Participatory model and scenario building at larger scales for usefulness, accuracy and adhesion. For instance, participatory appraisal tools could help identifying various uncertainty factors (e.g. technology, land-use option, user practices, etc.) that lead to specific impacts on biodiversity;
- Participatory model and scenario building in which multiple stakeholders explore the impact of different drivers of change in the contributions of ecosystem services to human wellbeing and social equity. To foster the dialogue among different social actors (including researchers) with complementary knowledge systems in participatory scenario planning can enrich governance of biodiversity and ecosystem services by fostering creativity and social innovation[81].
- Practical and effective approaches to evaluating uncertainty associated with models and scenarios, e.g., using model-data and model-model comparisons. This should also include how the research community can communicate about uncertainty towards policy-makers and a wider audience.

Expected socio-economic impacts

With rising awareness of global environmental changes, reinforced monitoring of biodiversity and ecosystem services, meta-analyses based on existing data, and development of scenarios will help (a) understanding the role and impact of drivers and causes of biodiversity change; (b) analysing processes and mechanisms of change; and (c) laying the foundation for modelling and 'predicting' future changes, which will subsequently inform management and policy options. This should guide local adaptation and management strategies for, e.g., urbanization or agriculture, and should help identify ecological thresholds to, e.g., extractive activities. Together, these measures will help to safeguard the future conservation and sustainable use of biological diversity in mainland Europe, ORs and OCTs.

4. Steps toward an implementation plan building on the SRIA

Based on this SRIA, BiodivERsA partners will develop an implementation plan (the first one will cover the 2017-2018 period). The objectives of the implementation plan will be to:

(i) identify the range of activities that may be used to promote joint programming and support of research on biodiversity and Nature-based solutions across Europe. This will imply the use of a broad range of alignment activities (Table 3). The implementation plan will prioritize these activities.

(ii) identify and hierarchize topics to be targeted by these activities, in particular, topics for joint calls, but also for mobility schemes, etc…, while expliciting their European added value.

(iii) detail which activities may benefit from collaboration with other European or international initiatives. The complementarity between the BiodivERsA activities (and selected topics) and activities/topics directly supported by the EC through H2020 will be presented.

[81] Oteros-Rozas, E., B. Martín-López, T. Daw, et al. (2015). Participatory scenario planning in place-based social-ecological research: insights and experiences from 23 case studies. Ecol. Soc. 20:32

(iv) establish a time line, over 2 years, for the implementation of these activities.
(v) present clear objectives and associated indicators for assessing the success of the accomplishment of the implementation plan (see section 5).

The implementation plan will then be updated every 2 years.

Table 3: Increase in the range of alignment activities performed by BiodivERsA from its phases 1 to 3. Categories are based on the ones identified in the 'Report on the definition and typology of alignment' of ERA-Learn.

		BiodivERsA1	**BiodivERsA2**	**BiodivERsA3**
Research planning	Joint foresight activities	Agreement on common priority topics	Analysis of foresight views of BiodivERsA partners	
	Joint mapping activities	x	Mapping of the funding research landscape & mapping of European and international priorities	
Research strategy	Common strategic research priorities	x	X	Shared SRIA
	Adoption of a common strategic implementation plan	Common priority topics for a joint call	Common rolling agenda for topics to be selected for joint calls	Implementation plan for joint activities
	Conduct of joint stakeholder consultations	x	X	Broad consultation process of stakeholders, scientists and policy-makers on the SRIA
	Cooperation with JPIs & other European initiatives to better address cross-sectoral issues	x	Cooperation with FACCE-JPI	Continued cooperation with FACCE-JPI; Links with other JPIs (OCEAN, CLIMATE, WATER, URBAN)
	International cooperation to promote a research open to the world; cooperation with neighbouring ACP countries	x	x	Joint mapping exercise for ERA-LAC collaboration with ALCUE-Net; collaboration with the Belmont Forum; link between BiodivERsA and NetBiome; promotion of ORs and OCTs as an active frontier of Europe for international

