SUSTAINABILITY SCIENCE

UNDERSTAND, CO-CONSTRUCT, TRANSFORM

Collective thinking coordinated
by Olivier Dangles and Claire Fréour

IRD Institut de Recherche pour le Développement
French National Research Institute for Sustainable Development

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French National Research Institute for Sustainable Development
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IRD, Marseille, 2023

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PREFACE

Valérie Verdier
Chairman and Chief Executive Officer
French National Research Institute for Sustainable Development

Sustainable development and its 17 associated goals (SDGs) – adopted by the United Nations as a worldwide compass – are the horizon we are aiming for and must reach.

From the outside, IRD has been a pioneer in embracing these goals, raising many questions, from epistemological to geopolitical, and in implementing them, which has continually fuelled our thinking and ignited debate. This has focused on how a research organisation such as ours, which works for development, can best tackle the issues raised by the Sustainable Development Goals, especially in countries of the Global South – the main focus of our intervention and attention – with our partners and for their benefit.

For this reason, I felt it was necessary to appoint a researcher to work alongside me so that research at IRD, beyond the interdisciplinarity rooted in our practices, would be reinforced by a cross-disciplinary paradigm – sustainability science – to guide the Institute forward. Within the Directorate for Science, this is the role of the Deputy Delegate for Sustainability Science and of the team formed around him and linked to our "knowledge communities".

This (non-exclusive) strategic focus, which lies at the crossroads between fields and disciplines and has been a hallmark of the actions and decisions I have taken since I first took up this role, reflects the challenges of our time without losing sight of the need for excellence in the research we produce with our partners.

This acculturation work has expanded. There was a clear need to apply the principles of engaged research to the major challenges and social responsibility that we must all embrace. This cross-cutting approach adopted within the Institute, not only in our decision-making process and means of action, but also through our openness to other sectors of society, has proved to be a valid one. It is attracting a great deal of interest from young researchers from both the Global North and South who are keen to strike a balance between scientific excellence and civic engagement.

Among the many actions and initiatives on sustainability science, the "Sustainability Science Reference Articles" presented in this booklet are both a genuine basis for discussion and a useful teaching aid for everyone's use. Sustainability science, as applied to development, supports the transformation of societies while protecting ecosystems and the planet. It has its own set of concepts and methods, and this booklet explains some of the key ones and provides examples of projects that illustrate them.

These articles have been organised around the triptych of "Understand/Co-construct/Transform", three concepts that are open-ended and interconnected. They have been produced in collaboration with what we like to call "the IRD Planet". This extremely rich and culturally diverse community, drawn from our staff and partners, reflects the vitality of this shared commitment to sustainability science, which in turn fosters excellence in research, training and capacity building.

So, thank you to the IRD Planet.

INTRODUCTION

Olivier Dangles and Claire Fréour
IRD Directorate for Science

Planet Earth is like an island floating in space. An island inhabited by life. An island that is only habitable for everyone if its natural resources – rivers, soils, oceans and forests – are used sustainably. However, since the Industrial Revolution, humankind has accelerated its impact on these resources at an unprecedented rate through the exponential growth in its activities. Even if the Earth still appears as a blue island from space, the changes that have transformed it are now so profound that they threaten the very functioning of the biosphere and put the future of humanity at risk.

What is scientific research doing to address this global sustainability challenge? For the past 20 years, it has been developing concepts and methods that can be used to devise sustainable solutions for creating and preserving an environmentally safe and socially just space on the planet.[1] A whole new field of research has emerged: sustainability science. It looks at the complex interconnections between natural, social and technical systems, and how these interactions affect, over time and space, the planet's life support systems, socioeconomic development and human well-being. This approach gives researchers a better overall understanding of the main sustainability issues facing our societies, with the goal of providing answers to the 169 targets of the Sustainable Development Goals. Sustainability science is an umbrella term that covers activities as diverse as acquiring new fundamental knowledge, researching technological applications, engaging in sociocultural innovation and defining new social, political and economic models. It also involves the way in which knowledge is produced, harnessed and applied, thereby improving the link between the academic world and the problems confronting our societies.

1 • Raworth K., 2012 – *A safe and just space for humanity: can we live within the doughnut?* Oxfam Discussion publications.

However, many questions remain open about what sustainability science really encompasses. Knowledge is plural, interdisciplinary and even transdisciplinary; it must be discussed and debated and can therefore only emerge through an integrated, collegial and participatory approach. This is why, in spring 2021, IRD decided to publish a series of "sustainability science" reference articles. Their aim is to provide a channel for all IRD staff and partners to express their views on the many facets of sustainability science. These articles have been published on a regular basis since April 2021 (https://www.ird.fr/la-science-de-la-durabilite-en-action) and have now been compiled into this booklet. It contains contributions from more than 70 authors from the IRD Planet – scientists, directors and heads of departments, mission managers and members of civil society – who all share their knowledge and expertise on research for sustainable development. The thirty-four articles that make up this booklet have been grouped around the foundational triptych of sustainability science – "Understand", "Co-construct", "Transform" – following the analytical framework proposed by Julien Blanco and Clémence Moreau (see p. 20). However, this triptych is amorphous since, according to the two authors, sustainability can be perceived as "a boundary object that connects those producing knowledge about sustainability (understand, co-construct) and those working for sustainability (transform), with the expectation that this will lead to much sought-after theoretical and applied innovations".

Throughout these pages and through the comparative views of the various contributors, you are encouraged to build an interdisciplinary and cross-sectoral vision of sustainability science, which will stimulate your reflexivity on this emerging approach. You may choose to read this booklet in the sequence presented: 1) Understand, 2) Co-construct, 3) Transform. Alternatively, you may wish to jump from one article to another depending on what you find interesting or are curious about. An index is provided at the end of the book to facilitate more selective reading based on the topics and concepts you wish to explore in

more detail. This booklet provides an insight into sustainability science that can be seen as an opportunity to take a step back, take a critical look at our practices and rethink what research for sustainable development means today.

In the words of the philosopher Edgar Morin, in these times of crisis, should we not have the courage to "see the greatness of contemporary science along with its shortcomings?" To stay connected with the times, to be heard and play a determining role in major future strategic directions, stakeholders in the world of research and development wish to question their subjects, their tools and also their research practices, turning their attention to "sustainability science". Rethinking research by combining disciplines around societal challenges, co-constructing solutions with society, integrating various forms of knowledge, taking into account the different levels at which solutions may be provided to drive societal transformation: these are the challenges of the 21st-century citizen researcher, a researcher who must also train future generations in research committed to tackling major challenges, and raise their awareness of a science that is fundamentally open to others. This is how the academic world will "do its part" to ensure that planet Earth remains environmentally safe and socially just for future generations.

UNDERSTAND

Understanding how to safeguard the well-being of current and future generations within planetary boundaries is at the heart of sustainability science. There is a growing demand for integrated knowledge about the Earth, social systems and their interfaces. This calls for new conceptual and methodological approaches. This section features contributions from three young scientists recruited by IRD through its sustainability science competition in 2021 and 2022 and six prize-winning projects by IRD researchers and their partners, submitted to the 2021 Belmont Forum Pathways to Sustainability call for projects. What they all have in common is the development of holistic approaches to gain a better understanding of the complex interactions and feedbacks between natural and social systems.

Sustainability science: Finding sustainable solutions within planetary boundaries

Olivier Dangles and Claire Fréour,
IRD Directorate for Science, Marseille, France

Background

Protecting the biosphere is now a global priority that demands changes in societies and lifestyles. In response, science is being called upon to provide sustainable solutions, and many are voicing support for us to move faster, advise on public policy, propose alternatives and solve problems. These expectations are well founded, but we need to be better prepared in anticipating new challenges so we can avoid future disasters. Contemporary research remains fragmented, discipline-based and fails to bridge the gap between results and proposed solutions to address the magnitude of the problems. If we are to stand any chance of responding to and coping with environmental crises, we need to work differently together.

Contact
olivier.dangles@ird.fr

Further reading

Clark W. C., Harley A. G., 2020 – Sustainability science: Toward a synthesis. *Annual Review of Environment and Resources*, 45 : 331-386.

What is sustainability science?

Sustainability science officially emerged as a research field in its own right at the beginning of the 21st century. It looks at the complex interconnections between natural, social and technical systems, and how these interactions affect, over time and space, the planet's life support systems, socioeconomic development and human well-being. Sustainability science is an umbrella term that covers activities as diverse as acquiring new fundamental knowledge, researching technological applications, engaging in sociocultural innovation, bringing about a change in governance and defining new social and economic models. Sustainability science is therefore based on "problem-centred" research, which is rooted in confronting real-world situations, rather than in the underlying dynamics of the scientific disciplines it draws upon. This approach gives researchers a better overall understanding of the main sustainability issues facing our societies, with the aim of providing answers to the 169 targets of the Sustainable Development Goals (SDGs). As a research field, sustainability science has its own collection of concepts and methods, scientific journals, conferences and experts.

Looking ahead to a sustainable future

Questioning what sustainability means is essential to understanding the science that bears its name. A turning point was reached in 2009 with the definition of planetary boundaries in the seminal paper by Johan Rockström and colleagues. This paper examines sustainability in relation to the limits of natural processes that regulate the biosphere, such as climate change and biodiversity loss. Later, in her 2017 book *Doughnut Economics*, economist Kate Raworth backs up planetary boundaries with the concept of the social floor for human rights and needs that are essential for a dignified life on Earth. Today, the global transformation of our societies in both the Global North and Global South is necessary to ensure that we live within these boundaries, in an environmentally safe and socially just space.

The bridge allegory

The way in which sustainability science harnesses and applies knowledge in its practical application bridges the gap between the academic world and societal problems. This unique function is evident in:

- the high degree of transdisciplinarity, justified by the fact that global problems call for an interdisciplinary and cross-sectoral approach, especially between environmental sciences, social sciences and humanities, and the stakeholders (as in the case of the green SDGs, which interact with the societal and economic SDGs);

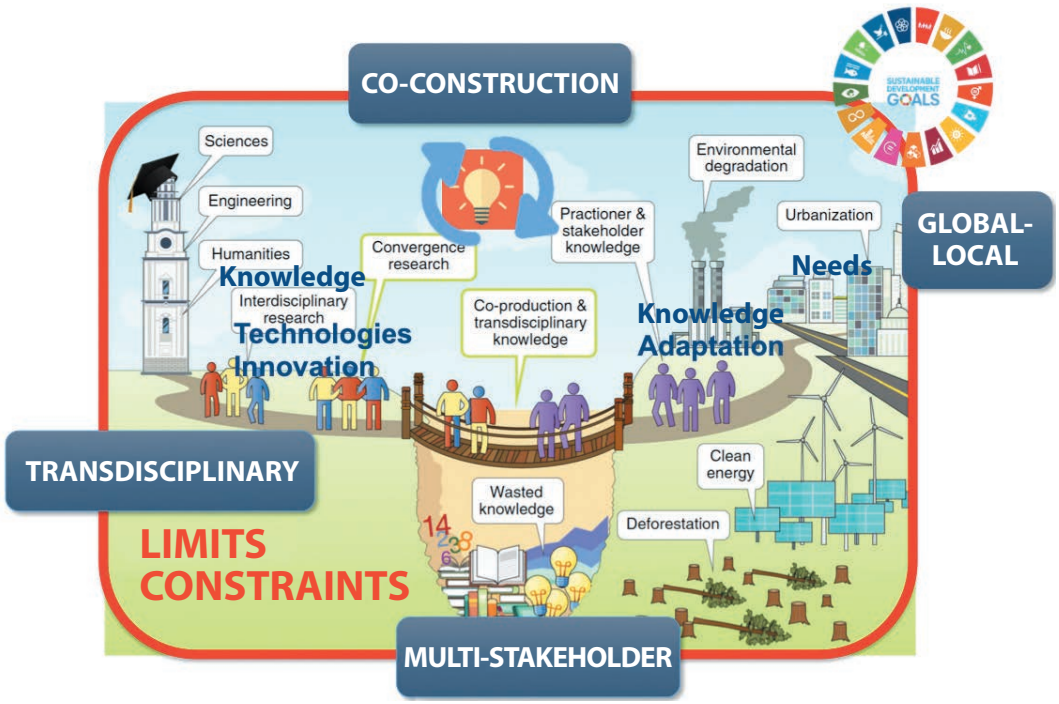
- multi-stakeholder co-construction of research projects involving the academic world and a wide range of stakeholders, with the aim of

highlighting issues related to society's needs. This co-construction, which helps us think more effectively about how to produce new knowledge and provide solid elements for decision-making, requires a specific framework for its implementation over a long period of time and for assessing its impact;

• a global-local approach that considers the impact of solutions at different levels to ensure that improving a situation at the local level does not negatively affect other levels.

Legitimacy of IRD

IRD still has several challenges to overcome if it is to fully implement the bridge allegory: cross-pollination between social and environmental sciences is still too limited; the visibility of researchers and their colleagues from the Global South in international journals and debates on sustainability science is poor; the structural and functional organisation of the institute and the academic community is compartmentalised. Still too few research projects



Sustainability science builds a bridge between the research world and societal problems (from Irwin *et al.*, 2018, *Nature Sustainability*, 1: 324-326).

are co-constructed with civil society stakeholders and their impact on sustainable development in partner countries is rarely explored. Moreover, there is little consensus among researchers on the adoption of the 2030 International Agenda. They often see it more as a straitjacket with no real scientific interest rather than an opportunity to rethink the objects, methods and impact of their research. However, because of its history, the geographies it covers and its mission of research for development, IRD has always carried out work focused on the needs of local populations. Collaboration between researchers on areas of common interest in the Global South provides scope for integrated, interdisciplinary and participatory approaches. The opportunities therefore appear promising.

Need for reflexivity

Sustainability science is a young science with blurred boundaries, and it needs to be approached with a certain degree of reflexivity. The normativity it introduces to the notion of sustainability challenges the definition of development, while the urgency of the problems it addresses challenges the possibilities of finding solutions. The multi-stakeholder approach explores the implications of integrating non-scientific knowledge into research practices. The complexity that characterises its systemic approach raises questions about how it can be effectively integrated into policies. Finally, sustainability science reconsiders the role played by research in addressing societal issues, both in terms of its freedom and its responsibility.

KEY POINTS

Sustainability science is a process that generates solutions for a more sustainable world. It therefore concerns not only researchers, but all IRD staff. The idea is not to impose our vision on our staff, but to co-construct it with them, and to show them in a practical way how it might be useful to them while helping us to position ourselves as a major scientific player in the collective effort required to respond to major global challenges. In so doing, we will be able to involve as many people as possible, embrace this strategic vision and generate real and sustainable systemic change for the planet.

Understand, co-construct, transform: a triptych in need of social sciences?

Julien Blanco and Clémence Moreau,
IRD, UMR SENS, Montpellier, France

Background

Sustainability science (SS), still to be accepted into mainstream science, is the source of many questions in the scientific community. And for good reason. The term itself only appeared in international literature in 2001, which is only yesterday in terms of the history of the construction and dissemination of knowledge. Given this context, it seems only natural that we – scientists rooted in one, sometimes two, disciplines – should question our position with regard to SS. To look further than an instinctive response to this question, we sought to gain a better understanding of the scientific landscape of SS, which is still under construction.

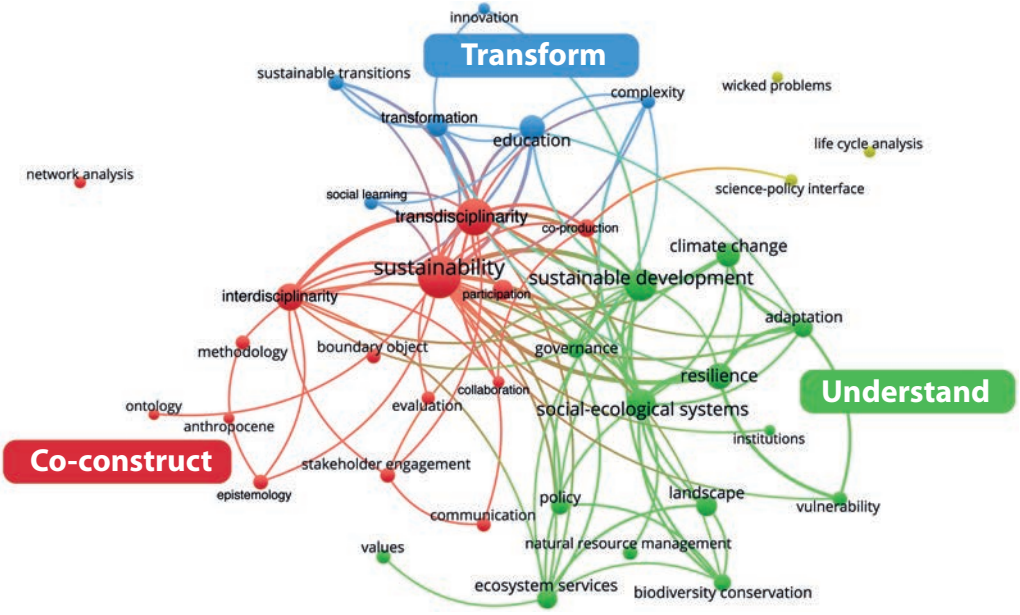
Contacts
julien.blanco@ird.fr
clemence.moreau@ird.fr

Further reading

Sörlin S., 2012 – Environmental Humanities: Why Should Biologists Interested in the Environment Take the Humanities Seriously? *BioScience*, 62 (9) : 788-789.

Knowing and re-assessing your niche: a common theme for scientists

"How does my scientific work contribute to my discipline, to my working group, to society?" This is a question that all scientists ask themselves many times throughout their career, in a constantly changing scientific landscape, requiring them to continuously re-assess their "scientific niche" – their field of expertise – and to be on the constant lookout for emerging concepts, paradigm shifts, new approaches and the latest tools. It was with this in mind that we sought to gain a better understanding of SS, to identify what it encompasses, to position it in relation to our individual and collective "scientific niche" and to find out how we contribute to it, if indeed we do. To do this, we conducted a semi-quantitative analysis of the publications on the Web of Science claiming to be in the field of Sustainability Science (1,129 publications). Here, we present the three main findings from that analysis.



Network of the 39 most frequently used keywords in sustainability science publications.

The triptych of sustainability science: understand, co-construct, transform

Through the keywords used by the authors and their co-occurrences, we identified three foundational pillars of SS, all of which the available studies cover to different degrees while maintaining a close relationship between them:

Understand:
This pillar focuses on the analysis of socio-ecosystems and how they behave (in terms of resilience, adaptation and vulnerability) when faced with contemporary environmental issues (climate change, protection of biodiversity and natural resources). Although less prominent, issues related to the governance of socio-ecosystems (institutions, policies) are also addressed;

Co-construct:
This pillar focuses on engaging stakeholders in interdisciplinary or transdisciplinary research, with the aim of stimulating the co-production of knowledge. This aim is associated with major methodological challenges, linked in particular to fostering dialogue between disciplines and between stakeholders, and with the inclusion of various epistemologies and ontologies, both scientific and lay;

Transform:
This pillar of SS reflects its commitment to the transformation of the relationship between humans and their environment. To do this, SS draws on innovation, education and social learning, themes that are closely connected with co-construction.

Sustainability science, a new arena for discussion, a potential source of innovation

Understanding socio-ecosystems, working on interdisciplinary studies, creating partnerships and finding solutions to (sustainable) development problems are all issues that pre-date SS. They reflect not only disciplines and theories that are already well established, but also IRD's traditional missions. While these issues are then by no means new, it seems to us that SS provides fertile ground in three respects. Firstly, environmental issues are not confined to traditional disciplines (such as ecology and geography), but also extend into a variety of disciplines, as evidenced by the many fields dedicated to them within generalist disciplines (environmental psychology, conservation biology, ecological economics, etc.). However, since these disciplines vary in their understanding of each other, SS encourages them to (re-) recognise that they are working on a common issue – sustainability – and, in so doing, to exchange their perspectives more often. Secondly, the emergence of an "undisciplined" field of research, focused on one issue, is not new, as agronomy and forestry illustrate. Both these fields are understood less by the disciplines they draw on than by the research objects and societal issues they address. Understood as an attempt at de-sectoralisation, SS may certainly look more closely at how the sustainable development goals are interconnected, whereas to date these have only been considered in isolation. In conclusion, rather than a completely

new science, SS seems to offer a new arena for researchers from different backgrounds, working on different objects, but feeding into a common reflection about sustainability. At the centre of this arena, sustainability becomes a "boundary object" that connects those producing knowledge about sustainability (understand, co-construct) and those working for sustainability (transform), with the expectation that this will lead to much sought-after theoretical and applied innovations.

Social sciences and humanities neither visible nor sufficiently involved?

If interdisciplinarity is at the heart of SS's "project", we note that social sciences and humanities (SSH) are difficult to situate in the current landscape. The overwhelming majority of the 1,129 publications analysed are related to environmental sciences and ecology (798 publications) and technological sciences (463). Geography (51), education sciences (36), various social sciences (23) and sociology (17) are only marginally represented. These figures are all the more problematic given that, in parallel with SS, the environmental humanities movement is expanding, aiming to bring together all the SSH that focus on the environment. This trend shares the same initial observation as SS (i.e. the cross-sectoriality of environmental issues), but this does not necessarily mean that it defines its objectives in the same way. With environmental humanities, are we not therefore reproducing, or maintaining, the separation between "hard" and "soft" sciences, from which SS aims to free itself? Or are environmental humanities and SS bound to enter into close dialogue while maintaining their own specific characteristics? In light of these unresolved questions, it seems crucial that SS does not take interdisciplinarity for granted, but instead see it as a research front that will undoubtedly require innovations both in "our sciences" and in our ways of doing and evaluating science.

KEY POINTS

Various disciplinary and interdisciplinary movements contribute to sustainability science (SS) as building blocks for a broader project aimed at understanding and transforming the relationship between humans and their environment. If interdisciplinarity is at the heart of this project, it seems crucial that, beyond mere words, SS develops the means to really implement it.

Sustainable solutions to fishing-marine megafauna conflicts

Paul Tixier,
IRD, UMR Marbec, Sète, France

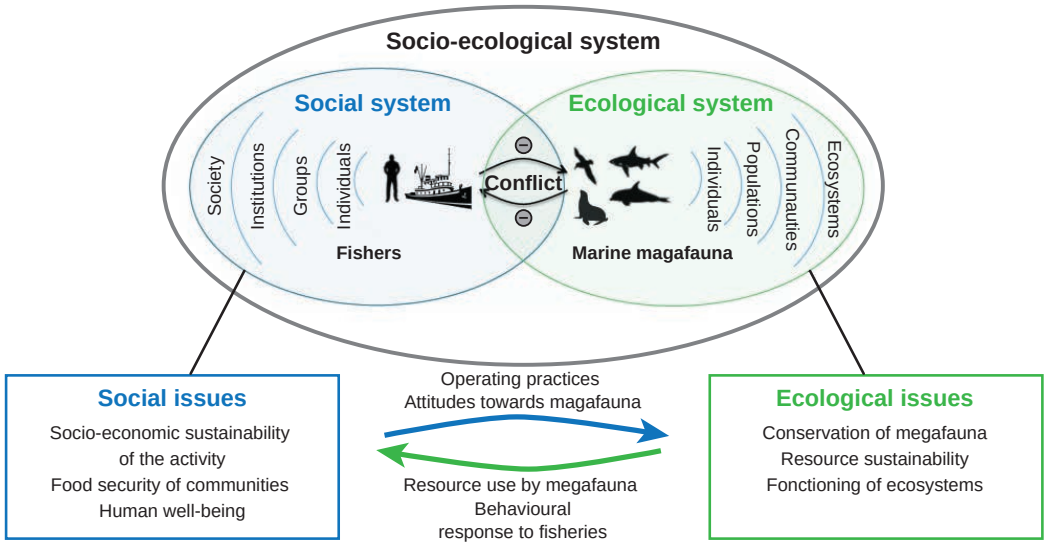
Background

Conflicts of use between fisheries and marine megafauna (sharks, turtles, mammals and seabirds) now extend around the globe and are exacerbated by the intensification of fishing, the decline in fish stocks and significant conservation issues. Although the end of the 20th century saw a shift from an approach of eradicating megafauna to one of human-wildlife coexistence, there are still only limited sustainable solutions. To tackle the major societal and environmental challenge posed by this coexistence and to provide integrated decision-making tools, it would seem appropriate to develop transdisciplinary and trans-sectoral research at the socio-ecological system level, following the approaches adopted by sustainability science.

Contact
paul.tixier@ird.fr

Further reading

Nyhus P. J., 2016 – Human–wildlife conflict and coexistence. *Annual Review of Environment and Resources*, 41 : 143-171.



Socio-ecological system and issues associated with the fishing-marine megafauna conflict.

Socio-ecological complexity of the conflict

The fishing-marine megafauna conflict is a typical environmental problem at the interface between societal and ecological issues, with impacts that disrupt multiple compartments of marine socio-ecosystems, threatening their balance, their functioning and, consequently, their long-term sustainability. For example, the behaviour of sharks and marine mammals, which feed on fish catches from fishing equipment, has socioeconomic costs for fishers (loss of yields, material damage and extra effort) and negatively impacts the predators themselves (by catch mortality and/or fisher response), fish stocks (skewed assessments) and associated ecosystems (changes in trophic interactions). This type of conflict affects coastal and offshore fisheries in all sectors (industrial, artisanal, subsistence and recreational) worldwide, but the various effects produced vary from region to region and can, in some areas of the Global South, threaten the food security of communities.

Transition towards transdisciplinarity

The majority of scientific studies have, until now, examined conflicts through piecemeal approaches, focusing on a limited number of socio-ecosystem components or on a single type of issue (social, economic or conservation) and separating human activity from other functional groups. These studies, generally used as an aid to decision-making in fisheries management, result in single-track measures pitting the socioeconomic viability of fisheries, the sustainability of fish stocks and the maintenance of marine megafauna populations against each other, creating contradictions within the governance systems themselves.

Generic research recommends interdisciplinary approaches for effective coexistence, but their implementation may be hampered by the complexity of socio-ecosystems and the lack of cross-sectoral expertise needed to catalyse knowledge in an integrated manner. In addition to the transition that has already begun at the individual (researchers broadening their disciplinary field) and collective (mobilisation of a range of expertise in research programmes) levels, particularly at IRD, a transition from interdisciplinarity to transdisciplinarity is also needed. This involves developing and deploying integrative scientific tools to identify, by taking into account social, economic and ecological interactions, the conditions for maintaining an entire socio-ecosystem that is stressed by the conflict. Such tools already exist – for example, ecosystem models with human components or bioeconomic coviability models – but their application is still limited.

The importance of social sciences and humanities (SSH)

While studies on the ecological mechanisms and impacts of conflicts dominate the literature and provide the first clues to mitigation, they must be complemented by SSH studies to identify the barriers to coexistence related to fishing activities and their modes of governance. At the level of fishers, this involves understanding social and economic constraints, along with attitudes and perceptions towards megafauna. For example, the analysis of perceptions – which are linked to individuals' culture and life history and often determine how a conflict arises – can be used to direct eco-awareness efforts towards increased acceptance of megafauna. On a broader scale, SSH, and in particular research in environmental humanities, are essential for understanding how stakeholders organise themselves around the conflict, the power games played and how knowledge (local, scientific, expert opinion, etc.) is put into practice in the decision-making process. Together, as part of a process of transforming existing governance methods, these studies can activate the levers needed to remove the obstacles to fisheries and marine megafauna coexisting by bringing together stakeholders (fishers, fishing industry, managers, scientists, environmentalists, economists, policymakers and the general public) with often divergent interests.

Adaptive co-management as a lever for transformation

One of the transformation levers is adaptive co-management. It combines different knowledge systems and different types of knowledge by promoting information flows and cross-sectoral collaboration, proactively engages all stakeholders, and has been put forward as a management method suitable for mitigating human-wildlife species conflicts. However, adaptive co-management is still only rarely used in fishing/marine megafauna conflicts because the benefits only become apparent in the medium and long term. Actions with immediate effects, such as financial compensation or the use of technological systems to keep megafauna away, are therefore often preferred. These approaches can be effective at the local level, but must be integrated into an adaptive co-management process and accompanied by more radical transformations to guarantee long-term coexistence. By developing a more holistic understanding of the issues, processes and impacts of the conflict, significant changes in fishing practices or techniques can be tested, assessed and adjusted in an iterative manner until socioeconomic and ecological compromises are found that can maintain the entire system.

KEY POINTS

While fishing-marine megafauna conflicts cannot be eliminated, sustainable solutions for coexistence are possible. This coexistence requires innovations in fishing practices, based on knowledge acquired in all compartments of the socio-ecological systems associated with the conflicts. This knowledge is acquired through developing integrative transdisciplinary research that identifies the balance points that allow the social and biological components to work within sustainable margins. It is also essential to re-examine how the various stakeholders could mobilise and organise themselves around this objective of coexistence. Sustainability science, as a "problem-based" research field, advocating the socio-ecological approach and building on the pillars of understand, co-construct and transform, can act as a catalyst for transitioning to adaptive co-management methods and shifting from conflict to coexistence between fisheries and marine megafauna.

Volcanic soils and health: what are the risks?

Lucie Sauzéat,
IRD, UMR LMV/iGReD,
Clermont-Ferrand, France

Background

With more than 800 million people living on volcanic soil, managing the risk of prolonged exposure to volcanic particles is a major public health issue, and one that is critical to achieving the Sustainable Development Goals. Although holistic approaches are becoming more widespread (in particular to include sociocultural aspects), the health-related challenges involved in quantifying the parameters and mechanisms of toxicity operating at the organism level are not yet sufficiently understood and do not provide a basis for developing sustainable actions to protect human health in volcanic environments.

Contact
lucie.sauzeat@ird.fr

Further reading

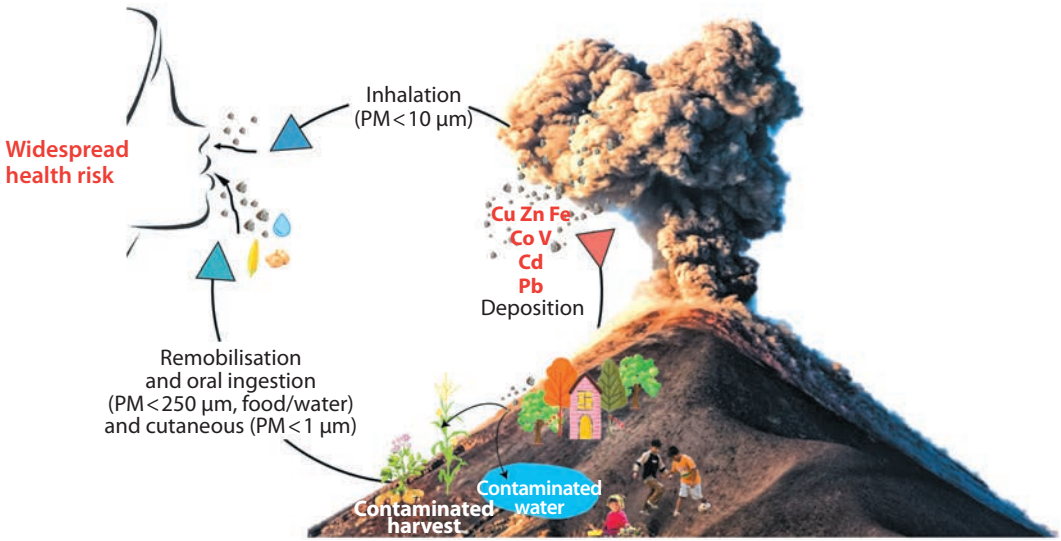
Sauzéat L. *et al.*, 2022 – Metallome deregulation and health-related impacts due to long-term exposure to ground-deposited volcanic ash: new chemical and isotopic insights from la Soufrière de Guadeloupe volcano. *SSRN Electronic Journal* [http://dx.doi.org/10.2139/ssrn.3982115 | 10.2139/ssrn.3982115].

The volcanic environment: balancing benefits and dangers

Soils, and the volcanic environment more generally, offer a range of benefits that contribute to the socioeconomic well-being of local populations. For example, volcanic soils are fertile lands that help to ensure that agriculture flourishes. They are also a rich source of metal deposits (such as gold) that could be mined. The geothermal activity of some volcanoes also provides clean and sustainable energy (for example, green electricity). Volcanic soils are therefore very attractive environments, and more than 800 million people currently live atop them, mostly in developing countries. However, the flip side of all these advantages is that volcanic soils are also rich in certain heavy metals (such as Cu, Zn, Fe, Cd, Mo), which may be harmful if they are in constant contact with our bodies. Metals such as copper (Cu) and zinc (Zn) are involved in the activity of a large number of proteins and enzymes and are common catalytic and structural cofactors in several metabolic pathways of living organisms. These metals are vital to life, but only if their concentration is regulated in the body. In a volcanic setting, metals initially present in the soil can accumulate in the body, not only through food (water and nutrients enriched in metals drawn from the soil), but also through other absorption routes, some of which are still poorly understood (inhalation and oral and cutaneous ingestion of volcanic particulate matter [PM]). This accumulation in the body can lead to major metal homeostatic disturbances and therefore become a major health risk factor. However, not all volcanic soils have the same degree of toxicity, as this depends on their specific physico-chemical properties and on the sociocultural practices of local populations.

Developing an interdisciplinary approach

Understanding the risk from prolonged exposure to metals from volcanic soils requires an integrated scientific understanding of the mechanisms of action and the biological effects induced at the whole-body level. To date, given the complexity of the biological processes and metabolic pathways regulated by metals, our understanding of metal pollution resulting from exposure to volcanic particles and its impact on health is still incomplete. Furthermore, the only studies that have reported a proven causal link between health and direct exposure to volcanic particulate matter (PM) focused on the impact of exposure via inhalation or intratracheal injection of fine particles (PM <10 µm). Although adverse effects on the respiratory and pulmonary tracts have been identified, both the exposure conditions and the biological functions investigated in these studies are restricted, limiting our overall understanding of volcanic risk at the organism level. To assess the dangers of chronic exposure of a population to volcanic particles and to identify the vital functions most affected by this toxicity



The volcanic environment: a complex system with multiple sources of metal contamination.

at the whole-body level, it is now essential to adopt a systemic approach based on interdisciplinary research at the interface between (I) the social sciences (to take into account the socioeconomic factor in health vulnerability) (II) isotope geochemistry (to quantify the toxic potential of volcanic soils and the metallomic imbalances induced at the organism level) and (III) health (to identify the associated physiological dysfunctions and, subsequently, to consider appropriate solutions for promoting the health of the most vulnerable populations).

What if isotopes could take us further?

Until recently, measuring stable isotopes such as copper (Cu), iron (Fe) and zinc (Zn) was used exclusively in the earth sciences to quantify major geological processes. It has now been extended to the medical field. This innovative approach, at the interface between geology and health, has provided a better understanding of the complexity of certain biological processes (such as the body's ageing process, cancers, neurodegenerative diseases) and has

also shown promise for the diagnosis, prognosis and monitoring of a range of liver diseases. Recently, measuring copper and zinc isotope ratios for medical purposes in volcanic environments has also highlighted the potential benefit of using these biomarkers as new diagnostic tools specific to pathophysiological disturbances developing these environments. Although the factors governing these isotopic fractionations still need to be explained, these findings once again highlight the growing interest in using isotopic measurements in medicine and hint at new, post-diagnosis therapeutic avenues aimed at promoting the health of populations most exposed to this volcanic risk.

KEY POINTS

Because soils are enriched with certain metals, ongoing exposure to soils, and volcanic particles in general, poses a real danger to human and animal health. Volcanoes cannot be moved, nor can the 800 million people living on these volcanic lands, but there are potential alternative and sustainable solutions to support the health of these populations. This requires the development of interdisciplinary research to (I) quantify the toxic potential of volcanic soils and (II) identify the biological mechanisms and functions predominantly affected by chronic exposure to volcanic metals. Consideration of these health issues is now essential to support a holistic approach to risk management in volcanic environments.

Supporting sustainability science

Ignacio Palomo,
IRD, UMR IGE,
Grenoble, France

Background

Sustainability science is officially 20 years old. Today, it is a dynamic and growing field that has demonstrated its ability and potential to contribute to solving the challenges of sustainable development. However, for sustainability science to flourish, a change in our scientific culture is needed.

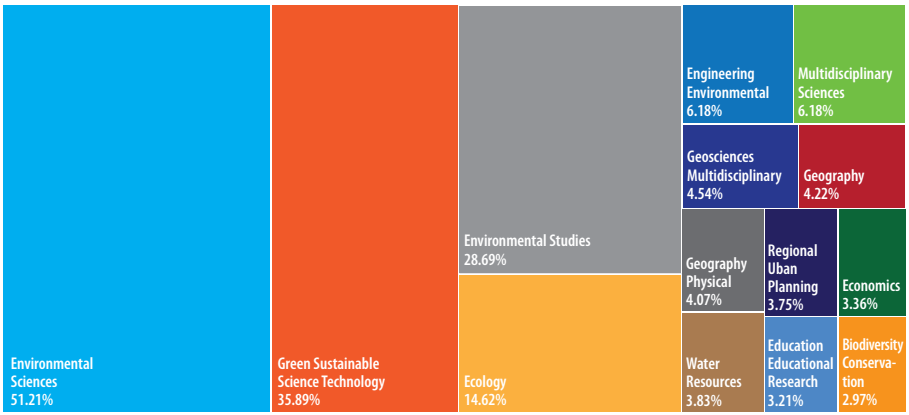
Contact
ignacio.palomo@univ-grenoble-alpes.fr

Further reading

Palomo I., Locatelli B., Otero I., Colloff M., Crouzat E., Cuni-Sanchez A., Lavorel S., 2021 – Assessing nature-based solutions for transformative change. *One Earth*, 4 (5) : 730-741.

Introduction

A landmark moment for science occurred in 2021 with the twentieth anniversary of an article that marked the emergence of a continuously growing discipline: sustainability science (Kates R. W., Clark W. C. et al., 2001 – Sustainability Science, Science, 292: 641-642). Sustainability science is, like agricultural science or health, defined by the subject it addresses: sustainable development. Sustainability science, therefore, seeks to understand the fundamental way in which nature and society interact. As a solution-oriented science, the key attributes of sustainability science, are its engagement with the policy agenda, such as the Sustainable Development Goals (SDGs), interdisciplinarity and transdisciplinarity. The figure below shows the most common disciplines incorporating sustainability science, which is still largely dominated by the environmental sciences, with a smaller contribution from the social sciences and humanities. The rapid rise of sustainability science is evident from the number of publications that explicitly cite it. It is also evident in the long list of university programmes focused on sustainability, the continued growth of the Sustainability Science journal (launched in 2006), and the involvement of the United Nations Educational, Scientific and Cultural Organisation (UNESCO) in multiple programmes on sustainability science. Wikipedia features a list of 126 environmental research institutes from 35 different countries. The Global Sustainable Development Report, created at the Rio+20 conference in 2012 and published every four years, is written by an independent group of scientists appointed by the UN Secretary General. The latest report, published in 2019, assesses progress towards achieving the SDGs.



Percentage of publications on sustainability science across various disciplines.

Advances in sustainability science

Over the past twenty years, sustainability science has demonstrated its ability and potential as a research discipline. One example is the emergence of the concept of ecosystem services or Nature's Contributions to People (NCPs), understood as the direct and indirect contributions of biodiversity and ecosystems to human well-being. They include aspects such as the provision of drinking water or timber by natural ecosystems, the regulation of the climate and water cycle and the pollination of crops, along with the recreational and health benefits of frequent contact with nature. Recognising these contributions is another ethical reason why we need to conserve biodiversity given its intrinsic value. It highlights how our economic system, our health, our well-being, and even our own survival as a species, depend on nature. The emergence of these concepts in the 1990s has given us a better understanding of how human activities that have an impact on nature can ultimately have negative effects on humans. NCPs are not automatically transferred from ecosystems to society but are instead the result of a process of co-production and interaction between societal and ecological systems. The field of ecosystem services is also one of the drivers of the United Nations System of Environmental-Economic Accounting (SEEA), which combines economic and environmental data to provide a more complete picture of the interrelationships between the economy and the environment.

It is also an essential component of Payment for Ecosystem Services (PES) schemes and similar efforts that support biodiversity conservation and human well-being around the world. For this progress to take place, significant advances have been made in interdisciplinary research, and disciplines such as environmental and ecological economics are now well established. Transdisciplinarity and the co-production of knowledge with non-academic stakeholders is also one of sustainability science's long-term goals. Considerable progress has been made, especially through international science and policy initiatives such as the Intergovernmental Panel on Climate Change (IPCC) and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). However, several challenges still need to be met to increase transdisciplinarity in sustainability science.

The challenges and the way forward

Sustainability specialists often struggle to take part in traditional recruitment competitions or to identify funding programmes that are aligned with their work. Without competitions that focus specifically on sustainability science, their research may be viewed by the social sciences as too ecologically oriented and vice versa. Transdisciplinarity may be difficult to achieve for some sustainability science researchers, given the considerable time commitment, the sometimes conflicting motivations (academic development vs. problem solving) and the specific skills needed to be

involved in the decision-making arena. Growing competition in the research and development world for permanent positions, with a need for short-term results and publications, does not foster transdisciplinarity either, as it often takes a long time to develop. This difficulty is compounded by the fact that the research world still places too much emphasis, when recruiting, on the quantity of scientific output rather than on its quality and impact. Some of these challenges can be overcome with a fundamental change in current scientific culture. If sustainability science is going to respond to the major challenges we face, such as the climate emergency and the biodiversity crisis, greater recognition must be given to researchers whose work contributes to solving these challenges. This would require a shift away from the current tendency to measure academic excellence solely in terms of the quantity and quality of published articles.

This paradigm shift, which may seem easy, is in fact a considerable challenge in itself because of how difficult it is to assess the impact of researchers' and academics' work on society or, for example, on environmental management and restoration. For sustainability science to be viable, both the academic or research institutes that drive each institution's own strategy and the research funders must work hand in hand on its core elements: interdisciplinarity and transdisciplinarity. There is a need to assess and value the merits of sustainability science and researchers not through traditional indicators (list of papers published, number of projects, number of students supervised), but through innovative impact indicators. The recent development in France of highlighting the impact of researchers' work in their curricula vitae, emphasising the importance of a limited number of outputs (not only research articles, but also computer programs, videos, protocols and patents), is an important step in this direction.

KEY POINTS

Sustainability science has helped to provide important solutions to environmental challenges such as the climate emergency and the global biodiversity crisis. However, solving these challenges, which are among the most important that humanity has ever faced, requires stronger and more aggressive sustainability science. To achieve this, individual researchers and academic institutions need to embrace a cultural shift in the way we define and measure scientific excellence.

Pathways to supporting sustainable development in the Pacific Ocean

Alexandre Ganachaud,
UMR Legos,
IRD, Toulouse, France
Elisabeth Holland,
University of the South Pacific, Fidji

Background

Exploring the link between researchers and stakeholders is a major challenge in sustainability science. To be able to make informed decisions at the right time, on the right scale and in the right time frame, policymaker and other stakeholders urgently need interfaces that provide easy access to reliable information and data. These tools need to be co-constructed with the people living in this region, as part of a transdisciplinary approach. Designing such an approach is the goal of the PACPATH project, funded under the Belmont Forum Pathways to Sustainability Collaborative Research Action (CRA), which aims to develop pathways to transforming socio-ecological systems for sustainable development in the South Pacific.

Contact
alexandre.ganachaud@ird.fr

Further reading
https://www.youtube.com/watch?v=e4cbvbAAcmU

The ocean and global challenges

The oceans fulfil many vital functions for the Earth system and human societies. Combining conservation and sustainable use of ocean spaces and resources is an urgent challenge. The ocean is the focus of one of the 17 Sustainable Development Goals (SDGs) – SDG 14. The challenge is to transform the way we think about and use the ocean by recognising and involving all relevant knowledge, stakeholders, authorities and institutions. The United Nations Decade of Ocean Science for Sustainable Development (2021-2030) was created to foster participatory and transformative processes for scientists, policymakers, managers and users to work together to increase understanding and improve governance of ocean spaces and ecosystems. Good management of the oceans is essential for the health of the planet, the well-being of societies (especially in the South Pacific) and for achieving SDG 14 and the other SDGs. The quality of the ocean environment is very closely linked to climate change, making it one of the priorities of the next UN Oceans Conference (2022).

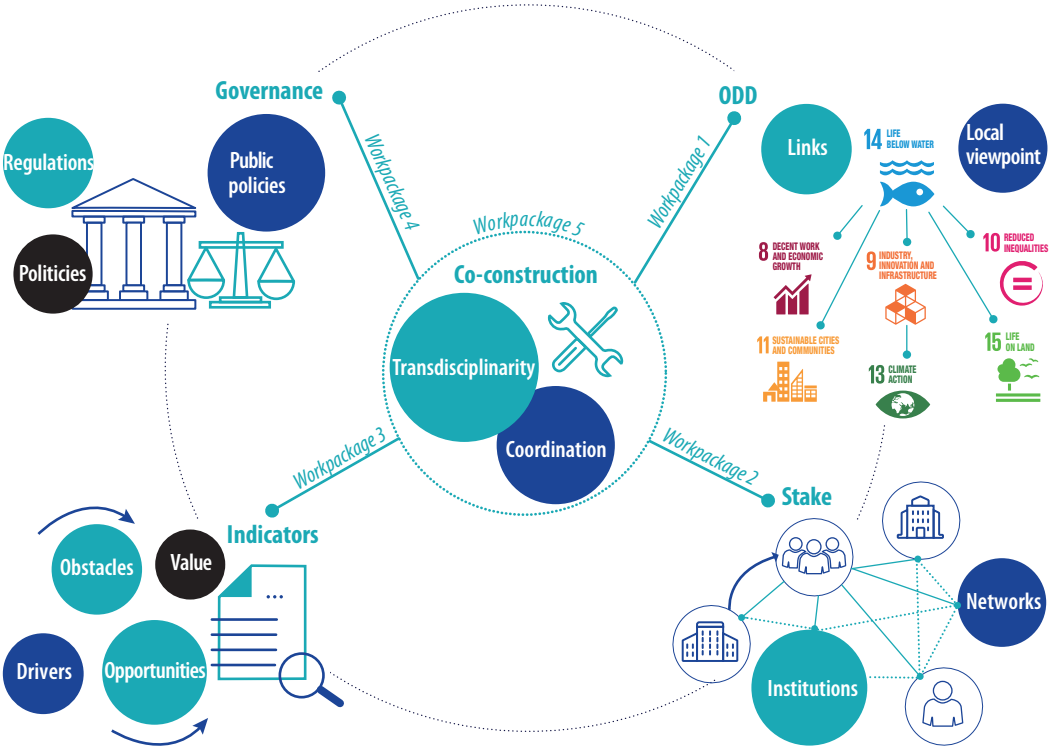
PACPATH's goals

PACPATH aims to establish a network of stakeholders from South Pacific island countries and territories to strengthen a common understanding of the ocean. The goal is to co-design a robust and shared ocean governance strategy based on innovative initiatives and pathways to sustainability. To achieve this, it is assembling an interdisciplinary consortium and targeting pilot sites, including Fiji and New Caledonia. These sites will be used to design the framework and methodology for building a common space for scientists, local socioeconomic stakeholders, civil society organisations, customary authorities and policymakers to co-construct the knowledge and responsibilities needed for decision-making in response to SDG 14. To have the best chance to be translated into effective actions, the development of ocean science and services will be based on a transdisciplinary approach involving regional and local stakeholders. To strengthen the effectiveness of policies and the creation of appropriate indicators, PACPATH will adopt a co-constructed scientific approach, at an appropriately early stage, and will build a knowledge base that includes non-academic and local knowledge. The expectations of the project are: (I) a better shared understanding of the state, variability and change of marine environments; (II) robust strategies for ocean governance and management in the South Pacific; and (III) innovative initiatives to protect coastal environments.

Project organisation

PACPATH is divided into 5 interconnected work packages (WPs). WP 1 will identify how data, science and information can best support sustainable development on regional and local scales ("the ocean's influence on you, and your influence on the ocean"). WP 2 will develop a

mapping of the various networks, stakeholders and relationships related to SDG 14 and other related SDGs, through the use of institutional and governance assessment tools. WP 3 will identify key values, levers, obstacles and opportunities around both the local translation of the SDGs and the feedback of local views, with the aim of improving ownership and integration of relevant information and indicators. Work package 4 will focus on policy making and governance arrangements for the SDGs at regional and national levels. WP 5 will provide all WPs with methods to support the effective participation of all stakeholders in the co-construction of knowledge and actions, and to assess whether key issues, such as social inclusion, equity and gender balance, have been taken into account.



PACPATH's 5 work packages.

PACPATH consortium

The PACPATH consortium brings together 14 organisations: 10 universities and institutes from France, Germany, the United States and the Pacific region: New Caledonia, Cook Islands, Fiji, Kiribati, Nauru, Niue, Republic of the Marshall Islands, Samoa, Solomon Islands, Tokelau, Tonga, Tuvalu and Vanuatu, a regional organisation (the Pacific Community – PC), a private sector company (Mercator Ocean International) and a government department (DIMENC/Coastal Observatory of New Caledonia). PACPATH members are experts in the relationship between ocean, climate and societies, adopting interdisciplinary and transdisciplinary approaches. Their areas of interest and expertise include sea level rise adaptation and resilience (two experts are lead authors of the IPCC Special Report on the Ocean), analysis of the social and economic impacts of climate change, and governance of resources and infrastructure for sustainable development. They also draw on disciplinary approaches such as marine ecology, socio-ecology, anthropology and geography.

KEY POINTS

PACPATH hopes that its pilot sites will reveal how to co-construct interfaces between interdisciplinary and local scientific knowledge, on local and regional scales, to transform the ways in which the ocean's resources are used and looked after (SDG 14 and other related SDGs). For PACPATH, sustainability science and its priority research questions are designed as a network and are deployed in a transdisciplinary manner. This co-construction process aims to develop sustainable development pathways with a wide range of academic and non-academic stakeholders in South Pacific island countries.