				cooperation
Research funding	Synchronisation of national calls for research proposals	x	X	First national program alignment planned in 2017
	Organisation of joint transnational calls for research proposals	1 joint call implemented (28.4 M€)	4 joint calls implemented (total 75.2 M€)	1 Co-fund call in 2015-16 (64 M€) ; several additional calls planned
	Joint calls between different European and international initiatives	x	1 call with FACCE-JPI (2013-2014)	Joint co-fund call with the Belmont Forum planned in 2017
Research implementation	Promotion of networks of researchers on a thematic area of research and (bioclimatic) regions	x	Promotion of researchers networks on specific topics though ad-hoc meetings (kick-off meeting of funded projects; clustering workshops, etc.)	
	Involvement of stakeholders in research activities	Promotion of stakeholder engagement in research; production of tools to help them doing so (e.g. BiodivERsA Stakeholder Engagement Handbook)		
Research evaluation and reporting	Alignment of evaluation frameworks (common monitoring and evaluation)	Common rules and criteria for single evaluation process of BiodivERsA joint call		
	Harmonised and standardised reporting	Common reporting of BiodivERsA funded projects (unique template for the reporting)		
Training and capacity building of researchers	Joint training of young researchers	x	X	Scheme to promote early career researchers
	Joint training of researchers to increase their mobility and network	x	X	Mobility scheme for researchers (between academia and business; between continental Europe and overseas and within overseas)
	Training activities and capacity building for researchers and	x	x	Exchange of know-how between researchers from different

	stakeholders to increase research impact and their competitiveness			countries and territories to improve their competitiveness in joint calls Schemes to enable results uptake to increase societal impacts (policy-making, economy, biodiversity management, research capacities building)
Research infrastructures and data	Shared use of existing national research infrastructures	x	First mapping of research infrastructures	Portal presenting existing infrastructures, and framework to promote the use of RIs in funded projects
	Open access to national scientific research data	x	X	Development of a strategy for sharing data generated by BiodivERsA funded projects
Research dissemination and uptake	Coordinated dissemination of scientific results	x	Production of policy briefs	Joint promotion of research projects' outputs (through policy briefs, syntheses for IPBES, etc.); collaboration with EKLIPSE and OPPLA
	Promotion of the innovation potential of research	x	X	Business@biodiversity events; link with KTTOs; engagement in the multi-stakeholder dialogue platform on Nature-based solutions

5. Evaluation and monitoring of activities and impact

The progress of BiodivERsA toward reaching its strategic objectives will be surveyed by the BiodivERsA partners, the BiodivERsA Advisory Board and the European commission, in order to implement the necessary adjustments to our activities and to the SRIA itself. The BiodivERsA outputs, as well as short and longer-term impacts, will be assessed using a set of indicators embedded in the following framework[82]:

[82] Adapted from various sources including the Logical Framework Approach of the U.S. Agency for International Development (USAID); approaches presented in ERA-LEARN 2 Deliverable D4.3 "Monitoring and Assessment Framework for P2P Activities; and impact assessment frameworks" presented by JPI ERMP and JPND during the ERA-LEARN 2020 Workshop on P2P evaluation and impact assessment

Type A indicators of the performance of the BiodivERsA network

i.e. indicators to assess the following: BiodivERsA objectives → BiodivERsA Activities → Expected outcomes

Type B indicators of performance of BiodivERsA-funded research projects

i.e. indicators to assess the following: Objectives of BiodivERsA-funded projects → Projects' Activities

Type A and type B indicators will be reported to the BiodivERsA partners, the Advisory Board and possibly the European Commission on a regular basis (typically every 2 years) in the form of a balanced scorecard. Tables 4a and 4b present the type A and type B quantitative indicators respectively. In addition, BiodivERsA will implement a number of qualitative indicators for both types. An example of type A qualitative indicators could result from the survey of national and European perceptions of the impact of the BiodivERsA collaboration, targeting relevant players (including other European initiatives, BiodivERsA national partners, relevant DGs from the EC) or from the survey of perceptions of national research communities on the type of research promoted by BiodivERsA, linking scientific excellence and inter/trans-disciplinarity and the engagement of societal stakeholders in research projects. An example of type B qualitative indicators could result from the survey perceptions of stakeholders on their involvement in projects or the uptake and use of knowledge and technology developed under BiodivERsA projects. Another type of qualitative indicators to be implemented by BiodivERsA, encompassing type A and type B indicators, would be the production of "impact case-studies" relating successful examples of how BiodivERsA's activities or funded research project's outcomes have resulted into wider socio-economic or political impacts and changes.

The BiodivERsA implementation plans will take the evaluation results into account, as well as the BiodivERsA SRIA itself to ensure it operates in support of BiodivERsA goals and reaches the intended impacts and outcomes.

Table 4a: Type A indicators of the performance of BiodivERsA

Core objectives	Activities	Expected outcomes	Examples of quantitative indicators
Generate relevant knowledge to better preserve, restore and manage biodiversity and to develop and deploy innovative nature-based solutions tackling key societal challenges and improving human well being	Foresight and identification of research priorities	BiodivERsA identifies emerging research priorities and acknowledges these in its activities	- Number of topics jointly identified and used to support knowledge generation - Reports analysing research agendas and synthesising common priorities
	Funding in support of research projects through the launch of recurrent joint calls	BiodivERsA offers a recurrent and well-identified funding source for pan-European research on biodiversity and nature-based solutions	- Number of joint calls launched - Volume of funding (from national/local organisations and from European Commission) - Number of projects and research teams funded, and level of trans-national collaboration
	Funding in support of research projects through alignment of national programmes	BiodivERsA helps coordinate national programmes supporting research on biodiversity and nature-based solutions	- Share of total European investment in biodiversity and nature-based solutions coordinated with the help of BiodivERsA
Reduce the fragmentation in knowledge generation for the development of new paths for biodiversity	Enlarge geographical scope of cooperation	BiodivERsA reaches a critical mass to coordinate research on biodiversity and nature-based solutions	- Number of countries, regions and OR/OCTs involved in the consortium - Number of participating countries, regions and OR/OCTs participating in joint calls

conservation and Nature-based solutions across Europe		across Europe	
	Share information and practices among BiodivERsA partners, build capacities	Information and best practices are known and accessible to BiodivERsA partners	- Number of projects/programmes/countries in the BiodivERsA database - Number of countries involved in Staff Exchange Schemes - Shared rules and procedures, incl. evaluation procedures and joint monitoring of projects
	Analyse the research landscape	BiodivERsA provides a complete view on European biodiversity and nature-based solutions research	- Number of reports analysing the research landscape (e.g. funding, type of research, collaborations, research infrastructures) - Portal for improved access to European and national research infrastructures
	Share priorities in support of joint programming	BiodivERsA partners share a common vision on how to support biodiversity and nature-based solutions research	- Common SRIA produced and updated as needed - Implementation plan produced and updated as needed
	Align research programmes within and between countries	BiodivERsA identifies successful approaches to the alignment of national programmes	- Number of national mirror groups set up - Number of programme alignment implemented
	Engage with other European initiatives working on or with links to biodiversity and nature-based solutions	Research programming and funding on biodiversity and nature-based solutions is addressed in a concerted manner with relevant European initiatives	- Initiatives engaged (JPIs, FP7&H2020 projects and CSAs, etc.) - Number of joint activities (including joint calls) with other European initiatives (e.g. JPIs, OPPLA, EKLIPSE, etc.)
	Increase the sustainability of the structure	BiodivERsA is supported by Member States, Associated and Candidate Countries through (a) perennial tool(s)	- Support through European tool(s) beyond the COFUND scheme
Promote an efficient liaison between science & society/policy, and research & innovation, throughout the whole research process	Implementation of the stakeholder model of research (transdisciplinary approach)	BiodivERsA promote the engagement of relevant stakeholders throughout the whole research process, and provides the knowledge basis needed by stakeholders	- Number of consultations of the Advisory Board, and inputs taken up by BiodivERsA - Number and range of stakeholders consulted on SRIA and implementation plan - Number and range of stakeholders involved in foresight and dissemination workshops - Number and range of stakeholders involved in the selection of research projects - Number of tools developed to support stakeholder engagement - Assessment of the uptake of BiodivERsA and funded projects' outputs by stakeholders
	Develop links between research and innovation/business	BiodivERsA supports the transfer of knowledge and technologies developed in research projects it funds to support a sustainable economic development in Europe	- Number of implemented science-business mobility schemes - Number of workshops dedicated to science-business interactions and knowledge transfer - Number of technology transfers in funded projects; number of businesses spinning off/benefiting from funded project results
	Promote the efficiency of science-society and research-innovation liaison	BiodivERsA contributes to the transfer of knowledge and technology from research to society	- Number of policy briefs produced and disseminated - Number of stakeholder and policy-maker intended outputs by research projects