Community-based rodent management in African cities

Gauthier Dobigny,
UMR CBGP, Montpellier, France
Soanandrasana Rahelinirina,
IPM/LP, Madagascar
Meheretu Yonas,
Mekelle University, Ethiopia
Karmadine Hima,
Abdou Moumouni University, Niamey, Niger

Background

The current health crisis has put the spotlight back on the need to consider integrated and sustainable approaches to prevent future zoonotic emergences, rather than focusing solely on a response to an epidemic. For this to happen, it is more important than ever to recognise that human health and well-being are intimately linked to the state of biodiversity and the environment ("One Health, Eco Health" approaches). Rodents are a prime example of these complex interactions between health for all, the fight against hunger, sustainable communities and cities, and biodiversity protection. However, our knowledge of methods to reduce the socioeconomic and health impacts of urban rodents is surprisingly incomplete, often leaving people already weakened by chronic poverty and a degraded environment to fend for themselves.

Contact
gauthier.dobigny@ird.fr

Further reading
https://www.ird.fr/attenuation-communautaire-de-defis-lies-aux-rongeurs-en-milieu-urbain-africain

Ladji, one of the intervention sites of the SCARIA project in Cotonou, Benin.

Environmental control of rodent pests

Chemical rodenticides cause both environmental (poisoning of humans and non-target species, for example) and efficacy (increasing resistance) challenges. Ecologically-Based Rodent Management (EBRM) is a sustainable alternative to chemical rodenticides that used a preventive approach: it involves adapting the environment in such a way as to make it unsuitable for rodents to gain a foothold and proliferate. This type of approach is based on sound knowledge of the diversity and ecology of the targeted pests, and requires a good understanding of the extent to which the stakeholders affected by the pests and the associated economic implications are involved. EBRM tends to be community-based, involving the people directly in need. Since the 1990s, EBRM has been tested, developed and evaluated in various rural contexts, most notably in Asia where it now provides practical solutions tailored to local needs. Similar programmes have since been launched in various continental African countries and in Madagascar (for example, the Green Rodent

Control network, run by IRD researchers and their partners). However, attempts to apply EBRM to urban socio-ecosystems are almost non-existent, especially in Africa.

The challenge of rodent management in urban areas

The world is currently experiencing an acceleration of urbanisation, particularly in Asia and Africa, where the pace of urban expansion and/or densification is sometimes so fast that it does not always leave sufficient time for appropriate urban planning. This can result in large, densely populated areas, characterised by substandard housing and a lack of basic services, such as access to drinking water, medical care, education and waste management. These areas suffer from extremely degraded socio-environmental conditions, providing shelter (cluttered and poorly sealed homes, low predation pressure) and food (accessibility of foodstuffs stored in homes, abundant uncontrolled dumping grounds) for the rodents that thrive there. Surveys conducted in Ethiopia, Benin and Niger confirm that significant damage to housing and food stocks is widely reported by slum dwellers. Furthermore, health ecology research shows that rodents in these areas contribute significantly to the risk of infection by being the source of many zoonotic pathogens, some of which have high epidemic potential (for example, hantavirus, Lassa virus, leptospirosis, plague bacilli, typhus agents, etc.). Controlling them is therefore a major economic, food and health issue.

SCARIA, a pilot EBRM project in African cities

The SCARIA project (whose full title is Towards Sustainable Community-Based Mitigation of Rodent Issues in African Cities), funded by the Belmont Forum Pathways to Sustainability programme, aims to tackle the challenge of mitigating rodent impacts in African cities. It is based on identifying and preparing EBRM strategies adapted to the different socio-cultural contexts of four urban sites: Ankasina in Antananarivo (Madagascar), Gamkalley in Niamey (Niger), Hdassie in Mekellé (Ethiopia) and Ladji in Cotonou (Benin). Its first goal is to set up multi-stakeholder working groups bringing together academics, representatives of operational services (such as plant protection services and health services), development organisations (such as humanitarian companies) and communities (such as traditional and religious authorities, community liaisons, non-profit organisations and NGOs). Their combined knowledge and expertise will be used to design EBRM actions that are adapted to local economic and cultural realities. SCARIA's second goal is to define socio-economic, ecological and epidemiological indicators through surveys and field monitoring. These indicators will provide both a baseline of the situation at the start of intervention and valuable tools to assess the effectiveness and sustainable ownership of EBRM by the local people themselves.

Looking beyond the SCARIA project

The SCARIA project deliverables, focused on co-constructing community-based EBRM strategies and defining socio-economic and biomedical indicators, will form the basis for the practical implementation and assessment of EBRM at the four study sites during a second implementation phase (as planned by the Pathways to Sustainability Collaborative Research Action). The feedback gathered from the SCARIA project will also help identify the obstacles and levers and shed light on the commonalities and divergences observed during the EBRM co-construction processes in Benin, Ethiopia, Madagascar and Niger. These results will provide valuable information for the hoped for scaling up of community-based rodent control in deprived urban areas in the Global South.

KEY POINTS

Commensal and peri-commensal rodents are a major obstacle to the economic stability, food security and health of the poorest populations, especially in deprived urban areas where they thrive. Ecologically-Based Rodent Management (EBRM) is a sustainable alternative to the widespread use of rodenticides, but it has rarely been tested and evaluated in cities. The SCARIA project is mainly based on dialogue between disciplines, on the one hand, and on the other, academic, operational and community stakeholders. It aims to implement management strategies in pilot sites in four African cities (Antananarivo, Cotonou, Mekellé and Niamey). It is therefore perfectly suited to a sustainability science approach.

A research partnership for improving sustainability science methodologies

Alexis Drogoul and Jeanne Cottenceau,
IRD representation in Vietnam
Ngoc Doanh Nguyen,
Thuyloi University, Hanoi, Vietnam

Background

Sustainability science still lacks "methodological anchors" that can be used to bring together researchers and societal stakeholders to pursue a shared long-term vision for the sustainable management of socio-environmental systems and explore possible ways of realising this vision. Several digital technologies, based on artificial intelligence, modelling or sensor networks, being studied in connection with the Sustainable Development Goal dedicated to industry, innovation and infrastructure (SDG 9), offer attractive prospects in this respect. The PREMISS project, funded under the Belmont Forum Pathways to Sustainability call, was set up to study and assess how applicable these technologies are.

Contacts
alexis.drogoul@ird.fr
jeanne.cottenceau@ird.fr

Further reading
https://www.youtube.com/watch?v=LhyhylCH8m8

Imagine…

Imagine an engineer adapting a model of an irrigation system to assess the impact that adding dikes would have on the "sustainability index" of the water supply system and the communities that depend on it. Imagine residents discussing with their local council the increase in temperature in several of their neighbourhoods and negotiating the development of green spaces with the help of an interactive tablet combining individual sensor measurements, satellite data and simulation results. Imagine farmers using their local knowledge and data from sensors co-constructed with researchers to compare different types of crops and agree on the best way to optimise their income while conserving natural resources. These situations would have been difficult to imagine ten years ago. Today, although they are within our technological grasp, their use is still in its infancy. This is precisely why the PREMISS project consortium has brought together academic and non-academic partners from South Africa, France, Turkey, Vietnam and Taiwan, with the aim of fostering the co-design and use of these types of digital methods in the sustainable management of complex socio-environmental systems. The modelling, simulation and crowdsourcing methods targeted by the project allow scientists and stakeholders to explore the sustainability of different options or scenarios "before implementation" in the virtual world. Then, once a solution has been successfully implemented, they empower stakeholders to deploy and monitor the chosen options, but also to evaluate their relevance and impacts.

Use of digital technologies and sustainable management of socio-environmental systems

Initially, PREMISS aims to provide as comprehensive an overview as possible of how the above-mentioned digital technologies are used. Two systematic reviews will use a collaborative and transparent process to define the research questions, identify sources, assess their quality and synthesise the results in a qualitative or quantitative way. The reviews will use scientific sources, but will also draw from the grey literature, to identify uses, tools, challenges, gaps and key application areas. The second phase of the project will use data mining to provide a more quantitative analysis. The two scientific articles that will be published will make operational and policy recommendations. These front-end studies will feed into two other objectives presented below.

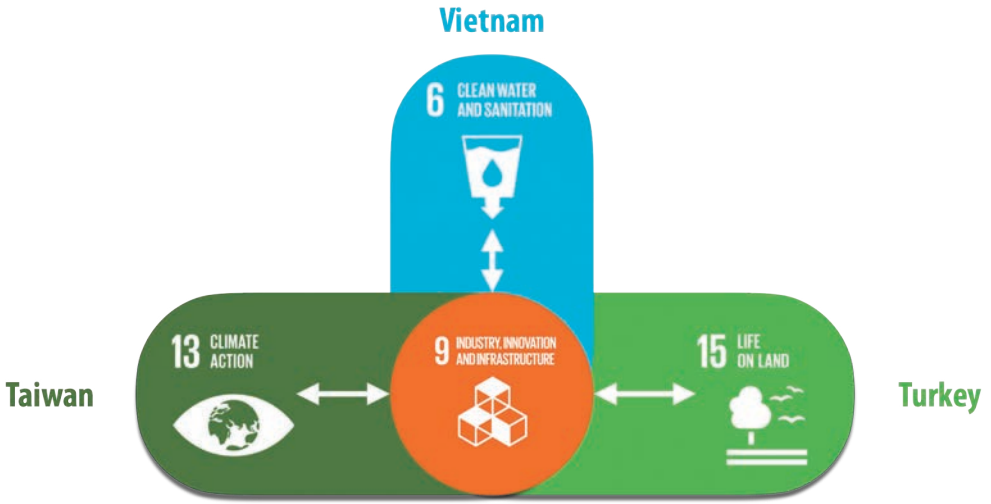
Integration of case studies to identify and test practices and methodologies

Under the leadership of Thuyloi University (Vietnam), this workstream will investigate the effects of the use of sensor and modelling

technologies in three different case studies in Vietnam, Taiwan and Turkey. In the context of the 2030 Agenda, these studies will analyse the interactions between SDG 9 and, respectively, SDG 6 (ensure access to clean water and sanitation for all – Vietnam), 13 (fight against climate change – Taiwan) and 15 (protect and restore terrestrial ecosystems – Turkey). This work will be used to compare methodological innovations, stakeholder involvement and transdisciplinary approaches between case studies from very different socioeconomic and cultural backgrounds, but which are all at the crossroads of several disciplines. It will also be an opportunity to test in real life some of the methodological proposals discussed in the systematic reviews on the use of digital technologies.

An academic book and methodology guide for sustainability science

Among its contributions to the sustainability science research community, the consortium plans to produce an academic book and a methodology guide based on the research processes of all its partners. The academic book will be a collection of papers from the research carried out during the project on the use of technological innovations in the sustainable management of complex socio-environmental systems. The methodology guide will provide support to other researchers also implementing "computer-assisted" transdisciplinarity,



The three nexuses targeted by the PREMISS case studies.

based on the methods and results of the case studies. The outputs of the PREMISS project will feed into several other projects developed in Vietnam, including those of the ACROSS (Advanced Computational Research for Sustainability Science) international joint laboratory. The deliverables will be shared within the Pathways Community of Practice, which encompasses all the winning projects of the Belmont Forum Pathways to Sustainability call, but also with local partners and through IRD's Knowledge Communities.

KEY POINTS

The PREMISS project was prompted by our lack of knowledge of the effects and impacts of technological innovations on the implementation of transdisciplinarity in the sustainable management of complex socio-environmental systems. The added value of this project will lie in the publication of an academic book and a methodology guide proposing practical solutions for implementing these new approaches within the framework of sustainability science. The recommendations developed can be used to support projects that place digital technologies at the heart of their approaches, thereby providing the first steps towards a long-term methodological framework for sustainability science.

Artisanal fisheries through the lens of the Sustainable Development Goals

Rodolphe Devillers,
UMR Espace-Dev, La Réunion
Esther Fondo,
Institut KMFRI, Monbasa, Kenya

Background

Artisanal fisheries are the lifeblood of coastal societies in the Global South, providing jobs and food for millions of people. Despite their importance at the interface of many Sustainable Development Goals (SDGs), these fisheries are still relatively unknown and are often marginalised by public policies that favour industrial fisheries. These fisheries are more difficult to manage and also more likely to develop in an unsustainable manner. The field of artisanal fisheries has been the subject of many studies in both the natural & fisheries sciences as well as social sciences. However, few studies have attempted to marry the two communities to pave the way for more holistic studies that promote the sustainability of these activities in wider socio-ecosystems.

Contact
rodolphe.devillers@ird.fr

Further reading

FAO, 2015 – *Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication.*

Artisanal fisheries: a complex issue

For a long time, studying the sustainability of fisheries has been confined to assessments of exploited fish stocks, encouraging the extraction of fish resources below the permitted limits to ensure that fish stocks can recover. However, both in terms of ecosystems – under pressure from factors other than fishing, such as climate change or the destruction of important habitats – and socioeconomically, small-scale fisheries are part of complex socio-ecosystems, on which their sustainability depends. Truly sustainable fisheries management requires a better understanding of the complex relationships between the various components of the system, whether it be the health of the ecosystems, how they adapt to natural and anthropogenic pressures, the fishing activity itself and the investment needed to carry it out, the economy of the fisheries and the income it generates for the various stakeholders, or how the fisheries are used for personal consumption and the nutritional value they provide. For example, should fishing quotas in a given context simply be reduced to preserve stocks over the long term? Or, conversely, should they be increased to increase employment and ensure food security? Is it a good idea to subsidise the industry to encourage access to more remote fishing grounds? These seemingly simple questions reveal complex underlying mechanisms with multiple implications in which sustainability issues appear to be multi-criteria.

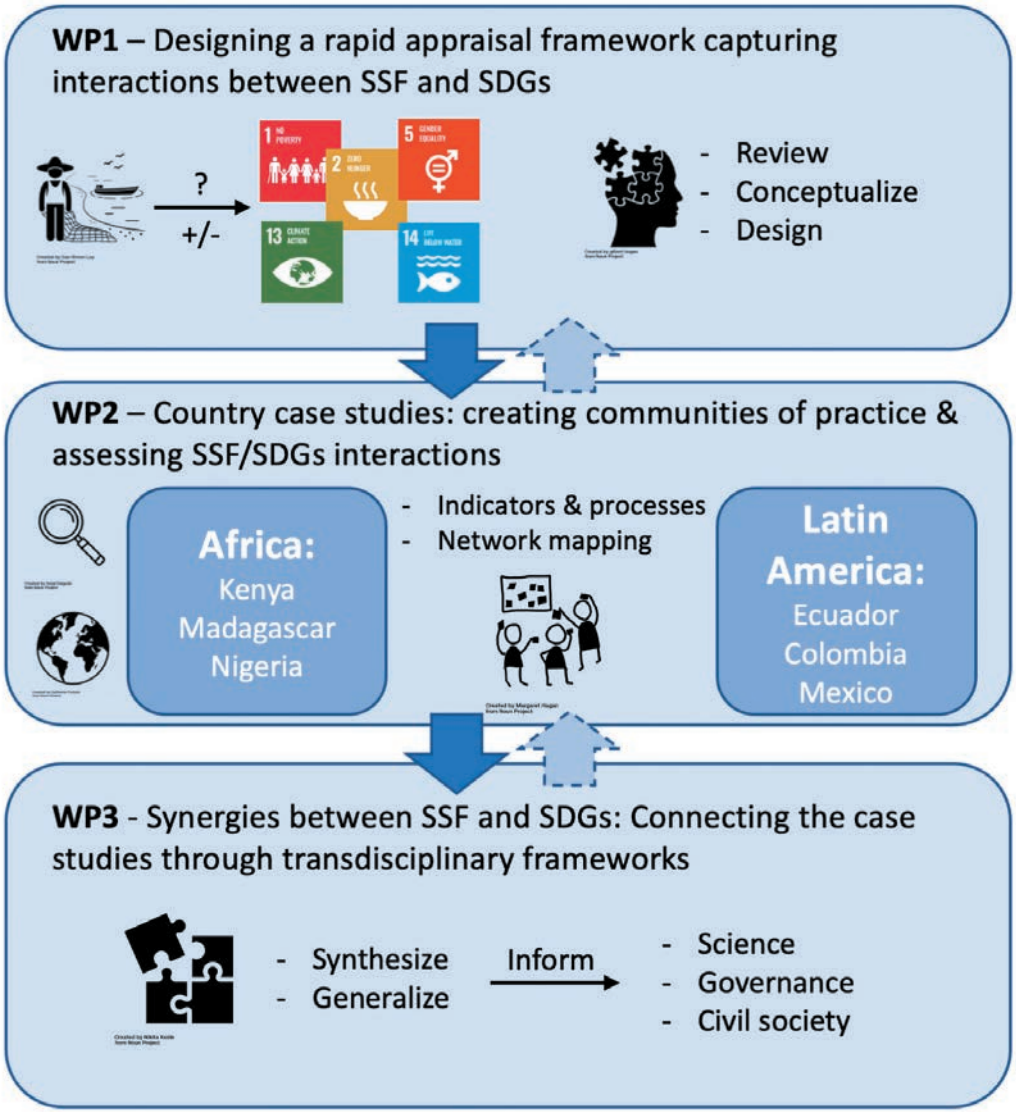
The angle of sustainability science

The approaches proposed by sustainability science seem particularly appropriate in this context. A general analysis of these socio-ecosystems can certainly provide a better understanding of the positive and negative interactions between the components involved in artisanal fisheries. These components can be mapped onto the SDGs and their indicators to ensure that specific actions aimed at supporting certain SDGs do not unnecessarily penalise other important SDGs.

Fish2Sustainability project

The Fish2Sustainability project (Pathways to Sustainability, Belmont Forum, 2021) focuses on Small-Scale Fisheries (SSF) and involves more than 30 researchers from 12 different countries. This highly interdisciplinary group includes experts from the social sciences (e.g. environmental economists, gender specialists, political scientists, geographers, sociologists), the natural sciences (e.g. marine ecologists, fisheries scientists and climate scientists) and the data sciences (e.g. geomatics and open data specialists). These experts include scientists, but also representatives of governments, the United Nations and non-governmental organisations (NGOs).

The group also collaborates with more than 15 partner organisations in the six countries studied, thereby reaching out to a variety communities involved in fisheries and their



Organisation of the Fish2Sustainability project.
SSF: Small-Scale Fisheries; SDG: Sustainable Development Goals.

governance. Together, these stakeholders are coordinating their actions across three main work packages (WPs): designing an approach (WP1), testing it with partners in three African and three Latin American countries (WP2), and building knowledge that can inform decisions (WP3).

KEY POINTS

Sustainability issues in artisanal fisheries raise very complex problems with multiple ramifications that extend well beyond issues of fishery resource sustainability alone. Lying at the crossroads between natural and social systems, these issues lend themselves well to sustainability science approaches, which study the causal relationships between components of complex socio-ecosystems. The Fish2Sustainability project aims to develop and test methods for formalising these relationships to provide a more meaningful analysis of a given study context and suggest ways to improve the sustainability of these fisheries and the socio-ecosystems that depend on them.

Socio-ecological coviability as a response to the planetary emergency

Olivier Barrière, David Williamson,
IRD, UMR Espace-Dev, Montpellier, France
Olivier Hamant,
Inrae, France
Zakinet Dangbet,
University of N'Djamena, Chad

Background

The collapse of biodiversity, climate change, health crises: the ecological emergency is forcing modern societies to adapt and, more importantly, to transform in order to survive. The question is *how* to achieve not just an "ecological transition", but also a real metamorphosis so that we can remain viable and have a future. The Sustainable Development Goals propose a lane change, a different way of living on Earth, by reconnecting to the biosphere. Should we therefore pursue a process of "development" or instead opt for a future state of "viability" for the sustainability of human societies?

Contacts
coviability@gmail.com
olivier.barriere@ird.fr

Further reading

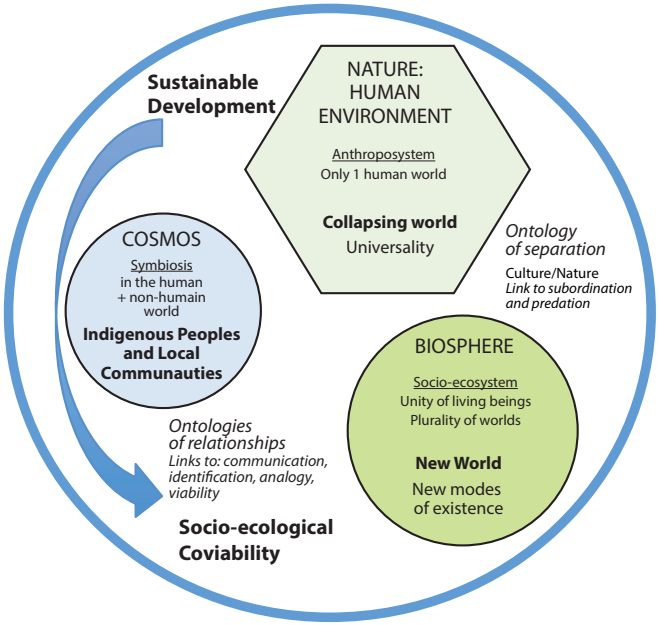
Barrière O. *et al.*, 2019 – *Coviability of social and ecological systems*. Springer, 2 vol.

From development issue to sustainability issue

The finiteness of the planet's resources has led us to envisage another form of economy, one that is no longer based on continuous growth and development, but on the ability to adapt, or become resilient, to the expected and ongoing effects of disruptions to ecosystems (violent climatic conditions, land degradation, pollution, artificialisation, etc.). Sustainability is the ability of an entity to live and survive, but it is important to specify that this must happen in a state of well-being (social and in terms of personal physical and mental health) and even happiness. The viability of any system, human or non-human, depends on other systems that surround it to a greater or lesser extent. Viability is therefore only possible through coviability, both for human societies and for the rest of the living world. Socio-ecological coviability is therefore best understood as interdependence between humans and non-human species, characterised by a close relationship involving its regulations and constraints. This relationship creates a viability link that depends on co-evolution in an integrated socio-ecological system (Barrière *et al.*, 2019). Coviability therefore focuses on the spaces and thresholds of viability. It acknowledges the importance of the relationship between humans and non-humans to achieve joint viability, which translates into a sustainable mode of existence. In this respect, coviability is intimately linked to the challenges of sustainability science.

Being part of the biosphere

The ecological emergency is driving modern societies to rethink their relationships with other living creatures by thinking in terms of socio-ecosystems. Human diversity generates a variety of ways of living and existing in the world. Modern societies have invented the concept of "nature" on the grounds of a rational approach that separates humans from non-humans. The challenge is to move away from the idea of nature – a truly artificial construct – as a mode of existence based on the separation of living things, and to move towards relationship-based modes of existence between humans and non-humans: the future of humans is now intimately linked to non-humans. One obstacle to overcoming this lies in the globalised liberal economy, which provides a relationship of appropriation of living things that is characterised by "capitalisation" (leading to the concept of "nature capital"). The most obvious example is land, which has been transformed into a commodity by the property ownership system. The concept of "nature" clearly demonstrates the duality: modern societies separate themselves from other living things on the basis of supposed supremacy that justifies a relationship of subordination and predation. Breaking out of this paradigm, or at least creating a hybrid version of it, requires us to enter another dimension (ontological relationships with non-human species: ways of being and existing), as exemplified by indigenous peoples or certain local communities.



The transition from the human environment (nature) to the biosphere (the living) requires relationships to be formed.

Three pillars of socio-ecological coviability

1. Coviability is structured around three elements that underpin its materiality: interdependence between humans and non-humans, underperformance and local territoriality.

2. Ecological solidarity: achieving interdependence. The idea of mutual dependence crosses the human social space to reach an ecological dimension. This was introduced into French law in 2006 and 2016, for example, through the concept of functional connectivity between habitats and species, defined by the interactions within living organisms. The interdependence of human societies with ecosystems reflects a joint viability and a "reliance" between humans and non-human species.

3. Sub-optimisation: restricting performance. Living beings are not optimal, they are sub-optimal. Optimisation is detrimental because it reduces pathways to a narrow range, thereby limiting the ability for adaptation and even resilience. Living systems can bypass difficulties because they always operate in a dynamic

state, exploring possibilities. The evolution of living creatures did not select performance as a continuous state, but as an exceptional one: for example, the rise in body temperature for the immune system to function at full capacity before returning to its suboptimal norm. By contrast, evolution did select the ability to survive environmental fluctuations and to transform oneself – if conditions demand it – with two "weaknesses", randomness and redundancy, which cancel each other out.

4. Resettlement: giving ourselves a future. The local territory is a key factor in the ability to adapt to climate change and to deal with the ecological and social emergency. The implementation of land stewardship, a form of empowerment by territorial stakeholders, can transform the relationship that social groups have with their living environments through being involved in their future as part of a contributory democracy.