Increase the profile of European science and innovation on biodiversity and Nature based solutions	Build capacities	Early career researchers have opportunities to build European collaborations and link their research to societal needs	- Number of early career researcher schemes implemented - Number of early career research positions in funded projects
	Develop links with international initiatives promoting and programming research	European research is coordinated and valued in international research frameworks through BiodivERsA	- Number of joint activities implemented (including joint calls)
	Develop links with the IPBES	Research supported by BiodivERsA is coordinated with and feeds into international research efforts on biodiversity and nature-based solutions	- Volume of knowledge obtained by BiodivERsA-funded projects synthesised and feeding into IPBES assessments

Table 4b: Type B indicators of the performance of BiodivERsA-funded projects

Type of outcome	Expected outcomes	Examples of quantitative indicators
Academic	Generation of new knowledge advancing scientific concepts and knowledge	- Number of publications in peer-reviewed journals - Number of publications in top-generalist journals - Range and average impact factors - Number and range of publications in non-natural sciences peer reviewed journals
	Exploit complementarities between different national research communities	- Average number of countries involved in projects - Number of joint publications across countries, and countries involved - Funded projects publishing in both natural and social sciences journals
Societal	Engagement of non-academic stakeholders and building of evidence-based decision-making	- Number of projects using tools to support stakeholder engagement (e.g. Stakeholder Engagement Handbook) - Number and range of stakeholders involved in projects - Timing of engagement of stakeholders, roles, and methods used - Intensity and sustainability of stakeholders' engagement in projects - Number of publications in practitioners- and applied sciences journals - Number of products intended for stakeholders
	Transfer of knowledge and technology to non-academic stakeholders	- Number of projects engaging with businesses and knowledge and technology transfer organisations - Number of patents and spin-off companies resulting from projects - Number of policy briefs/options produced by projects - Number of other stakeholder-intended products produced - Number of stakeholder-intended workshops and meetings organised - Number of interventions in non-academic events

In particular, it is needed to evaluate the impact of stakeholder engagement, promoted by BiodivERsA, on the academic quality of the research as well as on the environmental and socio-economic research impacts. An innovative methodology has already been developed by BiodivERsA to jointly assess the academic and non-academic outcomes of funded research projects[83]. Efforts will be made to test and future-proof the 'expected' socio-economic impact expectations set out in the present SRIA, by monitoring –as far as possible- user uptake of research outcomes in decision support, and the benefits, which they may realise.

[83] Lemaitre F. & Le Roux X. (2015) Analysis of the outputs of BiodivERsA funded projects: BiodivERsA 2008 joint call on "Biodiversity: linking scientific advancement to policy and practice". BiodivERsA report, 64 pp.

In addition, the level of access of data and material associated to the funded projects will have to be evaluated. BiodivERsA will also have to demonstrate how it helps researchers to comply with laws, rules and approaches associated to the ABS protocol (including specificities for some OCTs).

6. Synthesis: the role and added value of BiodivERsA for building the European Research Area on biodiversity and Nature-based solutions

Through joint programming of research, BiodivERsA will play a key role for the generation of knowledge informing how nature can be part of the solution for a sustainable future in Europe

Given that the global population now consumes the production of 1.6 planets per year[84], it is increasingly recognized that humans should use the multiple services provided by nature sustainably and within limits for the future. At the same time, action is still needed to protect nature, in addition to economic imperative for nature. Actually, more and more stakeholders and policy makers in Europe see nature as being part of the solution for a sustainable future (i.e. using resources in a sustainable way, decreasing substantially greenhouse gas emission and pollutant production, and inducing no harm to biodiversity, while offering numerous jobs of high quality and improving human well-being). This is calling for an ambitious plan to reinforce and develop Nature-based solutions and deploy them at large scale to tackle a range of major societal challenges, while improving the efficiency of biodiversity protection efforts.

Solid policies to reach such an ambitious plan will have to rely on a solid knowledge basis that continues to evolve and grow, and the European Research Area should play a key role here. In this context, BiodivERsA will further develop its capacity to promote joint programming on biodiversity and Nature-based solutions, across borders and disciplines/sectors. BiodivERsA will enlarge for better geographical coverage of European countries and territories (both mainland and overseas) and increased international cooperation, and diversify its activities (shared strategy, joint calls, program alignment activities, young scientist schemes, mobility schemes, etc.) for promoting a fully efficient joint programming approach. BiodivERsA will also seek for further support from Member States and EC through a tool fully adequate to its current and future ambitions. By doing so, BiodivERsA will further promote research (i) to gain a better understanding of the dynamics of biodiversity and ecosystem services under global change and how we can protect and manage them sustainably, and (ii) to reinforce knowledge and tools on the value and valuation of biodiversity and ecosystem services, as this is a prerequisite to propose options for policy and action. The research promoted by BiodivERsA will also (iii) guide the development of a sound package of indicators to account for natural capital and evaluate the actual success of policy instruments and governance systems aiming to reinforce sustainability and improved biodiversity status, and (iv) enhance the knowledge basis for developing and assessing Nature-based solutions and their ability to tackle major societal challenges while improving the sustainability of European societies and territories - both mainland and overseas.

BiodivERsA will reinforce its impact and added value within the European Research Area

Since its creation, BiodivERsA has thrived to avoid the common dichotomy between the so-called fundamental or pure research and the applied research, linked to the also common linear model of

[84] www.footprintnetwork.org

research[85]. Recognizing that it is needed to support fundamental research through devoted programmes, the role of BiodivERsA is actually to program and support a hybrid type of research, bridging the gap between fundamental research to solution-oriented research, while promoting stakeholder engagement throughout the whole research process as well as transfer and support to innovation. As the evaluation of BiodivERsA-funded research demonstrates the success of the approach for excellence in terms of both academic and non-academic productions, BiodivERsA will further reinforce this type of joint programming. This is particularly relevant to BiodivERsA's focus on biodiversity and Nature-Based Solutions, which calls for the generation of new knowledge at the scientific forefront as well as the integration of different types of research and effective capacity of research to help tackling pressing societal challenges.

BiodivERsA will reinforce its added value within the European Research Area by:

- Promoting and supporting medium-sized research projects (typically 1 to 1.5 million euros per project) that gather pan-European consortia (typically 5 to 8 teams from 3 to 6 countries, representing different disciplines as needed) and promote at the same time academic excellence, stakeholder engagement and research capacity to support practice and expand the scope of choice available to decision-makers. This complements the ERC scheme that is an individual- and academic excellence-focused scheme, and the H2020 work programme that is focused on innovation and demonstration and is able to support very large projects and demonstrators.
- Bridging the gap between biodiversity research and Nature-based solutions research. Because we have to explore how nature can be part of the solution for the future in Europe, one cannot promote research on biodiversity and ecosystem services and research on Nature-based solutions in a totally independent manner. BiodivERsA will thus promote at the same time strong research on biodiversity and ecosystem services (in its widest acceptance) that will help make a difference for developing and deploying Nature-based solutions through systemic approaches, and a solid research on Nature-based solutions that will help tackling pressing societal issues while also offering new options to improve the status of biodiversity and the natural capital in Europe. This approach will avoid sustainability research becoming simply tied in the straitjacket of utilitarianism, while maximizing the mobilization of a broad range of research forces and stakeholders on Nature-based solutions.
- Engaging with relevant JPIs to properly tackle cross-sectoral issues (see Table 1). The success of the pioneer joint call between BiodivERsA and FACCE-JPI has paved the way to a reinforced cooperation with relevant JPIs. In addition, BiodivERsA will engage as needed with other European initiatives like EKLIPSE and OPPLA for maximizing knowledge transfer to stakeholders and policy makers, and the future multistakeholder dialogue platform on Nature-based solutions for strengthening the link between knowledge generation and innovation on Nature-based solutions. BiodivERsA will also promote complementarities with the H2020 work programme and its ability to support ambitious projects and implement large-scale demonstrators. Links with other schemes like the Research Fellowship Programme 'Marie Skłodowska-Curie actions' will also have to be explored. All