The operationalisation of coviability: a territorial pact formalising a coviable existence project

Coviability can be achieved through local regulation, endogenous to the territory. The CovPath project (Pathways to Sustainability, Belmont Forum, 2021) proposes implementing this concept of socio-ecological coviability by starting with local stakeholders (populations, managers, policymakers, etc.) in eight biosphere reserves on four continents. The project plans to prepare a guide on the human and non-human interactions that define coviability. This work will lay the foundations and prospects for extrapolating this new pathway towards sustainability, firstly by developing a methodology for the co-constructed and participatory implementation of this pathway and, secondly, by setting up a system of governance (management and regulation) of natural resources.

KEY POINTS

Socio-ecological coviability is thought of in terms of socio-ecosystems: the viability of the human system is intimately linked to that of non-human species. The challenge is to determine "what constitutes coviability" and "what is not coviable". We start with sustainability science using empirical research. There is a clear need to identify the interaction networks, to understand their emergent properties, to extract the thresholds of viability with constraints and regulations. The operationality of an implementation of coviability requires investing in action research through experimenting with "coviability pacts" on a territorial scale to achieve ecological transformation through territorial stewardship.

Towards sustainable hydropower generation in West Africa

Arona Diedhiou,
IRD, Grenoble-Alpes University, Grenoble, France
Kouassi Lazare Kouakou,
Jean-Lorougnon-Guédé University, Daloa, Côte d'Ivoire

Background

Hydropower is a major component of the current and future renewable energy mix, helping to limit CO_2 emissions into the atmosphere and thus reduce the climate impact of energy generation. While the construction of large dams has declined in Western Europe and North America, it is still booming in many emerging countries, particularly in Africa. Rising to the challenge of sustainable hydropower management involves looking closely at problems of interdependence between various social, economic and environmental factors, and at the many conflicts of objectives and interests that pose complex dilemmas. In an attempt to resolve these, new transdisciplinary approaches have emerged in recent years, co-constructed between users and scientists within the framework of sustainability science..

Contact
arona.diedhiou@ird.fr

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Hydropower and climate change in Africa

Hydropower generation is the largest source of renewable electricity in the world and accounts for over half of all electricity generation in West Africa. The relationship between hydropower and climate is twofold. Firstly, hydropower has the potential to contribute to climate change mitigation through low or zero greenhouse gas emissions. Secondly, hydropower generation is impacted by climate change through disruption of the water cycle. West Africa has been impacted by the negative effects of global change, particularly in terms of the intensity and frequency of extreme weather events such as drought and floods. These events have affected many key sectors (such as water resources for agriculture or energy demand, generation and supply) and threaten countries' efforts to contribute to achieving the Sustainable Development Goals. An important challenge for West Africa is to gain a better understanding of the specific link between climate, water, energy and land use, and this must also factor in the countries' socio-oeconomic development scenarios. One of the main obstacles to making decisions to pursue sustainable hydropower generation pathways is that climate projections are uncertain and most studies on future land-use change do not address the issue of the relationship between water and energy for development.

Kpong hydroelectric dam (Ghana).

SUSTAINDAM

The SUSTAINDAM project (Pathways to Sustainability, Belmont Forum, 2021) aims to support the sustainable management and planning of hydropower generation in West Africa in the context of climate uncertainty and land-use change. The goal of the project is to build communities of practice that promote climate resilience and environmentally friendly solutions. SUSTAINDAM brings together stakeholders in hydropower generation, local policymakers, civil society representatives and women's market gardening associations to work together to address challenges and find synergies and trade-offs for the sustainable management and planning of hydropower generation. In particular, the project investigates the link between SDG 13 (climate), 6 (water) and 7 (energy) and the positive effects on SDG 15 (land) and 17 (partnership). SUSTAINDAM proposes a comparative study involving different decision support tools in four pilot sites in West Africa (Ghana, Senegal, Burkina Faso and Côte d'Ivoire) with different climatic and socioeconomic contexts. The project aims to provide a comprehensive description of the conditions that support sustainable development in the face of climate uncertainty. Sharing and joint learning between the case studies are an important goal of the project over the course of its implementation. It also aims to promote the use of decision support tools based on multidisciplinary data that are already available or will be acquired. Another goal is to train stakeholders to use these tools so that they can then work with them and apply their knowledge in the pilot sites. The aim is to provide flood risk management models, scenario-based impact models for use in dam operation and maintenance, socio-economic indicators, and maps of changes in land use and land cover.

Initial results

The preliminary results of modelling work on the impacts of climate change on power generation at the Kossou hydroelectric dam (Côte d'Ivoire) show that, on a monthly scale, the hydropower generated will be lower during the period 2030-2050 compared with the period 1980-2005, irrespective of the climate scenario used. Furthermore, simulations that take into account the effects of climate change, land use and socio-economic developments (increased water demand for irrigation, livestock, etc.) predict a decrease in hydropower generation from the Nangbéto (operational) and Adjarala (planned) dams in the Mono river basin (Togo, Benin). This decrease is even more pronounced as the demand for water from a wide variety of users increases. However, the impacts of land cover dynamics in the catchment area (reduction of vegetation and growth of developed areas) on runoff and water availability for dam generation could also affect output from the models and need to be better understood. Furthermore, land cover dynamics are associated with

water erosion processes and increased sediment transport that could be detrimental to the efficient operation of hydropower plants. These results show the need for an integrated approach to the various environmental and socio-economic components associated with hydropower generation. To address this, a crucial challenge for SUSTAINDAM is to incorporate the wide range of stakeholders involved in the different water uses and to use empirical data and simulations to identify the links between local uses and global changes.

KEY POINTS

A good understanding of the climate-water-land-energy nexus is crucial for the sustainable management and planning of hydroelectric dam generation in West Africa. There is a need to better understand the feedback loops between land-use changes (especially from urbanisation and agricultural intensification along rivers), regional climate and runoff processes, and water flows and how these will change in the future for sustainable development in Africa.


TAHUATA

CO-CONSTRUCT

Sustainability science promotes the co-construction of knowledge and practices, based on collaboration between scientists from different disciplines (interdisciplinarity) and non-academic stakeholders (transdisciplinarity), in a participatory and engaged approach. For research and development stakeholders, interdisciplinarity, transdisciplinarity and engagement are not imposed, but emerge from the professional background, attitude, reflexivity and curiosity of each individual. This section presents texts on the concepts of engagement (through the prism of the history of science and philosophy), interdisciplinarity (as seen by two research directors and a young researcher) and transdisciplinarity (including it in calls for projects, where to think about it and how to put it into practice).

Sustainability science, a more engaged science?

Frédéric Thomas,
UMR Sens, IRD, Montpellier, France

Background

Since it emerged in the early 2000s, the leitmotif of sustainability science has been to reorganise science in a way that makes it work for sustainable development by going beyond disciplinary boundaries and focusing on solution-driven research programmes. This approach is an implicit criticism of "conventional" science, which cannot or can no longer respond to the environmental emergencies of our time, because it is not pragmatic enough or engaged enough. Sustainability science therefore reflects a desire to break with our past ways of doing science. Through its analysis of the seminal article by Kates *et al.* (*Science*, 2001), this article examines the background to this break and what this engagement involves.

Contact
frederic.thomas@ird.fr

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Science, scientists, sustainability and environmental emergencies

The first in-depth considerations on the unsustainability of infinite growth date back to the Meadows Report (1972). In the 1980s, the OECD and the UN reformulated this observation in a less critical form in the Brundtland Report, also known as Our Common Future (1987). This marked the birth of the concept of "sustainable development". Since then, numerous scientific groups have regularly published alarming reports on the state of the planet, pointing out that they do not have the power to change the course of events. Scientists are therefore increasingly asking themselves how they can put science to use in transitioning to more sustainable models of production and consumption. In other words, they are questioning their relationship with action, with collective action, in a word with politics.

Answers from sustainability science

In this context, sustainability science has emerged as a way of providing answers to scientists. It suggests that they simply change the way they do science. The article by R. W. Kates and his colleagues in Science in 2001 is a good example. It is a landmark article (cited more than 4,000 times in the Web of Science) that encourages research to study nature/society dynamics by integrating them into models of complex interactions between the Earth system, human development and sustainability,


Le Monde

Le cri d'alarme de 15 000 scientifiques pour sauver la planète

IL SERA BIENTÔT TROP TARD...

The alarm call from 15,000 scientists to save the planet, reported on the front page of the French daily *Le Monde* on 24 November 2017 (World Scientists' Warning to Humanity: A Second Notice, *BioScience*, 2017).

with special attention given to consumption and population growth. In this endeavour, it urges researchers to explore issues of "risk", "vulnerability" and "resilience", and to define, based on scientific evidence, "limits" or "boundaries" beyond which the balance of our socio-ecosystems could be irreversibly tipped. Lastly, it assigns the social, economic and political sciences the role of seeking better "incentive systems" (among which the authors highlight the importance of "markets") to "improve as effectively as possible the social capacity to steer the interactions between nature and society towards more sustainable pathways". The article also severely criticises current social and environmental policies along with monitoring and observation systems for socio-ecosystems, which it claims are

not coordinated enough to be effective. It proposes replacing them with incentive systems that are integrative (developed by looking at the interactions between a variety of complex systems), which in turn must be non-binding to be effective. Sustainability science defined in this way is clearly a departure from "normal science", meaning science based on strong disciplinary paradigms and involving an entire community to avoid overarching research questions. However, sustainability science is a continuation of the old concept of "sustainable development" since, as we can see, this article does not in any way challenge growth and is fully in line with the neoliberal critique of overly coercive social and environmental policies. This raises serious doubts about whether it is revolutionary, and even whether it is counter-revolutionary (a backlash against scientists' warnings), just as the Heidelberg Appeal was in its time against political ecology and the rights of indigenous peoples at the time of the Rio Earth Summit.

Participatory and transformative approaches to sustainability science

To limit sustainability science to this agenda, however, would be unfair and reductive. In the last 20 years, sustainability science has developed into a dynamic field that has branched out in many different and often fruitful directions. In addition to the sciences of complex systems, sustainability science has a genuine interest in participatory mechanisms for co-constructing research with non-academic stakeholders that provides efficient answers to their resource governance problems (Ostrom, 2007). Sustainability science also encourages researchers to engage in socially transformative processes by stepping outside their strictly disciplinary practices to support civic engagement (Jäger, 2006). For historians and sociologists of science, who have long been committed to demonstrating that science is dependent on social issues and that it brings scientists together across disciplinary boundaries (Jasanoff, 1986), sustainability science may seem a little amateurish on these subjects; but for many scientists, it opens up new research perspectives. The fact that sustainability science affords research the platform to expand its engagement with society and produce knowledge for sustainability and the transition to more sustainable models is therefore an opportunity not to be squandered. This is particularly the case for IRD, which is tasked with the co-production of knowledge with partners in the Global South and the application of this knowledge in the field. Fully embracing sustainability science could, for example, encourage more researchers to analyse their work's impact pathways, to pursue true interdisciplinarity, particularly between the hard and social sciences, to rethink the boundaries and substance of their disciplines, to shake up academic conservatism, provided that they preserve the disciplinary knowledge and know-how without which interdisciplinarity and cooperation are an empty basket. Ultimately, the merits of sustainability science

lie in its ability to push the envelope, inviting researchers to step out of their comfort zones, move beyond their communities and even rethink the confines of their disciplines.

KEY POINTS

Is sustainability science something that IRD is doing? Yes, of course, it goes without saying. We have been putting it into practice for a while now, given that our missions involve co-constructing research programmes with our partners in the Global South (mainly with scientists, but not exclusively) aimed at answering their development questions and sustainability challenges, and supporting them in turning our joint results into practical applications. Are we part of the sustainability science movement? Certainly, if we avoid being naïve and we distance ourselves from certain articles that reduce sustainability science to a science that supports the transition of socio-ecosystems and the resilience of societies by abandoning any transformation of our own production methods. Rather than just being part of it, it would be better to embrace it so that we can more effectively address the challenges of the Anthropocene.

Sustainability science and philosophy: avenues for cross-fertilisation

Ludovic Cocogne,
International and European Relations Directorate,
IRD, Marseille, France

"While it seems natural to separate and maintain a healthy distance between science and philosophy, two very different ways of questioning the world, do they not have touchpoints in the very fabric of ideas?"

E. Klein (2021)

Background

There is a complex relationship between philosophy and science, involving both complementary and conflicting aspects, in that they both attempt to understand the world and find the truth, and they both eschew myth and common sense. This relationship assumes different forms in different historical periods, fields of study and systems of thought. Sustainability science is, more than any other field, ontologically linked to philosophy, since it tries to answer two of philosophy's founding questions: What can I know? What should I do? Which knowledge for which action? It is therefore desirable to lay the foundations for theoretical and practical dialogue around the cognitive and ethical concepts of sustainability. A recent article by Michuru Nagatsu, a philosopher at the *Helsinki Institute of Sustainability Science*, invites us to do so and outlines a number of avenues for moving forward together.

Contact
ludovic.cocogne@ird.fr

Further reading

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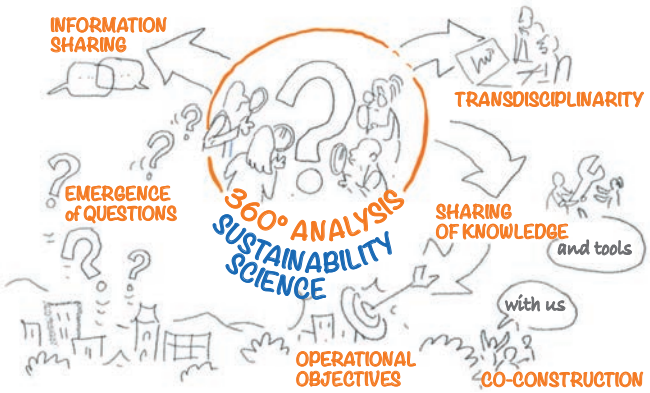
Philosophy, science and sustainability science

In the absence of a universally accepted clear definition, sustainability science can be defined as a science that seeks analytical and practical solutions to promote sustainable development. It is transdisciplinary and co-constructed, and requires public policy stakeholders and others in society to participate in a process of transformation and break down thematic, academic and geographical barriers. To establish itself as robust and credible, sustainability science has a natural rapport with epistemology, the philosophy of knowledge and analytical philosophy, through its contributions to the analysis of utterances, language and logic. However, as a science ontologically associated with practices of social transformation, it has an updated and potentially broader relationship with moral and political philosophy, without being related exclusively to particular systems or schools. Nagatsu *et al.* (2020) outline some of the avenues of collaboration and areas of partnership where the use of philosophy can accompany the development of sustainability science, strengthening its internal cohesion and explanatory power, giving it the ability to respond to objections, resolve certain ambiguities and clarify its stance on some of the issues it faces.

Epistemological and methodological issues

A methodological challenge for sustainability science is the shared obligation to produce knowledge that is both epistemically sound and practically usable, even when the prerequisites for cognitive correctness and action effectiveness may differ. Sustainability scientists have thus begun to discuss a



Main features of sustainability science (drawing by Lison Bernet).

range of methodological issues, including the transferability of transdisciplinary case study-based knowledge and the integration of scientific and non-scientific evidence and knowledge (for example, local knowledge and indigenous knowledge). Contexts also need to be analysed in detail to see if they can be compared sufficiently to justify an analogical, inductive approach through extrapolation and results transfer. There is therefore a need for methodological innovations that involve transgressing current epistemic norms and standards within disciplines by setting specific objectives, focused on the challenges of sustainability. Epistemological issues arise from the interactions between disciplines and the way in which the disciplinary structure of science supports the development of interdisciplinarity and transdisciplinarity. Transdisciplinarity is usually approached as a variant of interdisciplinarity, requiring that integrative interactions involve more stakeholders from outside academia. However, the role that disciplinary knowledge and methods play should not be overlooked. How does the emphasis on practical impact – for example, solution-oriented work carried out with non-academic partners – affect the reliability of the knowledge produced? Is there a trade-off between the immediate acquisition of applicable knowledge and the long-term development of general theoretical knowledge, which may later prove valuable in unexpected areas (e.g. evolutionary game theory)? It is important to work out answers to these questions collaboratively.

The question of values

Separating the world of facts from the world of values, the empirical from the normative, the "is" from the "ought", forms a traditional boundary between science and morality. Even though this Kantian or positivist dichotomy has been tempered, especially by the work of the philosopher Hilary Putnam, scientists are expected to confine themselves to the first of these realms and not to encourage any blurring between them. However, the 2030 Agenda is not axiologically neutral. It promotes a model of society in which certain choices are explicit (equality, gender, governance, poverty, etc.), while others are implicit and produce norms and behaviours (the Green Sustainable Development Goals, in particular). Some researchers and indeed some institutions working on sustainability advocate engagement with society, to develop interventions that make the world a fairer, more sustainable place. Although the ethics of science, according to the sociologist Robert Merton, include universalism, organised scepticism, disinterestedness and communalism, they do not suggest that value judgements should be rejected. In any case, "what to look for", "where to look" and "why look" are not "value-free" questions. Philosopher Heather Douglas insists that, for sustainability science to be successful, it is crucial to explain how certain values, including the ethical values of sustainability scientists, can legitimately be part of the research produced, and to design methods and institutions capable of counteracting the biases that

values can produce (in terms of objectivity or the questions asked for example). Exposing implicit values and negotiating between them is an essential task in sustainability research, one that must be taken into account if we are to avoid "blurring the lines" between passing on knowledge and promoting our own worldview or interests. The need for axiological neutrality in scientific research must be combined with the recognition of scientists' legitimacy to participate in society and in shaping the world.

KEY POINTS

It is important to work on researchers' reflexivity and how much they question their own practice. How are epistemic, ethical values from different disciplines integrated into integrative, concrete scientific practices? We need to engage more fully with these new and evolving practices, such as experimentation and action research with explicit ethical commitments, and develop relevant evaluation tools. This requires more constructive interactions between philosophers and sustainability scientists, including joint research, and a critical interchange point to stimulate productive interactions between the two communities.

Promoting socio-hydrological interdisciplinarity

J. Riaux (IRD), S. Massuel (IRD),
A-L. Collard (INRAE) and M. Kuper (CIRAD),
SocioHydro Team, UMR G-Eau, Montpellier, France

Background

Water is both a feature of the landscape and a potential resource. Water builds alliances and creates conflicts, and the way it is shared and used links together various conceptions of the relationship that humans have with their environment. Water requires us to connect – and sometimes to confront – different visions of the world and its future. Building sustainable relationships between societies and water, between water and societies, requires us to negotiate compromises, which are never perfect. The role of research in this scenario is to provide the many stakeholders involved in water with the knowledge they need to understand these social, political and environmental issues. Water is therefore a powerful vector of interdisciplinarity. After all, how can we understand and support the social challenges of water without providing insight into its physical characteristics and vice versa? The SocioHydro team of the UMR G-Eau is committed to meeting this challenge by building, step by step, an interdisciplinary "socio-hydrological" practice.

Contact
jeanne.riaux@ird.fr

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Fieldwork at the heart of the interdisciplinary relationship

As we know, genuine dialogue between social and natural sciences is never easy, for reasons as diverse as epistemological differences and the way in which each discipline constructs its objects, its research questions and how they are answered. There are also differences in the way researchers approach their subject, with some seeking to be neutral and others seeking to be subjective. The wide range of pitfalls is matched by a wide range of practices that help to overcome the difficulties inherent in this dialogue.

The SocioHydro team's interdisciplinary dialogue really began with a research experiment in Tunisia, during which researchers in hydrological sciences and social sciences worked together over a long period on the same site: the Kairouan plain, the site of a vast aquifer, whose increasing exploitation raises a number of questions, in terms of both hydrogeology and anthropology. Several researchers, posted together in Tunis, built a research programme aimed at developing collective responses to the physical and social challenges of understanding this "resource". The dialogue was organised during collective field missions, through experimentation with the working methods of the disciplines involved, discussions on practices, on the assumptions made by each researcher and on their respective ethics. Exposing the inner workings of disciplines gives us an insight into what they are based on, what their limits are and, by the same token, how the complement other disciplines. New research questions are then formulated, resulting from combining the views of the disciplines involved. In our case, the first step was to examine the history of the exploitation of the Kairouan aquifer and to understand why over-exploitation has become a red flag for the various stakeholders involved.

Listening to the field and its stakeholders

Interdisciplinary work provides the opportunity to construct new questions rooted in concrete situations and focused on the concerns of those working in the field. When it comes to shaping interdisciplinary research, researchers cannot blindly accept research questions that only work for their discipline, such as honing a data processing method or examining the foundations of a conceptual approach. Our experience in Tunisia has taught us that research questions shared by the researchers involved are built around issues that arise in the field and are defined by the conflicting viewpoints of water stakeholders on a specific situation. This is the case with the observation of "over-exploitation" of groundwater in Kairouan or "under-exploitation" of water in the small dams in the hills of Kairouan.

Very often, these conflicting viewpoints are the result of imbalances in knowledge, which researchers need to rebalance. This may involve making previously unheard viewpoints heard, as is often the case with local knowledge on water. In other cases, it may involve identifying and/or

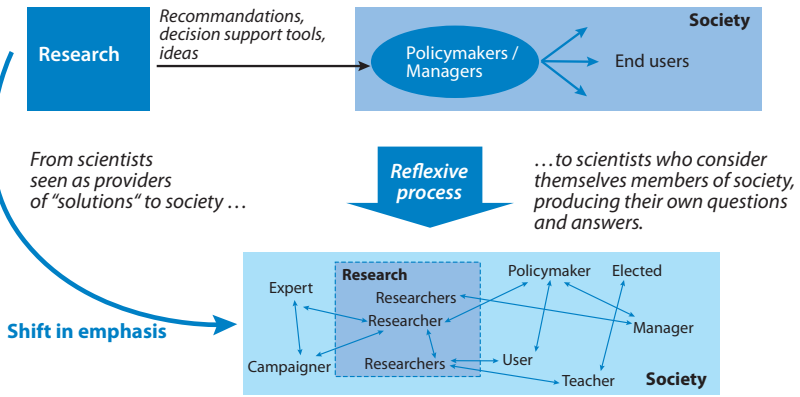
fulfilling certain knowledge needs expressed by water stakeholders by producing new data and analyses. Sometimes it involves highlighting and encouraging water stakeholders to question the conflicting viewpoints they convey through their own discourse on water.

Thinking about the role of research in society

While working on the viewpoints that various stakeholders hold on the exploitation of the Kairouan aquifer, we wondered about the way in which researchers see their role vis-à-vis society. This question was discussed at a workshop led by the NAILA International Joint Laboratory (LMI NAILA – Water resource management in rural areas) entitled "What is the purpose of water research in Tunisia today?" (Tunis, 2018). Based on this deliberately provocative question, the LMI researchers explored how they view and carry out dialogue with society. This helped us to make a shift in emphasis from talking about the usefulness of research to thinking about the functions of research in society (see figure below). Reflexivity on the part of the researcher is thus one of the essential outcomes of interdisciplinary dialogue.

Developing instruments for reflexivity

Fostering a collective reflexive process appears to be central to the success of interdisciplinary dialogue. The SocioHydro team is exploring several aspects of this goal. The first is sharing experiences from the field. The aim is to promote interdisciplinary research on the same field, but also discussion among those involved in these experiences. Interdisciplinary dialogue can, for example, take place



The reflective process as a product of interdisciplinary dialogue.

between researchers working on the same hydraulic objects (hill dams, irrigation canals, etc.), but in different contexts or with different questions. The second is interdisciplinary writing. This involves encouraging several participants to write articles, thereby combining several field experiences, while at the same time reflecting on the writing practices specific to the disciplines concerned and on what these practices mean for the message being conveyed. Finally, the third component, which makes the first two possible, is creating and maintaining discussion and "breathing" spaces that are always open and welcoming, where researchers from the natural and social sciences spend time discussing, exchanging viewpoints and listening together. Setting up these opportunities for sharing experiences and information provides a framework for interaction that has been carefully thought out in advance of the meetings (workshops, seminars, meetings), so that everyone taking part feels comfortable. This is essential if they are to overcome the reticence and discomfort inherent in interdisciplinary dialogue and express themselves freely.

KEY POINTS

What we now call "sustainability sciences" takes a wide variety of forms and covers – and sometimes conceals – a wide variety of scientific practices. At IRD, experience in the field, working in partnership and spending long periods of time working together on our projects have resulted in a unique way of interacting with the natural and social sciences. The balanced dialogue between researchers from different disciplinary backgrounds encourages them to pay attention to what is happening in the field and to the people involved, examining the variety of viewpoints on water and the impact on sustainability issues. This is the objective of the socio-hydrological approach adopted in various locations in West Africa, South-East Asia, the Maghreb and France.