[85] The linear model of research, in its first form, represents a flow of knowledge from basic research to applied research to development and ultimately societal benefits; in its second form, it suggests that achieving agreement on scientific knowledge is a prerequisite for a political consensus to be reached and policy action to occur

these collaborations will underpin the emergence of a strong and consistent ERA on biodiversity and Nature-based solutions, efficiently providing the relevant new knowledge that we need to better protect biodiversity and make it fully part of innovative solutions for a sustainable future in Europe.

BiodivERsA will also further engage with key international initiatives (Table 2), in particular the Belmont Forum, Future Earth and the IPBES. Promoting the international dimension of BiodivERsA activities will allow raising the profile of European research on biodiversity and Nature-based solutions at the global level, while better bringing the European perspective within these international initiatives.

BiodivERsA will help researchers on biodiversity and Nature-based solutions to act as honest brokers of policy alternatives

It is increasingly needed that scientists play their role as part of the societal debate on biodiversity protection, and the way we can see nature as the basis for innovative solutions tackling pressing societal challenges. This requires helping research consortia to discuss options and helping the transfer of knowledge obtained from their research results (collaboration with OPPLA[86] and EKLIPSE[87] being important here). But this is not sufficient, and BiodivERsA partners seek to shape the research process itself to put the researchers in the best position to play their role of honest brokers of societal and policy alternatives by promoting stakeholder engagement throughout the whole research process. In particular, by integrating scientific knowledge with stakeholder concerns in the form of different possible courses of actions within their scientific projects, researchers can play a key role to open the mind of citizens, stakeholders and policy makers and provide them with an enlarged portfolio of possible options. Europe needs a strong support from its research to make nature an integral part of the sustainable development portfolio, in particular through Nature-based solutions, and to make sustainable development a solution to the biodiversity crisis: BiodivERsA is committed to actively contribute to this goal.

[86] A hub about ecosystem services and Nature-based solutions: www.oppla.eu

[87] Knowledge and Learning Mechanism on Biodiversity and Ecosystem Services: www.eklipse-mechanism.eu

The BiodivERsA consortium

French Foundation for Research on Biodiversity (FRB), France - Coordinator
Belgian Science Policy Office (BelSPO), Belgium
The Research Foundation - Flanders (FWO), Belgium
National Science Fund Bulgaria (NFSB), Bulgaria
Estonian Research Council (ETAg), Estonia
Academy of Finland (AKA), Finland
French National Research Agency (ANR), France
French Ministry of Ecology, Sustainable Development and Energy (MEDDE), France
New Caledonian Economic Development Agency (ADECAL), France
Guadeloupe Region (GUA-REG), France
French Guyana Region (GUY-REG), France
Reunion Region (RR), France
German aeronautics and space research centre (DLR) on behalf the Federal Ministry of Education and Research (BMBF), Germany
German Research Foundation (DFG), Germany
Ministry of Agriculture (FM), Hungary
Latvian Ministry of Environmental Protection and Regional Development (MoEPRD), Latvia (associate member)
Research Council of Lithuania (RCL), Lithuania
Research Council of Norway (RCN), Norway
National Science Centre (NCN), Poland
Portuguese national funding agency for science, research and technology (FCT), Portugal
Regional Fund for Science and Technology (FRCT), Portugal
The Executive Agency for Higher Education, Research, Development and Innovation Funding (UEFISCDI), Romania
Slovak Academy of Sciences (SAS), Slovakia
Spanish Ministry of Economy and Competitiveness (MINECO), Spain
Regional Government of the Canary Islands (GOBCAN), Spain
Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (Formas), Sweden
Swedish Environmental Protection Agency (SEPA), Sweden
Swiss National Science Foundation (SNSF), Switzerland
The Netherlands Organisation for Scientific Research (NWO), The Netherlands
Ministry of Food, Agriculture and Livestock (MFAL), Turkey
Joint Nature Conservation Committee (JNCC), United Kingdom