Ethnoecology through the lens of sustainability science

Stéphanie Carrière,
UMR Sens,
IRD, Montpellier, France

Background

Today, social and environmental problems are challenges that are often intertwined, sometimes making them inextricable. Understanding them and analysing their ins and outs to identify solutions undoubtedly requires the implementation of multidisciplinary, or even interdisciplinary, research programmes. The use of interdisciplinarity to address these issues is in itself a major challenge that an increasing number of researchers are focusing on, even though they may find it easier to design and plan than to implement successfully and effectively. Sustainability science is one of the emerging research areas that is already grappling with this. Some of the more longstanding, traditional interfacing disciplines, such as ethnoscience, are less well recognised in this field, but have questions, themes and methods that deserve to be highlighted, not only in terms of how they converge, but also in terms of how they contrast or indeed disagree.

Contact
stephanie.carriere@ird.fr

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Hanspach et al., 2020 – Biocultural approaches to sustainability: A systematic review of the scientific literature. *Nature and People*, 2 : 643-659.

What is the interdisciplinary science of ethnoecology?

Ethnoecology studies the so-called biocultural interactions (cognitive, sensitive and practical dimensions) between humans and their local environment: inventories of knowledge and expertise on how a contemporary society works, the experience of humans in their environment, representations of the world and how it is organised, the needs of populations, assessing the possibilities for feeding, clothing and caring for oneself that the environment provides, characterising the effects of lifestyles on ecosystems, and evaluating the sustainability of a socio-ecological system. Like sustainability science (SS), it is essentially an interdisciplinary approach (social sciences and humanities (SSH), life and Earth sciences), which, depending on the situation, draws on disciplines from SSH, such as linguistics, anthropology, law, history, geography, sociology, musicology, and from the life and Earth sciences (ecology, biology, botany, pedology, agronomy, climatology), and sometimes even from data and model sciences, genetics, nutrition and medical sciences. Ethnoecology is an area where multiple collaborations take place, requiring a strong interest in scientific otherness and a marked preference for dialogue and interdisciplinary sharing. The mixed intellectual approach is by turns monographic, inductive and iterative (from SSH) and hypothetical-deductive (from life and Earth sciences). It specifically combines a dose of scientific theory (Western vision), a measure of local knowledge from the ethnosciences (a set of local conceptions and viewpoints) and, finally, the observation of the raw facts (which are often distinct from the discourse and viewpoints). This combination of knowledge and biocultural values provides a solid foundation for the co-construction of projects, solutions and indicators with local stakeholders and populations, in the same way that SS does. Ethnoecologists (as in SS) must become familiar with the different groups of stakeholders (populations, NGOs, policymakers, managers, etc.) and understand the different global processes involved at each of the scales of socio-ecological systems. They do this through their research topics and questions, which are designed to identify the problems affecting populations and their impacts on the environment (and, through a retroactive effect, on the populations themselves). The topics aim, for example, to understand the causes and consequences of competing access to land and resources, the development, sustainability and acceptability of practices in response to social and environmental changes, and the fast-paced dynamics of local knowledge.

Forging a strong stance

Practising ethnoecology in the field helps forge a strong professional and ethical stance, which has several objectives. Firstly, ethnoecologists strive to remain neutral in a given situation. They then consider the plurality of viewpoints without passing judgement on the knowledge, practices or logic of the stakeholders. They must understand without interfering, just as anthropologists do. It is not particularly desirable to

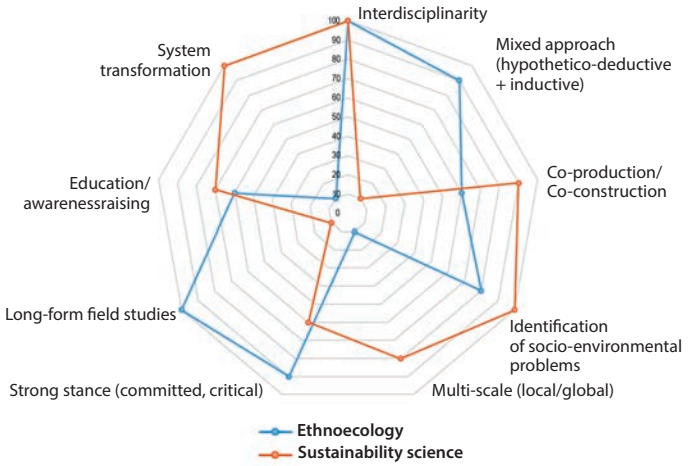
try to drive transitions, unlike SS does. Furthermore, a strong partnership is essential, and this is achieved through ongoing dialogue with academic and non-academic stakeholders, but without taking over their roles and remits, particularly with regard to finding solutions to problems in their territories. Lastly, ethnoecology aims to study and combine local knowledge and know-how with that which complements researchers' knowledge. This helps develop a co-constructed understanding of these systems and of the bio-cultural processes they support. In this way, and without in any way minimising the importance of environmental issues – in particular deforestation, which I study – the ethnoecologist tries to provide a scientifically supported counterpoint (for example, by researching practices that have positive effects on the dynamics of biodiversity), which SS rarely does, to balance an often stereotypical discourse on tropical family farming. This stance is far from being neutral. Instead, it is fully adopted and even becomes a commitment. Objectivity exists and is shaped by a reflective and collective approach. The ethnoecologist's concrete action lies in the detailed description, analysis and written representation of a system and its social, ecological or economic sustainability, of a practice, of values or of knowledge that is eminently evolving, just as one would do to relate a piece of history.

Thinking outside the box

In my view, it is inappropriate in the practice of ethnoecology to separate facts from norms, politics from science, the sensitive from the cognitive. Ethnoecologists prefer a more integrative, interdisciplinary, politically aware and even critical analysis of the political, socioeconomic and personal contexts in which questions, data, scientific analyses and dominant discourses on environmental issues emerge (rarely seen in SS). If we are to consider how and where the results of science can be used to raise awareness or educate society about the issues that drive us, we need to feed the scientific and societal debate with reliable data, as SS does, but, as we do in ethnoecology, we also need to find ways of using innovative and even sensitive media. For example, we have previously organised drawing workshops for children. The purpose of these workshops was to analyse children's representations and knowledge of nature, but also to foster interactions between various stakeholders (children, parents, teachers, donors, policymakers, media) on controversial issues or processes, such as deforestation. This work demonstrated that drawing could be used to create forums for dialogue that foster science-society interactions, similar to those proposed in SS.

Potential cross-fertilisation

There are many similarities between sustainability science and ethnoecology: inter/transdisciplinarity, co-production of knowledge, identification of socio-environmental problems, education and awareness-raising. However, they differ in a number of other areas.
Ethnoecology provides detailed knowledge of local systems, acquired through long-term field



Schematic and comparative representation of the respective emphasis of ethnoecology and sustainability science.

research (several months to several years) and conducted through immersion with local populations. SS does very little of this: it is more concerned with finding short- or medium-term solutions. In its most traditional practice, however, it refrains from proposing or encouraging transitions or even transformations, even when local stakeholders want them. Lastly, ethnoecology, like SS, is well versed in interdisciplinary work and the wide variety of approaches and tools used. Bridging the gap between the two fields, through dialogue, respect and experience sharing, should not, on the face of it, cause too much discomfort.

KEY POINTS

Ethnoecology is a traditional, multidisciplinary and interface discipline. Its origins, background and development have transformed it into a disciplinary field that is evolving alongside more recent approaches, such as sustainability science, whose own objectives are highly complementary.

Agrobiodiversity and sustainability: a collaborative approach

Adeline Barnaud, Cécile Berthouly-Salazar, Jean-Louis Pham, Yves Vigouroux,
IRD, UMR Diade, Montpellier, France
Frédérique Jankowski,
CIRAD, UMR Sens, Montpellier, France

Background

Ensuring food and nutrition security of populations in the face of climate change will be one of the greatest challenges in the years to come. Increasing attention is being paid to agrobiodiversity and agro-ecological practices as a pathway to resilience and sustainability of agricultural and food systems. This requires a greater focus on ecological and social processes in agrosystems, but also a greater consideration of the views and values held by agrarian communities, leading to more just and equitable sustainable agriculture. But how can we co-construct these pathways?

Contact
adeline.barnaud@ird.fr

Further reading

Heras M., Tàbara J. D., 2014 – Let's play transformations! Performative methods for sustainability. *Sustainability Science*, 9 : 379-398.

Perspectives on agrobiodiversity from the natural and social sciences

Plant agrobiodiversity – on which the livelihood strategies of small-scale farmers have been based since domestication over 12,000 years ago – is the result of processes linking agrarian societies, crops and their environment. Agrarian societies have played and still play a key role in creating and managing this biodiversity. Through their practices such as naming, selecting and circulating seeds, they have shaped agrobiodiversity to suit different environmental conditions, different cropping systems and their own cultural preferences. But more recently, research, the seed industry and agricultural policies have had an impact on the diversity of plants grown by farmers and their access to seeds. Apart from its functional and cultural roles, agrobiodiversity has an economic and political aspect and raises issues around food and seed sovereignty and farmers' rights.

Revamping partnership research practices

With smallholders managing 83% of the world's farms, producing between 30% and 53% of all calories, and conserving far more agrobiodiversity, it is clear that these agrarian communities are key partners in achieving new and ambitious goals for sustainable agriculture. This requires the co-construction of multi-partner collaborative research frameworks and moving from a community of researchers to a community of research. Involving new stakeholders in research projects is a challenge for everyone involved, both scientists and farmers. These challenges are linked to the plurality of issues and sometimes divergent interests, to the historical relationships between stakeholders, to the production of knowledge and the ways in which it is leveraged (FAIR database, co-publication), to project time frames, and to the lack of adequate institutional frameworks for collaborative approaches with non-institutional stakeholders. Overcoming these challenges to revamp our partnership research practices requires inventive means to engage and stimulate collective intelligence.

Arts and science through the lens of sustainability science

The last decade has seen renewed interest in the role of the arts in the natural sciences. There is a wide range of artistic approaches useful to science, including photography, drawing, writing, dance and theatre. These approaches bring in new elements – including emotions, beliefs and aesthetics – that can be used when observing and interpreting the world around us and when co-producing new knowledge with society. One of these approaches is forum theatre, a medium that fosters reflexivity and encourages individual, collective and institutional transformations. Forum theatre was devised by Augusto Boal in the 1970s to discuss situations of tension, intentional or otherwise, between a variety

of stakeholders, and has four stages: (I) creation of a play inspired by real events, depicting tension between various characters; (II) performance of the play to an "interested" audience; (III) at the end of the performance, a moderator invites the audience to share their feelings and interpretations of the play and the actions of the characters; (IV) having become "spectators", the audience is then invited to take the stage to explore together alternative ways of dealing with the tension depicted. The forum theatre format of action/reflection/action lends itself well to this collective exploration through reflexivity, experimental embodiment and emotional experience.

Showcasing research practices and collaborations on genetic resources: *TIRPAA ma graine*

The play *TIRPAA ma graine*[1] ("Don't mess with my seed") allowed us to explore the issues of agrobiodiversity governance and fair and equitable research practices with a variety of stakeholders (scientists, farmers, NGOs, policymakers, funding bodies, etc.). The play was written by researchers from various disciplines and backgrounds, and scripted by a professional Senegalese forum theatre group, the KadduYaraax, who introduced a range of artistic, scenic and aesthetic techniques. The play portrays

Performance of the play *TIRPAA ma graine* in Djimini, Senegal, as part of the 2018 International Farmers' See Fair.

various characters: an expatriate researcher, a national researcher, farmers and a gene bank. These characters are caricatures, as is typical of forum theatre. Caricatures are a good way to provoke reactions and make power relations, tensions or issues explicit to a wide audience.
The first scene deals with the communication issues between researchers and farmers during seed collection. The second scene highlights the many values and identity dimensions that farmers attach to seeds. The third and fourth scenes examine the national and international frameworks that govern the circulation of seeds in relation to the collaborative practices of researchers and farmers and the (non)recognition of local knowledge. The fifth and final scene raises the issue of intellectual property

1 • The title of the play is a play on the French words "Tire pas" (here meaning "Don't mess with") and "TIRPAA", the French acronym for the *International Treaty on Plant Genetic Resources for Food and Agriculture*.

rights and making good use of research findings at the individual, collective and institutional levels.

By addressing these different aspects in front of a variety of audiences (research institutions, farmers' fairs, etc.), forum theatre was deployed as a research method to identify the injustice felt by different groups and the conditions for developing more just and equitable agrobiodiversity research and governance practices from the viewpoint of the various stakeholders. This was only possible through close collaboration between the biological sciences and the social sciences and humanities. Forum theatre also provides a way of reaching and engaging with audiences beyond our research communities by opening up spaces for dialogue between science and society. Appealing to an audience's emotions and personal experience improves our understanding of the issues at stake and is a first step in engaging society in the issue of shared governance for the common good provided by agrobiodiversity.

KEY POINTS

Agrobiodiversity is one of the tools available to co-construct, with indigenous peoples and local communities, agricultural pathways that strike a balance between productivity, human well-being, biodiversity conservation and adaptation to climate change. Performative approaches like forum theatre provide fertile ground for environmental action research. These open innovation mechanisms support the co-construction of agricultural practices and research frameworks that reflect the diversity of issues and value systems encountered in a multi-partner collaborative research context.

Transdisciplinarity "Around 2°C"

Thierry Lebel,
UMR IGE, Grenoble, France

Background

The climate change issue is being raised in a growing number of calls for tenders, to such an extent that an ever-larger proportion of researchers are being encouraged to adopt a position in this thematic field, the boundaries of which are constantly expanding. Initially the preserve of physicists, research on the climate issue now involves life sciences and social sciences and humanities. This cross-cutting approach calls for investment in systemic and transdisciplinary science. At the same time, many researchers are examining their civic engagement and the need to improve the relationship between science and society. In response to these needs, the "Around 2°C" summer school combines training and dialogue on the emergence of this systemic and engaged science.

Contact
thierry.lebel@ird.fr

Further reading

MATHY *et al.*, 2021 – Les enjeux de l'interdisciplinarité de la recherche et des parcours de formation sur le changement climatique : l'école d'été « Autour du 2° C ». *Natures Sciences Sociétés*, 29 (1) : 68-76.

Strengthening systemic approaches in the French community

In 2015, at the many conferences and speeches held in the run-up to COP21, climate physicists began to stress the need for scientists to go beyond just warning of the looming climate emergency, encapsulated in the symbolic 2°C threshold. It is true that the planet's habitability will be drastically altered in the event of significant warming, but this warming will be accompanied by a whole series of environmental disturbances, the mechanisms or effects of which interact with the dynamics of climate change. Understanding how the different facets of global change interact requires systemic visions and approaches. However, two workshops organised by the French National Committee on Global Change with the French authors who contributed to the three cross-cutting reports of the IPCC's Sixth Assessment Report have revealed a lack of input from the French community on these systemic approaches. We are therefore faced with a particular need within the French academic community to encourage and strengthen systemic research on climate change mitigation and adaptation, over and above very generic scientific issues.

"Around 2°C" summer school

The "Around 2°C" summer school was instigated by Grenoble-based researchers from various thematic backgrounds who were aware of the wealth of questions raised by the climate issue in various disciplinary fields, but also of the wide range of approaches used by these communities. The title "Around 2°C" was intended to make it clear that the climate issue was the core focus of the summer school, while emphasising that all aspects of this issue must be considered. The week-long summer school, supported mainly by CNRS, INRAE and IRD, brought together a very varied spectrum of scientists of all ages and from a wide range of disciplines, leading to some very lively debates, particularly on mitigation and adaptation strategies and on the limits and unthought-ofs associated with the "solutions" they give rise to. They also led to an awareness of the lack of integration between certain issues (e.g. the effects of agricultural practices on climate on the one hand and on the quality of the environment on the other). The programme was structured into four stages:

1. The mutual knowledge stage requires each participant to give a 180-second presentation on their research problem and motivation for enrolling in the school. This provides a broad overview of the current issues facing different communities and ensures that everyone has the opportunity to speak.
2. The ex cathedra presentations provide an opportunity to identify the knowledge, questions and uncertainties of different research communities. These presentations often focus on "macro" issues (general circulation models, socio-economic trajectories, integrated assessment models), but also try to change the scale of analysis by looking at local

issues (the question of the survival of snow-based activities in medium-altitude mountain resorts, or the impact of short supply chains or organic food on greenhouse gas emissions, for example).

3. Working in sub-groups is at the heart of the summer school's transdisciplinary approach. The aim is to encourage group-based cross-disciplinary learning by breaking down barriers and discussing ways of co-constructing scientific problems or dealing with questions posed by society to scientists. To do this, groups are formed, each reflecting a cross-section of disciplines, and work on formulating scientific questions in a manner similar to preparing a call for tenders (French National Research Agency or European model). Then, different groups work on how they plan to respond to these calls for tenders, reformulating the questions if necessary if one discipline considers that they are not relevant from its own perspective.

4. The round tables are usually held on the last two days, after the participants have had time to get to know each other and are more willing to engage in discussion. The round tables provide a much-needed insight into the relationship between science and society and the position of researchers. In 2021, the closing round table brought together a member of the French High Council on Climate, two women from the Citizens' Convention for Climate and an elected regional official for an enlightening and fascinating discussion on the need to rely on scientists to help steer mitigation and adaptation policies and the difficulties this entails.

Conscious of the issues surrounding the relationship between science and society

During round-table discussions attended by elected officials and members of the public, the scientists realised that policymakers, who are unfamiliar with the scientific investigation process, are more likely to be looking for immediate expertise to solve their problems of adapting to climate change than for systemic insights that will help them understand and deal with the root cause of the problem, in other words, how to mitigate global warming itself. These meetings, in a setting free of power struggles or representation issues, provide a forum for addressing key issues that are increasingly shaping the thinking in laboratories: the gap between government rhetoric on the climate emergency (or the loss of biodiversity or environmental degradation more generally) and their actual response; the observation that researchers' words carry little weight when their discoveries run counter to socio-economic or electoral interests; the emergence of societies where people more readily listen to an expert rather than to someone who questions the world, and where belief takes precedence over reason; the existence of deep-seated divergences of interest, value hierarchies and practices within society, which often carry more weight than rational arguments based on facts. When confronted with the sometimes contradictory expectations of their interlocutors, it is not always easy for scientists to clearly identify how far they can

simplify the formulation of knowledge, its limits and uncertainties to draw attention to the societal implications of their discoveries, thereby turning them into de facto whistleblowers.
While they are fully aware that they need to keep knowledge away from being exploited by certain groups of people, many scientists are now claiming that, when the results of their research have such far-reaching and immediate implications, strict neutrality is no longer an option in environmental sciences. The summer school has also helped to revitalise the dialogue between scientists and policymakers by generating various follow-on initiatives: researchers' residencies in rural communities, involvement in local referendums, participation in the operational committee of the Grenoble-Alpes Metropole Citizens' Climate Convention, which starts in January 2022, and the formation of a political ecology workshop in the Paris region, bringing together academic and social stakeholders.

KEY POINTS

Compartmentalised in their disciplinary silos and facing the competitive pressure of responding to calls for tenders and from an increasingly bureaucratic research organisation, it is difficult for scientists to find any breathing space to reflect on the major changes required to carry out systemic studies on multi-factorial environmental issues. The "Around 2°C" summer school provides a week-long opportunity for transdisciplinary thinking and practice, helping to break down barriers and encourage risk-taking. The sense of urgency to do something that really transcends pure science has been clear at each year's summer school, and the resulting commitment of many participants shows how motivating this type of experience is, where discussion is more important than the top-down passing on of knowledge.

The World Water Forum: who discusses what and how?

Matthieu Blanchard et François Molle,
UMR G-Eau, Montpellier, France

Background

Sustainability science not only involves the practice of inter-disciplinarity but must also serve as a way of integrating – or at least a way of confronting – different points of view, world-views or ways of knowing. This should lead to knowledge production that is richer in plural values and, ultimately, to more inclusive and better accepted decision-making. For example, the wide variety of issues surrounding water are partly shaped within epistemic communities, but also at times when these communities intersect and interact. The World Water Forums (WWFs) are key events in this regard. However, on the eve of the ninth WWF in Dakar in 2022, the content of the debates in these forums is still relatively unexplored.

Contact
francois.molle@ird.fr

Further reading

Blanchard M., 2021 – *Les Forums mondiaux de l'eau parviennent-ils à exposer la diversité du monde de l'eau ?* Mémoire du Master Eau, université de Montpellier.

The unmissable World Water Forums

Water is crucial to our societies and our environment, and the number of major international water events continues to increase. Jointly organised by the World Water Council (WWC) – based in Marseille – and a host city, the World Water Forums are defined by the WWC as events that bring together "participants from all levels and fields, including politics, multilateral institutions, academia, civil society and the private sector" (WWC, 2021). They combine a series of thematic sessions and various "processes" (regional, parliamentary, ministerial, etc.) with an exhibition area hosting the pavilions of various countries or organisations. They have been held every three years since 1997 and are attended by between 15,000 and 30,000 people from around 170 countries, although the vast majority of participants are from the host country. The sheer scale of WWFs and the variety of topics discussed and people attending make each one an essential meeting of the "world of water". But how much networking, learning and consensus do WWFs really stimulate? Do attendees really talk about everything? How do they decide who is going to talk, about what and in which format? What mechanisms, intentionally or otherwise, create exclusion or facilitate inclusion? Some of the answers to these questions are given below, based on a study conducted in 2021.

Benefits and stated criticisms

WWFs can be used as a reference point to keep track of how water concepts and issues develop. Attendees can learn about new issues and expand their knowledge. But first and foremost, WWFs are just like any "trade fair": a unique opportunity to make new contacts and network with a wide range of stakeholders. However, the forums have been criticised for their disproportionately high cost, a lack of quantifiable results, sanitised messages, a lack of continuity (the feeling of "starting from scratch" each time), how they overlap with other events, such as the Stockholm or Singapore Water Weeks, and lastly their failure to obtain commitments from governments, given the absence of any link with the United Nations.

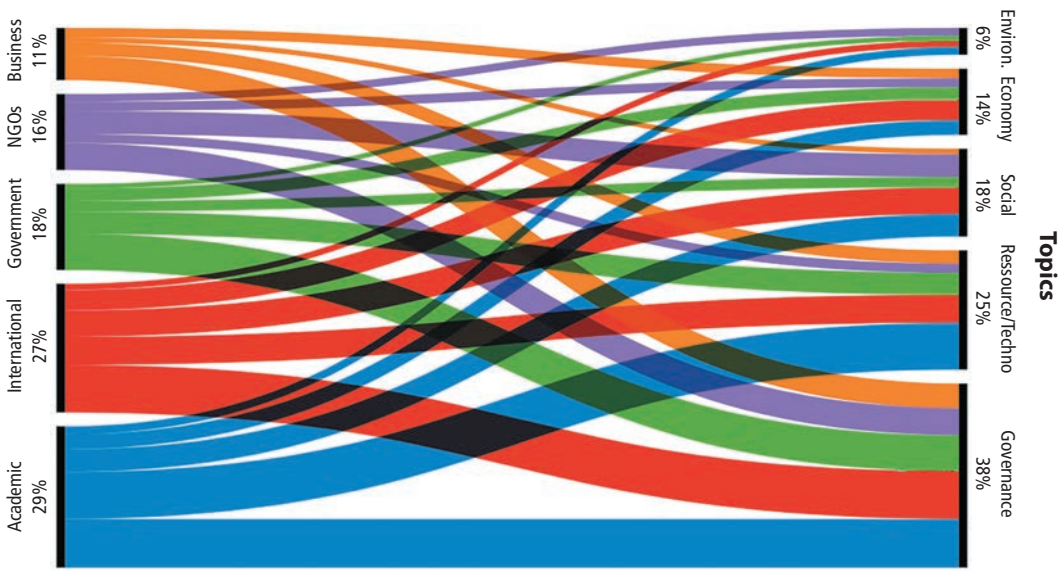
From structural constraints to inclusion

Increasing the number of sessions and topics does not necessarily mean that different sensitivities or worldviews will be represented. The topics and sessions, and also their coordinators, are defined during the preparatory process launched by a kick-off meeting two years before the forum. Attending numerous meetings and being involved in the coordination and organisation requires a lot of resources in terms of time and funding. Ultimately, organisations that have the necessary resources, knowledge of the system and an

interest in setting the agenda tend to dominate the process. As a consequence, civil society gets involved mainly through NGO platforms or coalitions (such as the "Butterfly Effect"), whose objective is more about visibility of causes and advocacy than about global or targeted protest. In addition to these constraints, the language barrier and the host country's shifting attitude towards civil society also influence citizen participation at the WWF.

Referring to an "international water community" and a search for consensus does not disguise the fact that international organisations (UN, professional associations, banks, etc.), a highly standardised format of expression and an "authorised language" (in Bourdieu's terms) dominate the debates, ruling out certain ways of seeing or thinking.

In fact, NGOs that disagree the most with the mainstream recommendations that WWFs tend to produce generally choose not to attend and/or contribute to the Alternative World Water Forum. This strategy combines the intention not to endorse the WWF's messages with the aim of gaining greater media coverage. It is most often adopted by citizen or alternative organisations, while international NGOs, such as IUCN or Wetlands International, along with international or state bodies, are more concerned with publicising their work and proving their relevance to the WWF



The WWF session coordinators and the topics they cover.

or the world of water. The most divisive issues are urban water services and their privatisation, dams and transboundary management.

A lack of legitimacy?

The WWC's legitimacy in bringing people together and its capacity for inclusion seem to be weakened by its internal governance structure. The election of the 35 members of the Board of Governors leads to coalitions prepared in advance by the mass co-option of organisations: the 12 countries with the largest number of members include seven of the eight countries that have already organised the WWF. France has had five governors (the maximum) since the WWC was founded, reinforcing the impression that the organisation is dominated by France and, for some, by the major French water companies. Some countries such as Canada, Germany and the UK have little or no representation. WWC's business model, based on the shared income from the WWFs and sponsors, relegates it to an organisational role, and its ambition to become a think-tank, for example, has not materialised. All these factors mean that WWC and its Board of Governors struggle to reflect the world of water as a whole and suffer from a lack of legitimacy, particularly in parts of the English-speaking world.

KEY POINTS

The World Water Forums, organised by the World Water Council and a host country every three years, are important meetings for the world of water. Despite the WWC's determination to secure broad participation from civil society, there are still many barriers to balanced debate. The organisational dominance of certain mainstream stakeholders who share a common vision, the level of resources required to participate in the process, and the lack of legitimacy of the WWC at the international level tend to limit the scope of the WWFs and the diversity of views and key messages that they generate. Addressing these limitations would improve the fairness of the multi-stakeholder discussions that take place at the WWFs, thereby strengthening a shared vision for water resource management.

"Pathways" at the heart of a transdisciplinary community of practices

Claire Fréour and Olivier Dangles,
IRD Directorate for Science, Marseille, France

Background

If humanity is to achieve the Sustainable Development Goals (SDGs), there is a need to identify clear pathways towards a just and equitable society within the limits of the Earth system. These pathways need to take many different aspects into account: environmental limits, the sustainability of dietary patterns, the potential for technological and social innovation and diffusion, the need for strong governance bodies, etc. In this context, there is a clear need to build innovative and transdisciplinary research projects. It is only by including these aspects that they can provide the best solutions to global challenges.

Contact
d2s@ird.fr

Further reading
https://www.belmontforum.org/cras/#pathways2020

Pathways to Sustainability

As an international partnership to fund research on environmental change, the Belmont Forum is taking the lead through Collaborative Research Actions (CRAs). The Pathways to Sustainability CRA and its first call for projects launched in July 2020 supports a collaborative research network of around 13 projects lasting one to two years. These projects focus on qualitative and/or quantitative approaches to developing transformation pathways for socio-ecological systems in support of sustainable development. In a break with traditional calls for projects that directly fund the research activities of established (and supposedly already operational) consortia, the Pathways to Sustainability initiative intends to allocate specific funding for the initial (and crucial) co-construction phase of research projects, so as to optimise their future transformative capacity. The initiative challenges its participants to consider all important interactions between the SDGs and to address cross-cutting issues among at least three explicitly identified SDGs. Project applicants are free to choose which interactions to explore depending on the research fields and questions involved, with a view to providing knowledge to help understand, mitigate and adapt to global environmental change.

A high level of transdisciplinarity

According to the terms of the Belmont Forum calls for projects, a transdisciplinary project must be developed and implemented jointly by experts representing as a minimum the natural sciences, social sciences and humanities, and stakeholders. The stakeholders must be clearly named and have been involved in developing the project concept. The definition of stakeholders is unusually broad and includes – but is not limited to – academics, government agencies, funding bodies and development partners, the private sector, non-governmental organisations, traditional authorities, neighbourhood associations, civil society organisations, faith-based organisations, think tanks, the media and parliamentary committees. Of the 154 partners in the 13 projects funded by the Pathways to Sustainability call for projects, 51 are non-academic organisations, mostly government agencies, but also NGOs and private-sector organisations. Six projects involving IRD researchers and their partners in the Global South, also financed by an IRD seed fund, were successful.

At the root of community of practice

Despite their diverse focus (urban, agriculture, small-scale fisheries, zoonoses, air quality, governance, etc.), these six IRD-coordinated projects, along with the other projects involving French researchers, form a community of practice centred around on developing pathways to sustainability. With six projects focused on Africa and four interregional projects that involve African fieldwork, Africa will

play an important role in this process. To support, strengthen and expand this community, several joint meetings and shared support materials will be used over the course of these projects (webinars, training, newsletters, workshops, syntheses, etc.).

These discussions will provide the means by which science engages with societal stakeholders to achieve the desired transformation, from the understanding of the problem to the design, implementation and monitoring of practical pathways and solutions.

The six winning projects coordinated by IRD

COVPATH • *Coviability Path, a new framework to sustainably link mankind and biosphere* – Olivier Barrière (UMR Espace Dev, Montpellier)
ODD 2, 3, 13, 15, 17

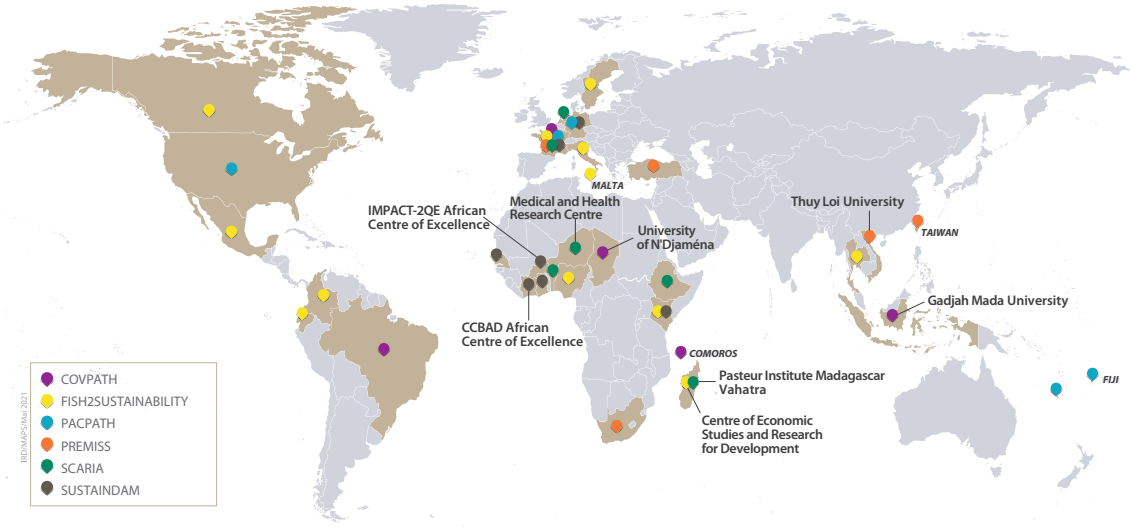
Fish2Sustainability • *Enhancing the contribution of small-scale fisheries to the sustainable development goals* – Rodolphe Devillers (UMR Espace Dev, Montpellier)
ODD 14, 1, 8, 2, 5

PACPATH • *Pacific Ocean Pathways in support of sustainable development: an integrated approach* – Alexandre Ganachaud (UMR Legos, Toulouse)
ODD 14, 13, 15

PREMISS • *Partnership for Research to Enhance Methodologies In Sustainability Science* – Alexis Drogoul (UMI Ummisco, Paris)
ODD 9, 6, 13, 15

SCARIA • *Towards sustainable community-based mitigation of rodent issues in African cities* – Gauthier Dobigny (UMR CBGP, Montpellier)
ODD 2, 3, 4, 11

SUSTAINDAM • *Sustainable management and planning of hydropower generation in West Africa under climate change and land use/land cover dynamics* – Arona Diedhiou (UMR IGE, Grenoble)
ODD 13, 6, 7, 15, 17



Geographical coverage of the partners of the winning Pathways to Sustainability projects coordinated by IRD, with the nine IRD-funded partners highlighted.

KEY POINTS

Six projects coordinated by IRD researchers are funded by the Belmont Forum through a call for projects entitled Pathways to Sustainability to help provide a scientific basis for achieving the SDGs. The adoption of the pathways approach allows consortia to take the time necessary to co-construct scientifically robust projects that are of value to society, thereby ensuring ownership of the results and their relevance for politicians and policymakers. It should also lead to greater social acceptance and empowerment of populations.

Knowledge communities as a basis for scientific multiculturalism

Muriel Mambrini and Gaëll Mainguy,
Learning Planet Institute (LPI), Paris, France

Background

As an institute committed to research that develops sustainable solutions to the complex problems faced by countries in the Global South, IRD has spearheaded the creation of nine Knowledge Communities (CoSavs). The CoSavs, successors of the Interdisciplinary and Partnership Structuring Programmes, bring together staff from IRD's three divisions – Science, Development and Support – to improve the way in which the skills of the various disciplines, departments and functions work together. To help set up these CoSavs, IRD has partnered with the Learning Planet Institute (LPI), a pioneer in the field of learning and collective intelligence in the field of sustainability issues.

Contact
muriel.mambrini@cri-paris.org

Further reading
https://www.ird.fr/les-communautes-de-savoirs-cosav

Choosing a community model

In many sectors of society, the concept of "communities" (of learning, of practice and of knowledge) has emerged over the past 30 years. It defines a group of people who share a common concern and who, in an effort to tackle it, share their expertise, know-how and interpersonal skills, thereby passing on their experience and knowledge. This collaborative working method is particularly useful at a time when the issues facing our societies are increasingly complex (so-called "wicked problems") and require interdisciplinary and transdisciplinary approaches. The participatory way in which communities operate highlights the crucial role played by the organisational patterns and behaviours that are fostered within groups. The dynamics of communities, how they develop in stages and ultimately their success in solving problems, depend on these common working methods. In autumn 2021, LPI organised three seminars with IRD to start a reflective dialogue leading to the co-construction of a shared understanding of what a knowledge community (CoSav) is, how it functions and what future actions would guarantee that it flourishes and is capable of achieving the sustainable development goals. The three seminars brought together CoSav facilitators with three objectives: (I) to identify the values of CoSavs and report on activities to implement them; (II) to share practices used and those desired for running these communities and to identify the first steps to be taken; (III) to design practical tools for implementation.

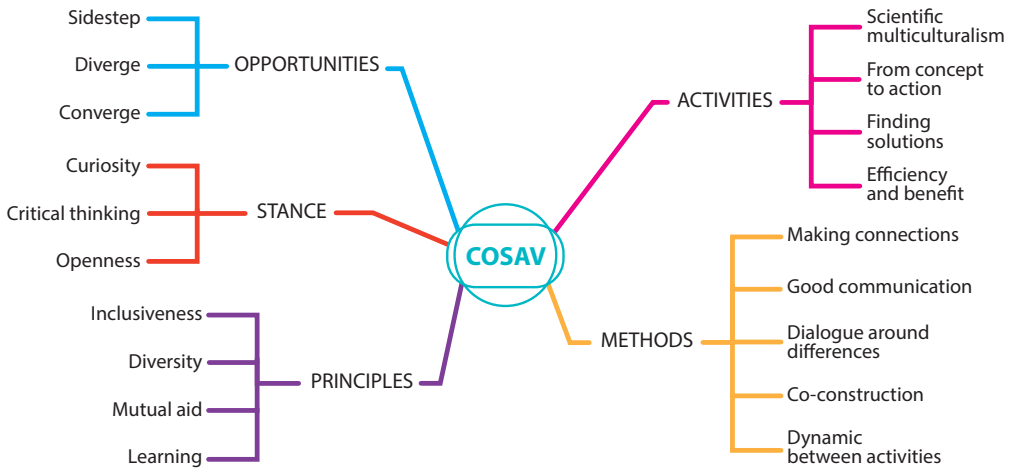
What are Knowledge Communities?

IRD's CoSavs are platforms of "scientific multiculturalism". They offer a space where new scientific fronts emerge and where practical and innovative projects are co-constructed in response to the challenges of sustainability. IRD researchers, engineers and technicians and their partners in the Global South (private, public and NGOs) come together to make a joint commitment to one of the following nine challenges: biodiversity; climate change; geo-resources and sustainability; coasts and oceans; migrations; soils and lands; food systems; One Health; sustainable cities. Their working methods are based on the following principles: (I) promoting inclusiveness and diversity; (II) focusing on mutual aid and solidarity; (III) developing listening skills and learning. The purpose of CoSavs is to effectively co-construct proposals from concept to action and to identify solutions whose scope has been defined through the convergence of knowledge such that they can be implemented rapidly and have an impact. Communities have the ability to test (prototype) and assess their relevance within a reasonable time frame. Along the way, communities develop new tools for harnessing knowledge, methods for creating links between academic and non-academic stakeholders, and ways to supply the science-policy interface with information to help decision-making. They also support the commitment of scientists, paradigm shifts and the emergence of transdisciplinary research fronts. They should soon be able to suggest new indicators for evaluating research (interdisciplinarity, connections with societies, low-carbon activities, etc.).

How to "build on scientific multiculturalism"

Knowledge communities need to be particularly vigilant. They should:

- help to generate collective intelligence by finding ways to give all "participating experts" the chance to speak freely and striking the right balance between exchanging of points of view and exchanging knowledge;
- recognise the specific characteristics of the research and knowledge production practices of the various experts by learning about the scientific value of interdisciplinary and transdisciplinary work and about the "knowledge of the other". The ways of doing this range from sharing interdisciplinary field experiences to interdisciplinary case studies, and even to experimenting with other research practices. One of the criteria characterising the capability to build on scientific multiculturalism is researchers' ability to change their stance;
- consider and develop interdisciplinary and transdisciplinary methodologies. Knowledge communities use a variety of approaches that can be ranked by increasing levels of knowledge integration. These approaches include: (I) thinking about new collaborative research starting from the impact and developing the "impact pathway"; (II) thinking about the shared issues and the types of expertise that are needed (and need to be better understood) to tackle them; (III) choosing a "research common", either a contemporary (or future) object or a problem; (IV) being the driving force behind a radically interdisciplinary research project.



Example of a mind map from the LPI seminars on knowledge communities.

KEY POINTS

Knowledge communities undertake a range of activities for sharing knowledge and co-producing new proposals. They include "making connections" and "good communication", co-construction between disciplines and stakeholders, sharing practices and solutions, developing interactive methods and dialogue around differences.

CoLAB: a multi-stakeholder methodology for research

IRD, makesense and Bond'innov, France

Background

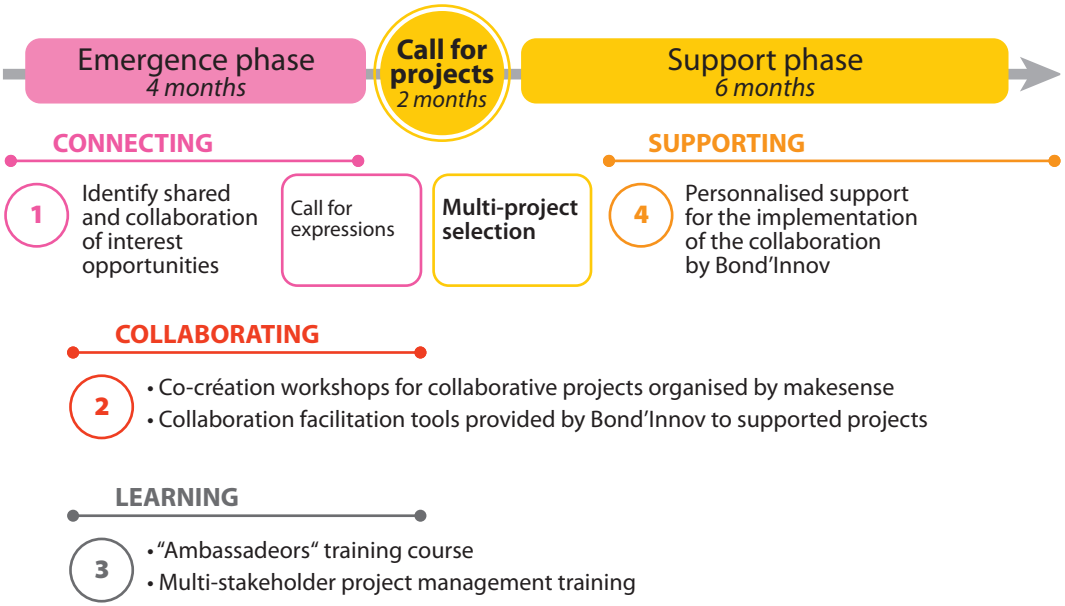
The Sustainable Development Goals, and in particular SDG 17 (Partnership for the Goals), highlight that collaboration between stakeholders from different sectors is becoming a necessity. It is from this idea of developing coalitions of stakeholders committed to the same issue that the CoLAB programme has emerged. However, collaborating on and developing multi-stakeholder projects is not straightforward, and involving stakeholders from different backgrounds may prove unsuccessful. By proposing a specific methodology, built around an ecosystem of stakeholders, CoLAB aims to foster the ability of research projects to tackle the challenges identified in a particular territory.

Contacts
myriam.habil@gmail.com
colab.innovation@gmail.com

Further reading
https://colab-innovation.org/

The CoLAB methodology

The CoLAB programme was designed and implemented for the first time in 2017 by makesense, Bond'innov and IRD, with the backing of the French Ministry for Europe and Foreign Affairs. CoLAB is a multi-stakeholder collaboration laboratory for experimenting with new methods for co-constructing projects and sharing knowledge and know-how within a community of committed stakeholders working collectively to develop innovative and responsible solutions. CoLAB responds to a specific need of stakeholders who, although willing to work together, struggle with the requirements for successful collaboration, including interdependence, shared governance and the importance of serving the common interest. The main difficulties identified were lack of time, lack of trust, lack of synergy and lack of understanding. The CoLAB methodology is built on four pillars to drive and support collaboration: connecting, collaborating, learning and supporting. These are implemented through a one-year programme broken into two phases, structured around a call for projects. The "Emergence" phase connects the identified stakeholders and leads



Key stages of CoLAB over a year.

them towards co-constructing projects. Following the call for projects, several innovative and impactful multi-stakeholder projects are selected for monitoring and support throughout the six-month "Support" phase.
The CoLAB methodology has been deployed in five West African countries through two programmes: one on food security issues and the other on mother and child health. The methodology is currently being adapted to new areas and themes: in Bondy on sustainable food, in the Caribbean and the Pacific against climate change, in Morocco on the protection of argan forests, and in Tunisia on the topic of water.
One of the challenges of CoLAB is to deploy programmes that draw on the skills, expertise and results of IRD's partnership research. The methodology is implemented within the territories in combination with partnership science deployed through structuring mechanisms such as LMIs (International Joint Laboratories), JEAIs (Young Teams Associated with IRD) and GDRIs (International Research Groups – South). For example, CoLAB Morocco's main partners are universities – including Mohammed VI Polytechnic University – and involved the MediTer LMIs (which dealt with agroforestry and the argan forests) and Trema (which deals with water resources). CoLAB Tunisia will be supported by several LMIs, including LMI NAILA. Other research stakeholders from IRD's structuring mechanisms and our partners are also involved. CoLAB 93, which is part of the ANRU+ programme, is supervised by two researchers attached to the Development and Societies Laboratory and the Resilience joint international research unit. The Sustainable Development City will also be invited to join the programme. One of the distinctive features of the CoLAB programmes is that they involve the various research stakeholders from start to finish. This allows them to co-construct the project and to use their knowledge, expertise and scientific rigour to experiment and develop the innovations of tomorrow. In this way, the CoLAB methodology is designed to:

- identify the skills, expertise and research findings for a particular theme;
- improve understanding of the field and the needs of beneficiaries;
- bring together communities of stakeholders to co-develop research programmes and innovations: NGOs, non-profit organisations, companies, start-ups and institutions;
- protect research findings through legal and intellectual property support;
- support the publication of scientific articles inspired by CoLAB projects.

Involvement of IRD researchers

The involvement of IRD researchers can take place at different levels.
As project leaders: researchers have initiated and led some of the projects in the two CoLAB programmes. The tools provided during the "Emergence" and "Support" phases

"CoLAB opens up new horizons; it pushes us to develop new research questions that we may not have thought of without this type of support. It encourages us to revisit our methodologies: on-the-ground concerns, which we do not routinely include in our research, are at the heart of this new approach."

Laurent Vidal, IRD representative in Mali and involved in the Mother and Child Health CoLAB

"It is an exercise in making the most of research work and it needs to go much further. There is a beneficial retroactive effect on the momentum for research, which is essential."

Renaud Fichez, IRD representative in Morocco and involved in the ARganier CoLAB

can significantly boost action research thanks to the multi-stakeholder collaboration and the relationship created with the beneficiaries. This also leads to increased visibility of researchers and added legitimacy within the research ecosystems.

As experts on the selection committee and for the scientific support provided to the projects: researchers may serve on the scientific committee responsible for validating the relevance of the winning projects but may also support implementation of the solutions.

KEY POINTS

The CoLAB programme facilitates experimentation with methods for co-constructing projects and encourages the sharing of knowledge and know-how within a community of committed stakeholders working collectively to develop innovative solutions that have a positive impact on the local area. By combining and linking knowledge and skills, collective intelligence is put to work for sustainability science.

The Future Of, bringing together open innovation, Southern inclusion and sustainability science

Alexandre Bisquerra,
Department for the Mobilisation of Research and Innovation for Development,
IRD, Marseille, France
Yoann Malinge,
SoScience, France

Background

Research practices, funding agencies and international development institutions suggest that research to address sustainability challenges is most effective when it is "co-produced" by academic and non-academic stakeholders. This co-production has the potential to improve how we respond to the complex nature of contemporary sustainability challenges compared with more traditional scientific approaches. IRD and SoScience have worked together since 2016, implementing open innovation programmes that bring together scientists, industries, start-ups and civil society stakeholders all over the world. These The Future Of programmes involve a multi-stakeholder community working on a transdisciplinary theme or societal challenge and give this community a platform to propose projects in response.

Contact
alexandre.bisquerra@ird.fr

Further reading
https://www.soscience.org/thefutureof

A recognised methodology

The Future Of (TFO) programmes bring together 30 to 50 international experts (researchers, social entrepreneurs, start-ups, companies and industries, NGOs and non-profit organisations, etc.) through a call for projects, with the aim of generating collaborative research projects. Each programme is divided into three phases:

Phase 1

Defining a specific issue around a transdisciplinary research theme or societal challenge:

- definition of the issue, co-constructed with researchers, partners and civil society representatives
- launch of the call for projects and receipt of applications.

Phase 2

To create synergies and develop multi-stakeholder collaborative projects that focus on the issue defined:

- selection of 30 to 50 participants from among all the applications received
- organisation and facilitation of a meeting to develop collaborative projects.

Phase 3

Structuring and driving/implementing the projects developed:

- selection of the winning projects with the organisational committee
- support provided by SoScience during the first six months of each project.

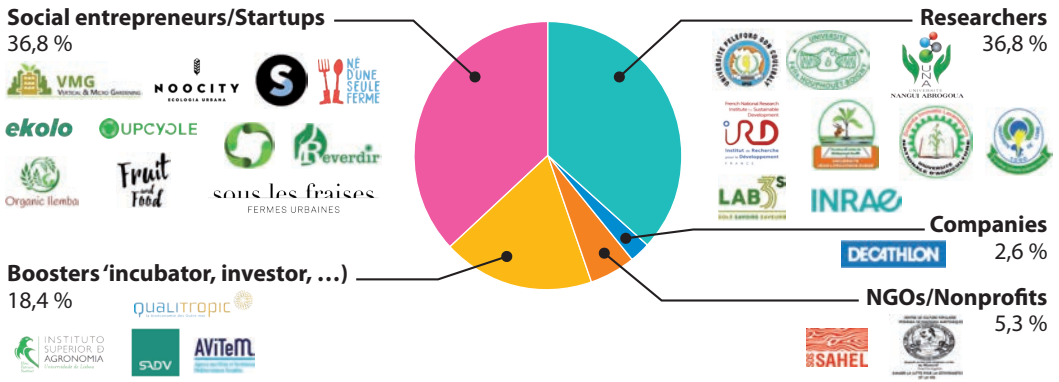
Since 2016, nine TFO programmes have been completed, including four in partnership with IRD on water, soil quality, urban agriculture and, in the Seychelles, on plastic pollution in the oceans.

The Future Of Urban Agriculture (TFOUA)

TFOUA launched in September 2020 with the "Sustainable Cities" interdisciplinary structuring and partnership programme and was supported by a committee of 14 experts including several IRD laboratories (iEES-Paris, Eco&Sols, Mivegec, G-Eau), French scientific partners (AgroParisTech, INRAE) and Southern partners (University of Lomé), non-profit organisations (SOS Sahel, SFR Racines, LAB3S, Reverdir), along with Qualitropic, a tropical bioeconomy competitiveness cluster. A call for contributions was launched in the autumn of 2020 on the issue of "What solutions and services should be developed with urban farmers to feed the local population while contributing to a sustainable city?" Of the 70 applications received, 27 were selected to join the panel of 13 experts on the organising committee. At the Partnership Days held online on 28 and 29 January 2021, 56% of the 38 participants came from Europe, 40% from Africa and 4% from South America, with the following diversity across sectors.

As a result of the meeting, three projects are currently being supported:

- a participatory research project for developing an urban farm on a polluted site in Martinique;



Exemple de diversité sectorielle des participants à un programme TFO, ici TFO *Urban Agriculture*.

- a research consortium carrying out a pioneering study to provide sub-Saharan cities with a method, tools and good practices to support urban tree planting;
- an R&D project to develop a grey water treatment module and a digital model to measure the benefits.

The ambassador programme: The Future Of Plastic Waste

TFO programmes are also being deployed in spin-off mode through the ambassador programme, which allows partners from the Global South to be trained in the methodology and then supported remotely by SoScience when they implement their first TFO programme. This is the case with The Future Of Plastic Waste programme in the Seychelles, within the framework of DiDEM (Science-Decision-Makers' Dialogue for Integrated Management of Coastal and Marine Environments) and in partnership with Monaco Explorations and the Seychellois Department of the Blue Economy. The Future Of Plastic Waste Partnership Days was held online in May 2021 and brought together 38 stakeholders, more than half of whom were from the Western Indian Ocean region (18% scientific stakeholders, 24% entrepreneurs, 13% companies, 21% NGOs and 24% boosters, such as consultants to blue economy departments, communicators, etc.).

KEY POINTS

After five years of partnership, IRD and SoScience have been able to enhance and optimise the methodology to make it easier for scientists to get involved, to open up the programmes more widely to the international community and to the entire "IRD planet", and to introduce a spin-off model to meet the demands of partners in the Global South who wish to deploy this type of programme. The upcoming challenges will be to strengthen the support given to winning projects, increase the momentum behind international and Southern spin-offs, and make it easier to share best practices between the partners and stakeholders involved in the various TFO programmes. The Future Of methodology was one of the models used to develop European public policies on open innovation (European MOSAIC project 2021-2023) and was internationally recognised by the UN in 2021 as an SDG good practice.

TRANSFORM

Sustainability science aims to provide answers to major global challenges and accelerate the transformations needed in our societies to cope with global changes and interconnected crises. In light of this, the world of higher education and research for sustainable development needs to reflect on how it can contribute to this global effort. This section presents texts dealing with three types of transformations being considered at IRD: science-society dialogue and the relationship to politics; teaching systems and methods; research practices (setting up sustainability science competitions, relationship to data, reducing the carbon footprint, measuring impact, institutionalising equitable research).

Science-society dialogue: a prerequisite for sustainability science

Marie-Lise Sabrié and Caroline Vilatte,
Scientific and Technological Culture Mission,
IRD, Marseille, France

Background

Sustainability science claims to be the science behind finding solutions to the major social, economic, health and environmental challenges of the 21st century. It is therefore confrontation with the "real" world that determines the research problems, rather than questions specific to the scientific disciplines involved. This exogenous approach implies that research must be sensitive to the expectations and needs of citizens, and must therefore maintain a dialogue with them, so that the resulting advances and innovations are appropriate to society and lead to truly sustainable solutions.

Contact
marie-lise.sabrie@ird.fr

Further reading
https://www.ird.fr/une-feuille-de-route-pour-une-science-ouverte-et-partagee

The paradoxical relationship between researchers and citizens

If sustainability science is to become an integral part of society, it must create the conditions needed for dialogue between the various stakeholders in society and the scientific community. UNESCO stresses that "it is critical to develop the necessary interfaces between science, policy and society that can help advance sustainability knowledge and action, enhance adaptive management and societal learning, and provide for scientific bases to policymaking and decisions and actions by civil society".[1] But where are we today in science-society dialogue? It is taking place in a context whose paradox has been highlighted by the health crisis. Studies and surveys conducted in the United States and Europe,[2] along with others in India and China, show that most citizens believe that science and technology play an important role in bringing about radical changes in society. The public expects science not only to produce new knowledge, but also to inform public policy and draw on scientific expertise to deal with environmental or health crises, for example. However, at the same time, the links between citizens and scientists are weakened by the mistrust that certain parts of society – which are growing in France[3] – have towards science. Scientists' objectivity, their independence or their ability to distance themselves from their own particular interests may therefore be called into question. Widespread support for theories – including those of climate sceptics, creationists and flat-Earthers – that challenge research-based knowledge is particularly worrying on the internet and social networks, where scientific knowledge and beliefs coexist on an equal footing. The Covid-19 pandemic seems to have deepened the mistrust of science. It brought doubt, hypothesis-based arguments and disagreements – all inherent in the research process – into full view, while the public, largely unaccustomed to being exposed to such uncertainty and conflict in the media, expected experts to provide firm answers to their questions and reassure them of their legitimate concerns.

Trust and reciprocity as a basis for dialogue

Sustainability science requires trust between scientists and citizens, which must be built on reciprocal exchange. In recent years, the design of mediation activities between the scientific community and the general public has moved in this direction. For many years, the dissemination of scientific culture or science

1 • https://en.unesco.org/sites/default/files/2511_17_f_sustainability_science_flyer_fr_f.pdf
2 • For Europe, see the Eurobarometer studies; for the United States: https://www.pewresearch.org/fact-tank/2020/02/12/ key-findings-about-americans-confidence-in-science-and-their-views-on-scientists-role-in-society/; for China and India: Rerimassie V. *et al.*, 2015 – *Public Perceptions of Science and Technology in Europe, China and India, Science and Technology Governance and Ethics*. Springer: 25-37.
3 • https://www.ipsos.com/fr-fr/barometre-science-et-societe-les-scientifiques-de-moins-en-moins-epargnes-par-la-defiance-des

communication was designed to follow the "deficit model". This model considered that citizens – because they were generally suspected of being scientifically illiterate – were not capable of appreciating the value of science, let alone debating the issues it raised, and that it was therefore necessary, through one-way communication or "instruction", to plug the gaps in their knowledge before even considering giving them the right to debate. Today, this model is outdated and sustainability science requires it to be so. A shift in the relationship between scientists and citizens is now under way and was promoted recently in the French Ministry of Research's strategy under the Research Programming Law, which calls for a renewed emphasis on the place of science in society.[4] This urges scientists to adopt a new approach: rather than imposing their expertise as a "top-down truth", they are encouraged to engage in a genuine dialogue that is used not only to share their knowledge and practices, but also to discuss their limitations and the doubts and questions raised by their research. This is a far cry from the deficit model based on the paradigm of the divide between researchers and the public, often illustrated with the image of an unbridgeable gap between scientific and "lay" knowledge. Now, the knowledge and experience of communities, especially those benefiting from research, is recognised and may even become an integral part of the scientific process, as is the case with participatory science. Sustainability science, which is intrinsically democratic, thus focuses on research that is co-constructed with the various stakeholders in society: "Scientists, elected officials and any other members of the public are potentially co-authors of the solutions to be implemented to support sustainability. They are involved at all stages of the process, from the creation of knowledge to its dissemination and use."[5]

A priority objective at IRD

Science-society dialogue is one of IRD's priority objectives, as stated in its 2016-2030 strategic plan (priority objective 6) and in its recent roadmap for open and shared science. For several years, mediation mechanisms designed by the Scientific and Technological Culture Mission have helped to strengthen these exchanges between researchers and the public. Particular emphasis is placed on young people, so that through an introduction to the scientific process and meetings with researchers, they can play a leading role in sustainable development, in an informed and critical manner. These mechanisms include IRD's Youth Clubs and the ePOP project, which encourage high school and university students from the Global South – more than 300 each year – to engage in research and debate with scientists. These are just a few of the initiatives undertaken by IRD that promote dialogue between

4 • Extract from the report appended to the French Research Programming Law https://cache.media.enseignementsup-recherche.gouv.fr/ file/culture_scientifique/41/7/Brochure_science_societe_1404417.pdf
5 • https://www.cairn.info/revue-natures-sciences-societes-2014-2-page-114.htm

science and society and are firmly rooted in sustainability science. There are many others, including experiments combining art and science, interactive exhibitions, serious games, multi-stakeholder programmes and participatory science. Although significant progress has been made at IRD and elsewhere to promote science-society dialogue, there is still much to be done. With this in mind, the roadmap for open and shared science recommends in particular that action in this area be included prior to research planning and throughout its implementation, that researchers' skills in this area be strengthened, and that activities focusing on science-society dialogue be given more weight in scientists' evaluation processes.

KEY POINTS

The health crisis has highlighted the ambiguous nature of the relationship between science and society, which is divided into two extremes: trust and mistrust. This situation makes it more necessary than ever to create the right conditions for dialogue between researchers and citizens, a prerequisite for sustainability science, so that development stakeholders can adopt the latest scientific advances and innovations and offer socially, economically and environmentally sustainable solutions. Accordingly, IRD's roadmap for open and shared science recommends:

- **strengthening IRD's capabilities around science-society dialogue;**
- **including the end-beneficiaries in the research process;**
- **ensuring that research findings on priority SDG issues can be readily adopted;**
- **taking activities related to science-society dialogue into account in the evaluation processes of IRD scientists and mechanisms.**

Universities and sustainability: a review of recent literature

Jean-Baptiste Meyer,
IRD, UMR Ceped, Paris, France

Background

Around the world, the academic community has been instrumental in shaping sustainable development and related concepts. The emergence of sustainability science and education for sustainable development in the mid-2000s led to the formal adoption of the SDGs in 2015. For the first time, the international community, with considerable expertise and diplomatic effort, had developed an agenda that was informed by global academic thinking. However, little is known about how this agenda is applied today, either to academia itself or – through it – to the wider society that uses its knowledge. This review of the literature clarifies this situation.

Contact
jean-baptiste.meyer@ird.fr

Further reading

Leal Filho W., Tortato U., Frankenberger F. (eds.), 2020 – *Universities and Sustainable Communities: Meeting the Goals of the Agenda 2030*. Springer.

Approach: identifying and monitoring the work undertaken by university stakeholders for sustainability

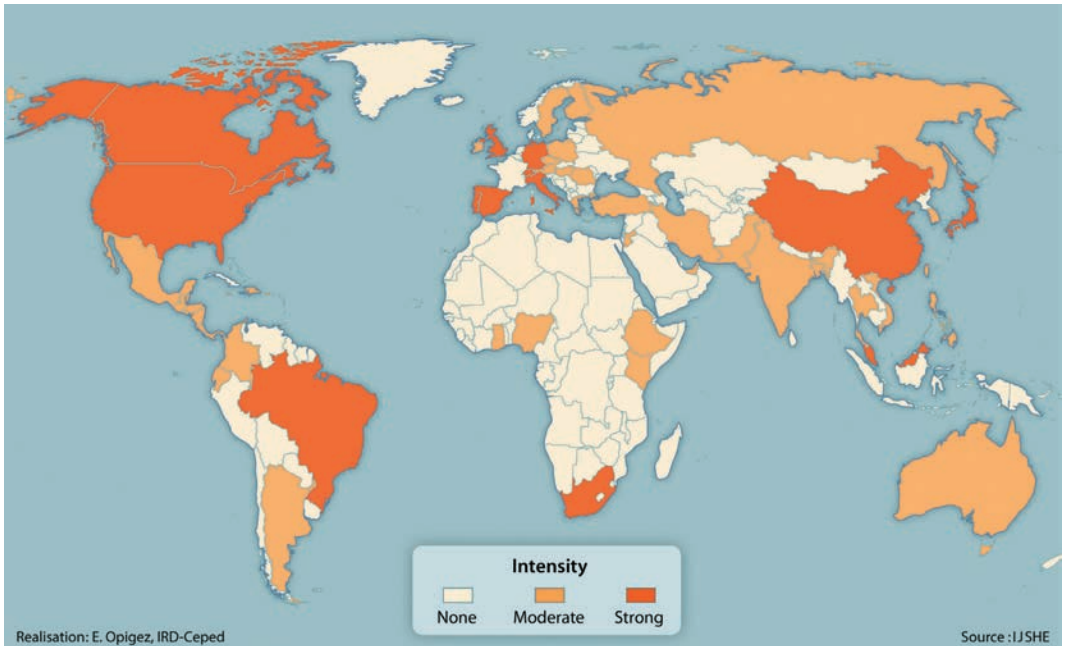
The aim is to assess how the academic community applies the principles of sustainability and the SDGs to its own activities, and how it works to bring them to society through its core functions (teaching, research and innovation). To do this, we consulted the stakeholders involved. We systematically collected details about their work on sustainability, including references not only from the academic world, but also from the users of its knowledge for sustainable development. This bibliographical study provides an insight into how universities go about implementing sustainable development within their own walls and beyond them. It also provides information on how this process is followed up and monitored on a global level.

Initial results: abundance and diversity of collected material

We identified 1,100 documents that refer to sustainability in universities. This included primarily academic literature of 800 articles in peer-reviewed journals, 250 chapters of specialised books from about 30 published volumes and several dozen institutional and grey literature documents, mainly online. This wealth of material indicates that university systems are working hard to implement sustainability in their own institutions. It is a field of knowledge cultivated by authors from all geographical, thematic, disciplinary and institutional backgrounds. Major scientific publishing houses and the most eminent journals are very well represented, but never exclusively. Sustainability at universities is very much part of the mainstream in terms of material, but remains highly dispersed in terms of content.

A wealth of disparate content

If we look at the key words used to describe these publications, we see that they cover a wide range of subjects, often immeasurable but extremely valuable. Measuring the carbon footprint on campuses, analysing student behaviour, transforming teaching curricula, introducing new teaching methods, using ICT, introducing educational serious games, reflecting on promoting cross-cultural values or on raising awareness through meditation – all aspects are covered, whether they are metrological, technical, economic, artistic, political, metaphysical or spiritual! By categorising the references according to the sectors from which they come, the activities to which they apply, the areas of the world to which they relate and the priority they give themselves, several findings emerge. The publications come mainly from and are aimed at the academic sector and are therefore peer-reviewed in keeping with the academic tradition. Teaching and research are on an equal footing when it comes to sustainability; the authors do not favour one over the other. Any distinction between the northern and southern hemispheres is dropped in favour of a global view of sustainability issues. Lastly, sustainable development as a whole, and not just its social



Global breakdown of publications on sustainability in universities between 2000 and 2020.

or environmental aspects taken separately, is given pride of place. The much-maligned "great divide" of Western modernity – nature/society and the developed North/developing South – seems to melt away while respecting the canons of the academic institution.

The SDGs for and by universities

First of all, universities set themselves the SDGs as strategic goals. These include reducing their carbon footprint and using environmentally friendly infrastructures (SDGs 13 and 9) and setting an ecological example internally so that they are credible when passing on their values through consolidation of their own institutional capacity, thereby guaranteeing stability (SDGs 4 and 16). In addition, universities see themselves as producers of sustainability through, in particular, the creation and dissemination of knowledge on the environment and society (SDGs 14 and 15), on health and hygiene (SDGs 3 and 6) and on innovation and local development (SDGs 8, 9 and 11). More importantly, universities strive to produce future global eco-citizens and, to this end, are developing active teaching tools (learning through research, problem solving, critical approach, etc.) that break with traditional education (SDGs 4, 5, 10 and 12).

Emerging countries lead the way, French-speaking countries lag behind

The BRICS countries are leading the way in this growing tide of thinking (graph). For their academics, sustainability is emerging as a vehicle for promoting their institutions to the top rankings in the world. French-speaking countries (apart from Switzerland and Canada), on the other hand, have been left behind in this trend until recently. Their institutions are setting up programmes, but their visibility is limited for the moment.

Looking ahead: the need for transformation

The Covid-19 pandemic and lockdowns have had a major destabilising effect on French higher education systems. Private institutions collapsed because students were unable to enrol. Others have seen the principle of universal access undermined by the reality of distance learning. A consensus is now emerging on a real paradigm shift, prompted by a sea change in framework conditions and accelerated by these events. The most recent statistical projections clearly illustrate the phenomenon. The combination of demographic change and higher education enrolment rates leaves no doubt that there will be a rapid and marked increase in student numbers in the developing world, particularly in sub-Saharan Africa. The pressure on institutions in the short to medium term threatens their very existence. The sustainability of universities is at stake at a time when their wider societal role is more crucial than ever.

KEY POINTS

A review of the literature reveals unambiguously that transdisciplinarity and partnership (SDG 17) are the benchmarks of sustainability, recognised universally across the academic world. They are foundational principles of IRD's work, both in terms of research and cooperation, and are now being brought to life within knowledge communities. Support for doctoral training seems to be a major issue in meeting the challenges of sustainability. It fits with IRD's dual mandate of research and capacity building and at the same time responds to the need to increase the capacity of universities to support growing student numbers, while developing the practice of active pedagogy, tailored to the major issues of the 21st century.

The "magic square" of transformation

Patricia Ricard,
Paul Ricard Oceanographic Institute,
île des Embiez, France

Background

The acceleration of sustainability issues within economic sectors and the shift from the desire for transition to transformative action highlight the need for diversified partnerships within ecosystems. Cross-sectoral and multi-stakeholder collaborations are essential to address the complexity of the challenges involved. During the 2019 Two Shores Summit, attended by five European and five African countries bordering the Mediterranean, hundreds of projects were studied by civil society delegations. It became clear that the strongest and most impactful projects were based on a partnership structure that we called the "magic square".

Contact
patricia.ricard@institut-paul-ricard.org

Further reading
www.institut-paul-ricard.org

Combining skills enhancement and action acceleration to deliver disruptive innovation

Green growth has led to the achievement of measured sustainability objectives, whether in energy, recycling or eco-design, or in terms of improving the consumption of raw materials and natural and bio-based resources. We are now entering a phase of what we could call "blue growth", involving disruptive innovation and operational processes that are radically different from, or even contrary to, the methods we have used until now. Disruptive, structuring and transformative innovations spring from the strengthening of interdisciplinary and multidisciplinary skills. Integrating these skills and related subjects from the project planning stage makes it easier to overcome scientific, technological or regulatory obstacles (information sharing). The need to move from "being willing to transition" to "implementing the transformation" requires the acceleration of multi-sector collaboration in developing and implementing innovative projects.

4 essential pillars for the transition to action

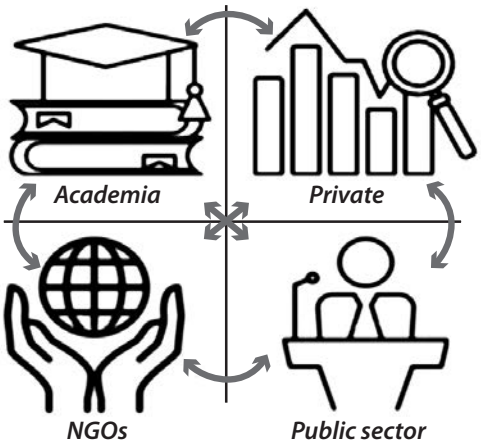
The only way to face the socio-environmental challenges while maintaining food security and sovereignty is to reconcile the dynamics of our "technosphere" with the balance of the biosphere (see the objectives of the Pikaia project). Four pillars are needed to support this transition to action.

Science at the heart of tomorrow's solutions: This first pillar of scientific knowledge relates to the research component of projects, which aims to develop, aggregate and disseminate knowledge. Interdisciplinarity accelerates the mediation and scientific acculturation of stakeholders. Today's tools of scientific observation lead to unprecedented progress in Earth and life sciences, bolstered by the digital revolution. A wide field of sustainable innovations is opening up. The European Centre of Excellence in Biomimicry in Senlis (CEESBIOS) and its interaction with major industrial groups exemplify this trend.

Businesses facing transformation: Being competitive, profitable and keeping businesses dynamically balanced with financial, commercial, social and regulatory parameters are the challenges facing the private sector. Changing consumer expectations, sensitive financial markets and tightening regulations, not forgetting the new aspirations of the younger generation, are forcing the private sector to accelerate its transition to greater sustainability. Companies need sustainable innovations to maintain their competitiveness and market share. In the process, industries, companies and start-ups are key players in ensuring that these sustainable innovations become a reality. The way companies operate and the requirement for them to meet targets within specific time frames are excellent drivers for implementing and transforming sustainable products and consumption patterns in the future.

The country and its institutions: The fact that a disruptive project is rooted in a particular territory provides the political support required to implement it, and possibly to support it through regulations and funding. Decrees and other regulations can help to overcome administrative or property-related obstacles. The national dimension also makes it easier for the public to support these innovations and transformations. Moreover, the national territory is probably the best scale for implementing an ecological and energy transition adapted to the geoclimatic reality.

NGOs, guarantors of social acceptability: NGOs now play a key role in the development of regulations and recommendations, whether national, European, or indeed international or UN regulations. They are an essential link between the three other pillars, as they interact with all parties and have real influence through advocacy and social networks. A good example of their influence is their awareness raising and developments in the shipping and food sectors. NGOs play a part in gaining acceptance of sustainability requirements through the societal pressure they generate. They also play an important role in raising awareness of scientific expertise in this field.



A skills and activation ecosystem.

An example: the Ar Jeenguen project in Senegal

The Franco-Senegalese project Ar Jeenguen is a good example of the magic square model. It brings together the Veolia Foundation (a corporate foundation), the Paul Ricard Oceanographic Institute (an NGO), the Senegalese National Aquaculture Agency (ANA, an institution) and the University Institute of Fisheries and Aquaculture at Cheikh Anta Diop University in Dakar. This project is based on an ecosystemic vision of local food production (circular economy), linked to empowering women in rural areas, and combines market gardening and fish farming through trophic relationships. Reusing the water from fish farming, enriched with organic matter, to irrigate market gardens provides the soil with naturally occurring nutrients, while the biological improvement of the fish farm increases the nutritional quality of the fish. A later phase will produce aquaculture feed by bio-converting (insect farming) available food scraps and discards, thereby improving food security and boosting local economic

development. Ar Jeenguen also has a financial dimension involving a revolving fund, allowing the model to be replicated through the repayment of the loan. ANA is a stakeholder in the project through the implementation of the regulations governing aquaculture in Senegal.

This "magic square" shows how it is possible to develop several proven innovations simultaneously at the local level, whether they are technical, scientific or financial. The magic square could also, if necessary, support regulatory change.

KEY POINTS

The cultural differences between civil society and the academic, economic, legal, institutional and political worlds and the way in which it is structured into silos are still the main obstacles to building transdisciplinary bridges. The magic square is a partnership coalition that brings together stakeholders around a shared project. It unites the economy, science, institutions and associations around a single action. As soon as bridges are created, the desire for expertise is transformed into a desire for collaboration and learning. This creates positive effects, such as the triggering of crucial funding, with leverage effects in the framework of public-private partnerships and concerted action for regulatory change. This is a great example of applied sustainability science!

Profiles of researchers in sustainability science

Laurence Maurice,
IRD, UMR Geosciences Environment Toulouse, France
Rodolphe Devillers,
IRD, UMR Espace-Dev, Montpellier,
France Chairs of IRD competition juries
Directors and research fellows in sustainability science

Background

IRD's science policy aims to strengthen the Institute's role in the development of useful, ethical and effective research to achieve the Sustainable Development Goals (SDGs). Recruiting young researchers as well as senior researchers in sustainability science is strategic for this policy to be sustainable. The aim of this recruitment policy is to encourage interaction between disciplines and to promote new ways of working together around common, problem-centred issues to tackle the social and environmental crises that affect the countries of the Global South in particular.

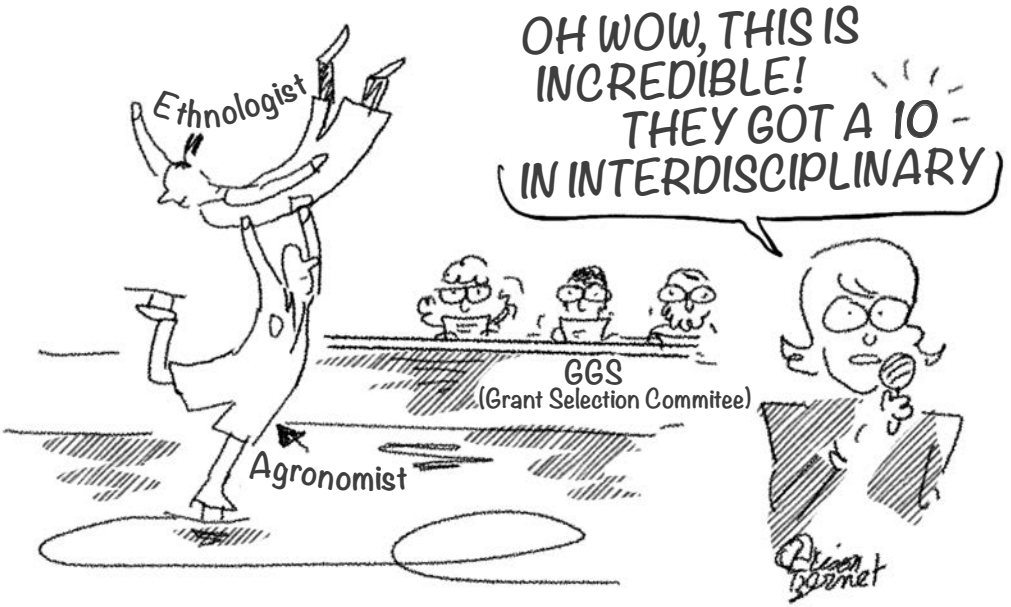
Contacts
laurence.maurice@ird.fr
rodolphe.devillers@ird.fr

Further reading
https://www.ird.fr/concours-chercheurs

Responding to today's major challenges

The current health crisis, like those of the climate, biodiversity or the global crises resulting from human activities, has forced us to rethink the role that research and researchers play in the development of solutions aimed at fairer and more sustainable development. Research has become ultra-competitive internationally, with highly selective and largely discipline-based recruitment processes that also focus on excellence in research and how research is used within the international scientific community.

This competition demands creativity, innovation, originality and, of course, conviction and perseverance from researchers when submitting their applications and research projects to recruitment bodies. Today, however, they need to think differently and apply their skills at an international level and in an interdisciplinary way in order to eventually develop models and scenarios based on excellent scientific data. These initiatives must involve society's stakeholders right from the design phase of research projects and in the co-construction of fair, sustainable and responsible solutions (participatory research approach with stakeholders).



Interdisciplinarity and sustainability science (drawing by Lison Bernet).

What kind of training should sustainability science researchers receive?

Sustainability science, by its very nature, requires an approach that transcends disciplinary and sectoral boundaries. Traditionally, interdisciplinarity is the result of collaboration between disciplinary experts on the same project, but it is important for researchers recruited to sustainability science positions to be able to step outside their disciplinary field and become part of interdisciplinary or even transdisciplinary teams (also co-constructed with non-academic stakeholders). This requires, for example, familiarity with scientific literature and research methods used by disciplines other than their own. Such experience may be the result of training that is itself interdisciplinary (e.g. a Master's degree in resource management or sustainable development), attendance at summer schools or even training in sustainability science. However, a profile of this kind is more often the result of a combination of disciplinary training and opportunities for collaboration in interdisciplinary projects. In this context, candidates with expertise in very different research fields (e.g. life and Earth sciences and social sciences) will be in a better position to undertake work in sustainability science.

Profiles sought

Future researchers in sustainability science will first have to meet the usual criteria for competitions, not only in terms of publications and other research achievements, but also in terms of supervision and teaching, scientific leadership, and so on. Candidates wishing to join IRD will also have to demonstrate either experience of collaborating with countries in the Global South, or the desire and potential to do so. Candidates' ability to collaborate with non-academic stakeholders (i.e. to engage in transdisciplinarity) and to integrate thinking on the co-construction of fair and sustainable solutions into their work will be particularly sought after. However, apart from these common criteria, candidates must also show that they have genuine experience in interdisciplinarity (through their training, thesis work, postdocs, projects, etc.), which ideally has led to publications or other outputs that are also interdisciplinary, integrating if possible very disparate fields, such as life and Earth sciences and social sciences and humanities. A candidate who presents a project in sustainability science, but who has only published work in one discipline, will have more trouble winning over a recruitment panel than a candidate who has already published in sustainability science or in a truly interdisciplinary context. Candidates with a particular interest in complex and multi-scale issues, integrating sustainability science as an object of research, will be particularly well suited to these positions. To ensure that they assess candidates fairly, recruitment panels, themselves interdisciplinary, must listen respectfully to the candidates and to each other to ensure that they strike the right balance between the various scientific cultures, particularly in terms of how research work is presented or methodological issues are addressed.

One of the "sustainability science" profiles selected in 2021 was that of a researcher whose work focuses on the implementation of collaborative environmental governance, adopting a geographical, systemic and reflexive approach to socio-ecological systems, and playing a twin role of analyst and coach.

Another project, carried out in the foothills of volcanoes and at the crossroads between geology and health, focused on diagnosing and preventing the emergence of pathologies affecting populations exposed to volcanic soils on a daily basis, representing a major toxicity risk for their health.

KEY POINTS

Since 2020, IRD has created positions for researchers in sustainability science with the aim of reinforcing the shift in its focus. Researchers applying for these positions must be fully committed to the importance of a transdisciplinary approach to research on issues in the South, in an overall context of climate change, ecological and energy crises, and social and territorial inequalities. Candidates for these positions must not only have strong research profiles but must also have solid experience of working in an interdisciplinary setting and be aligned with sustainability science. It is also essential that they know how to engage and interact not only with other disciplines, particularly life and Earth sciences and social sciences and humanities, but also with non-academic stakeholders, the private sector and civil society, as well as with policymakers and other public-sector stakeholders.

Interdisciplinary facilitators: polyglots at the interfaces

Quentin Struelens,
UMR Cefe, Montpellier, France

Background

Interdisciplinarity (working with people or teams from different scientific disciplines) and transdisciplinarity (including non-academic stakeholders in the knowledge production process) are the two main pillars of sustainability science. They are essential for understanding the complex problems of the real world, now more than ever. For researchers, these approaches cannot be prescribed, but rather depend on a set of professional pathways, experiences and stances that need to be analysed.

Contact
quentin.struelens@ird.fr

Pour aller plus loin

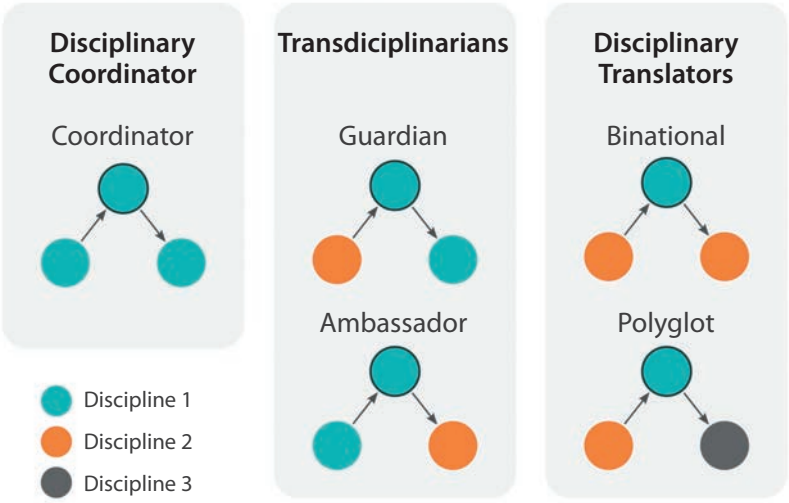
Augsburg T., 2014 – Becoming Transdisciplinary: The Emergence of the Transdisciplinary Individual. *World Futures*,70: 233-247.

Fertile interfaces

Just as biodiversity is richest at the interfaces between different habitats (at the ecotones), a wealth of original ideas emerges from the interfaces between disciplines, societal stakeholders and knowledge systems. Sustainability science (SS) urges researchers to explore these interfaces, to develop an ease of practice outside their comfort zone, shaped by centuries of tradition, in the belief that these *terrae incognitae* are brimming with solutions to the challenges of the 21st century. This is because SS helps to bring together different disciplinary perspectives, to involve new non-academic stakeholders in co-construction throughout the research process, and to explore and understand other forms of knowledge. Incorporating these new concepts into a scientific strategy requires changes in how research is organised. But how can we bring about these changes? One approach being pursued at IRD is to organise research work differently, within interdisciplinary knowledge communities, where disciplines interact and work together to identify solutions to complex problems. It is important that these communities include researchers who are themselves interdisciplinary, to help foster fruitful exchanges between disciplines. While these researchers are often less specialised in one particular field, they add a breadth of vision and epistemological agility to "disciplinary" researchers. The same applies to researchers who are used to interacting with stakeholders from different sectors: they will help foster transdisciplinary discussions.

Different types of interdisciplinary facilitators

Who are these interdisciplinary or transdisciplinary people? There is obviously a wide range of backgrounds and degrees of individual interdisciplinarity, but all seem to have some traits in common (Augsburg, 2014): increased curiosity and risk-taking, along with a propensity for institutional transgression and thinking outside the box. These researchers have backgrounds and experiences that reflect the concepts of SS. Some individuals, either during or after their PhDs, work across different disciplines, integrate divergent knowledge systems or venture into co-constructed research with a variety of stakeholders. Despite the diversity of these profiles, several typologies have been put forward that depict them along a gradient of individual interdisciplinarity. *Transdisciplinarians* cross disciplinary boundaries while being firmly rooted in one specific discipline. Among these transdisciplinarians, *guardians* tend to welcome researchers from other disciplines for dialogue, while *ambassadors* represent their discipline in another disciplinary sphere. *Disciplinary translators* go a step further: they are usually imbued with training or experience that gives them a strong grounding in two *(binational)* or more *(polyglot)* disciplines. Having mastered several epistemologies, they are particularly well suited to facilitating interaction and dialogue and translating information across epistemological boundaries. Of course, these types of profiles change over the course of a research career, depending on a researcher's tastes and their character.



Different profiles of individuals along a gradient of individual interdisciplinarity and their role in dialogue between different disciplines (adapted from Locatelli *et al.*, 2021, *Sustainability Science*).

An environment conducive to interdisciplinarity

A conducive environment is vital if all types of profiles are to reach a common understanding that facilitates effective communication and collaboration. Interdisciplinary research projects are often very challenging because they take time and energy and can lead to misunderstandings between stakeholders. Philosophical support for taking a step back can lead to a better understanding of the values and epistemologies of the various disciplines, and consequently to being more open to another discipline. One example is The Toolbox Dialogue Initiative, a research and advisory group based at Michigan State University, which includes members from ten US universities. The group facilitates capacity building for collaborating with partners around the world and explores the practice of collaborative research with a focus on understanding interdisciplinarity and knowledge production (https://tdi.msu.edu). There is also impetus to create physical spaces for multidisciplinary or

multi-stakeholder exchanges, such as laboratories redesigned around an architecture that promotes meetings (e.g. the Learning Planet Institute, https://learningplanetinstitute.org) or co-working spaces that bring together various stakeholders around the same topic (e.g. *La Ruche*, https://la-ruche.net/). Finally, the field sites in the Global South, where IRD is working with its partners, are places of interaction and mutual learning that are very powerful catalysts for conducting multi-stakeholder and transdisciplinary research, since a strong and lasting link unites the research stakeholders around a single concrete problem. This research on a common research area provides an opportunity to analyse the issue of dialogue between disciplines and to compare the logic behind the co-production of knowledge, which is constructed in different ways in the two hemispheres.

KEY POINTS

Researchers with interdisciplinary and transdisciplinary backgrounds are key to generating new research ideas and facilitating communication between disciplines and stakeholders. An appropriate physical environment, support to step out of disciplinary comfort zones and collaborations on common research areas are all opportunities to stimulate interdisciplinary exchange at IRD.

Science diplomacy: state of play and perspectives

Jean-Joinville Vacher,
IRD, UMR PALOC, Paris, France
Anne-France Piteau,
IRD, Department of International Partners and Funding Bodies, Marseille, France

Background

In response to the global challenges of the 21st century, science and technology have become stakeholders in the 2030 Agenda. As stated in SDG 17 ("Revitalise the global partnership for sustainable development"), finding lasting solutions to the wicked problems of living sustainably on the planet requires coordinated efforts from researchers, diplomats and policymakers. These urgent needs have revitalised the field of science diplomacy in recent years.

Contact
spbi@ird.fr

Further reading
http://www.paloc.fr/fr/actualites/la-diplomatie-scientifique-au-21e-siecle-etat-des-lieux-international-et-perspectives

Science diplomacy: a recent concept at the heart of the international agenda

The relationship between science and diplomacy dates back many centuries, but it is only in the last ten years or so that science diplomacy has attracted new attention. One of the first instrumental contributions is that of the American Academy for the Advancement of Science (AAAS), which in 2008 created the Center for Science Diplomacy and since 2012 has published the online journal Science & Diplomacy. In early 2009, the British Academy of Sciences joined forces with the AAAS to organise an international seminar on "New Frontiers in Science Diplomacy". In 2015, the European Union (EU), initially through its Parliament and then through its Commission, set out a strategy for Europe to be a key player in global science diplomacy. It then launched the Horizon 2020 programme with three projects focused on science diplomacy. The major multilateral institutions, including the United Nations (UN), the World Bank and the World Health Organisation (WHO), have since the early 2010s expressed their willingness to give science a more prominent place in international relations. The UN has also taken the unprecedented step of entrusting the task of assessing the Sustainable Development Goals (SDGs) to a group of independent scientific experts. In France, the Ministry for Europe and Foreign Affairs (MEAE), without input from the Ministry of Higher Education, Research and Innovation (MESRI) or scientific institutions, published a report in 2013 entitled *Une diplomatie scientifique pour la France* (Science Diplomacy for France). In stark contrast to the momentum gained in many countries, France has not yet held any major meetings, seminars or forums on science diplomacy.

The main role and growing recognition of science diplomacy is based on three main pillars: globalised science, world science and universal science.

Globalised science

In 2000, fewer than 20% of the approximately 600,000 articles published worldwide involved international collaboration; by 2018, this rate had increased to around 50% of 1,800,000 articles (Web of Science data). This growth has been driven by the planetary dimension of major scientific issues and the digital revolution. However, although international co-publications are now the majority, with a strong contribution from Asia and significant growth in other countries of the Global South, the production of scientific knowledge remains very unbalanced. G20 countries published 95% of global scientific papers in 2018 (Africa published under 3%), and for too many countries in the Global South, the proportion of local researchers involved in scientific publications on a topic in their country is still generally less than 40%. An important and pioneering factor

in the globalisation of research has been the development of major international scientific facilities. There are now more than 100 such facilities worldwide, 77 of them in Europe. The European Centre for Nuclear Research, founded in 1954, and the European Southern Observatory, established in Chile in 1962, are emblematic of this global science.

Proactive global science combined with diplomacy, to understand the challenges of global issues

Global challenges require worldwide collaboration, knowledge, diagnosis and shared analysis, as well as coordinated proposals and decisions. Science has a duty to launch this response. The scientific community has rallied first to produce new knowledge to address these issues and then, in synergy with diplomacy, to build international scientific networks and intergovernmental platforms. This commitment has been accompanied by a shift in the relationship between science and policy: we are moving from a linear system of knowledge transfer from science to its applications to a global system of interactions between all communities concerned. Two prime examples are:

- on climate: the Intergovernmental Panel on Climate Change (IPCC), founded in 1988, produces reports involving thousands of scientists and political representatives. They have a major influence on government plans on climate change and on agreements reached at the Conferences of the Parties (COPs);
- on biodiversity: the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), founded in 2012, is a multidisciplinary and international scientific organisation under the aegis of the UN.

Universal science as a vehicle for peace and solidarity

Science, with its universal common language, its demand for sharing and dialogue, and its values of neutrality, is a powerful vehicle of diplomacy for peace and solidarity. Following the Second World War, the scientific community, working in synergy with diplomats, undertook determined efforts to promote dialogue between peoples and peace. There are many examples, from declarations, forums and meetings to networks and the formation of real research centres. These include the historic Russell-Einstein Manifesto of 1955 against the use of nuclear weapons and the quest for peaceful solutions, and the Pugwash meetings held in 1957 on science and world affairs, which received the Nobel Peace Prize in 1995. More recently, the Malta Conferences over the past 15 years have brought together scientists, including several Nobel Prize winners, to help broker peace in the Middle East. The creation of international research centres is another great example. UNESCO has been instrumental in creating several of them, including CERN, IIASA and SESAME. The demand for international solidarity with researchers in cases of human rights abuses and repression of freedom of research should be central to science diplomacy.

Building a common strategy and agenda

Major advances have been made over the last ten years on the concept, tool, functioning, objectives and challenges of science diplomacy. These contributions are the product of multidisciplinary and international approaches, which all agree on the fact that this tool is underused. Science diplomacy would benefit from better coordination and organisation by building a common strategy and agenda, developing synergies and joint tools between MEAE and MESRI, and involving the main research institutes (in the first instance IRD and CIRAD) and universities, the French Academy of Sciences, the French National Research Agency (ANR) and the French Development Agency (AFD). Given the rich scientific partnerships built by IRD with countries in the South, the importance of our diplomatic network and our development agencies, France, together with our research partners in the South, can play a leading role in developing strategies for scientific diplomacy and influence to tackle the global challenges of the region and the SDGs, while strengthening the ethical and fair aspects of these partnerships.

KEY POINTS

Over the past fifteen years, the international scientific and diplomatic community has taken a keen interest in science diplomacy and has begun to rethink how it might be used more effectively. Across its three main fields (globalised science, proactive science and science as a vehicle for peace), French science diplomacy has some noteworthy and highly regarded assets. However, it suffers from a lack of coordination and synergy between its main stakeholders and is relatively absent from the major global debates in this field.

Societal impact assessments of research for sustainability science

Michel Cot, Laure Emperaire, Isabelle Henry, François Roubaud,
Florence Sylvestre, Laurent Vidal and Jean-Daniel Zucker,
for the methodological group
Éric Martin, Ghislaine Thirion,
Research Evaluation and Programming Mission,
IRD, Marseille, France

Background

The goal of sustainability science is to help find solutions to steer our societies towards more sustainable lifestyles. Its "problem-centred" approach is thus closely linked to the issue of research impact and evaluation. At the end of 2016, IRD launched a pilot project on identifying and describing the societal impact of IRD's work in the Global South, using a qualitative approach based on ex-post case studies. To date, five studies have been carried out, providing sufficient data for an initial assessment of the project.

Contact
eric.martin@ird.fr

Further reading

Smit J. P., Hessels L. K., 2021 – The Production of Scientific and Societal Value in Research Evaluation: A Review of Societal Impact Assessment Methods. *Research Evaluation* : 1-13. https://doi.org/10.1093/reseval/rvab002

Background to the pilot project

Two principles guided the pilot project on identifying and describing the societal impact of IRD's work in the South.

Accountability: A research organisation such as IRD, funded mainly by public money, has a duty to account for the relevance and usefulness of the work it carries out: major scientific findings, the dynamics and importance of partnerships, contributions to society. It also has a duty to contribute to the sustainable development of countries in the Global South, which makes the question of research impact a central issue.

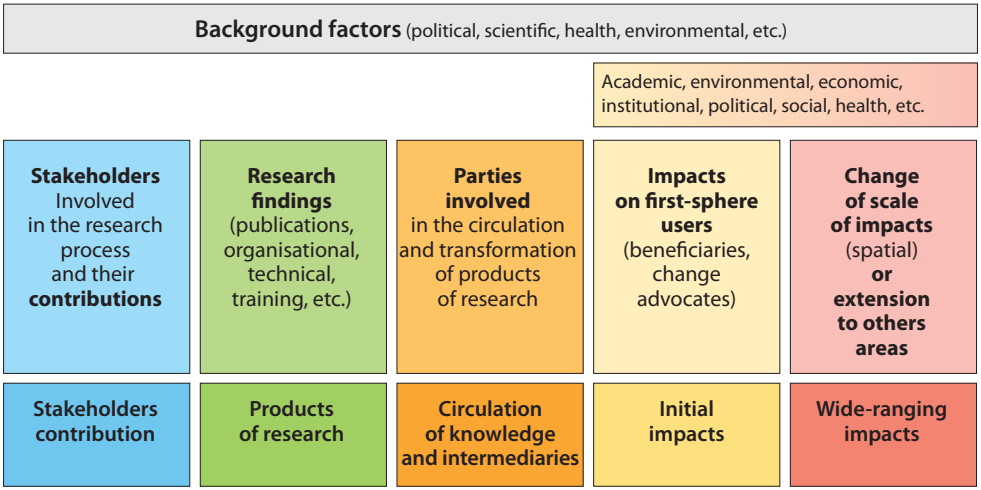
Reflexivity: Constructing and documenting the impact pathway of a research project means immediately questioning all aspects of scientific activity and becoming aware of the diversity of stakeholders who use research findings to achieve their objectives. Studying the impact of IRD research therefore means tracing the pathway taken and implemented to achieve research objectives, examining it, and emphasising that it is a long process, which is a prerequisite for successfully integrating our research into the priorities of countries in the Global South.

This project was supported by a methodological group, scientific rapporteurs for each case studied and a project team within the Research Evaluation and Programming Mission. The project had three main objectives: (I) to meet the expectations of IRD's supervisory bodies and the authorities of countries in the South with which IRD works regarding the impact of its research; (II) to improve the level of understanding of the stakeholders, factors and processes likely to facilitate the adoption of research findings, and thus their impact; (III) to provide teams with tools for analysing and describing the potential societal impact of their work, extending beyond the scientific sphere.

Description of the method and studies

The approach adopted was an adaptation of the ASIRPA and ImpresS methods, developed respectively by INRAE and CIRAD. It focuses on highlighting the impact path, its analysis and chronology; it describes how the research was carried out, its findings and how they were circulated beyond the academic sphere, the conditions for transforming and adopting them, and the impacts generated. Several impact dimensions, defined by the methodological group, are examined: academic, economic, environmental, institutional, political, capacity building, social-health-educational and cultural. The method focuses on highlighting the role of the stakeholders involved in this pathway, the causal links and background factors. The studies are documented through interviews with key stakeholders in the impact pathway and a report is produced using a standard template, which is then shared with the stakeholders involved to garner their feedback before being finalised.

Five studies have now been completed. They cover the following topics: (I) mining in New Caledonia; (II) the Humboldt Current and



Summary view of the impact pathway and its various components, documented with stakeholders.

fisheries management in Peru; (III) 1-2-3 surveys for measuring and analysing the informal economy; (IV) access to antiretrovirals in Africa; (V) volcanic processes and hazards in Ecuador. These studies were selected (from among 26 proposals from scientific departments) for their feasibility and the ability to cover differential impacts.

Some cross-cutting lessons

These studies describe research pathways with proven societal impacts. All of them highlight how important it is to involve IRD teams and their partners, not only in the research phase, but also in the intermediary phase (circulation, adaptation or transformation of knowledge, which leads to the first societal impacts).

In addition, they all lead to mutual capacity building. The partners consulted during the societal impact studies were interested in the methodology used and invested time in them. Aside from these shared characteristics, certain points specific to one or more studies appeared to be key to achieving a strong impact:

- multidisciplinarity, a driving force in the production of new knowledge for the mining study in New Caledonia and for the Humboldt Current and fisheries management study in Peru;
- the links forged with communities on the ground at the earliest stage of research, which made it easier for the populations concerned to accept and adopt the findings (volcanoes, antiretrovirals);

- a rapid response to government requests, made possible thanks to a longstanding partnership (antiretrovirals, volcanoes, informal economy);
- one or more IRD schemes (LMI/JEAI – for two studies) or foundational projects have had a positive impact on research momentum. IRD facilities were either behind the production of knowledge (Humboldt) or the completion of the initial research effort (volcanoes).

There may also be unexpected impacts. For example, work on evaluating the informal economy has resulted in a South-South transfer (from Vietnam to Peru) and a South-North transfer (to France for implementation in Mayotte).

KEY POINTS

The studies carried out in this pilot project serve as examples of how research work leads to societal impact, the diversity of paths taken and the key factors that produce strong impacts. These studies provide insights into how to build an impact culture specific to IRD. Apart from providing an after-the-fact justification of the relevance of IRD's scientific strategy and its policy of fair partnership, this type of study will provide a basis for building sustainability science that learns from experience and anticipates future impacts more effectively.

The Research Fairness Initiative (RFI): a tool for strengthening fair partnership

Perine Sanglier, Éric Martin and Julia Vallauri,
Research Evaluation and Programming Mission,
IRD, Marseille, France

Background

The Sustainable Development Goals (SDGs) represent an indivisible and universal agenda. All countries must equip themselves with the means to implement the transformations necessary to achieve these goals. Research and innovation for development require multidisciplinary and multi-institutional teams from the Global North and the Global South to work together (SDG 17). This cooperation is often challenged by imbalances in terms of resources, attainment and recognition. In this situation, the concept of a fair partner is more important than ever and, beyond the rhetoric, research stakeholders need to examine it in depth in order to achieve the SDGs. One of the pioneers in this area is IRD, which contributed to the Research Fairness Initiative (RFI) and has just submitted its first report. It is the first French organisation to do so.

Contact
julia.vallauri@ird.fr

Further reading
rfi.cohred.org

What is the RFI?

All research stakeholders (research institutes, universities, funding bodies, etc.) can be members of the RFI. The initiative encourages them to reflect on the equitable nature of their research partnerships and provides them with a range of resources and models to strengthen or supplement their practices. This process of reflection is especially important given that the definition of what is fair, and therefore what is equitable, can vary from one country to another and change over time. The RFI is now supported by the Council on Health Research for Development (COHRED), a non-governmental organisation that works to reduce inequalities and provide sustainable solutions to the health and development problems of people living in low- and middle-income countries. The RFI is therefore a significant contributor to SDG 17 "Strengthen the means of implementation and revitalise the Global Partnership for Sustainable Development". In practice, organisations wishing to contribute to the RFI write a report structured with headings and indicators agreed during global consultations organised by COHRED. The reports are produced every two years and are made public. The RFI initially focused on the health sciences, but has since expanded to cover all scientific fields, especially following the European CAAST NET Plus project (Advancing Sub-Saharan Africa-EU cooperation in research and innovation for global challenges, 2013-2017). This project was inspired by the Guide to Good Practice in Research for Development, published by IRD in 2015.

IRD's involvement in the RFI: a foregone conclusion

Promoting fair partnership is one of IRD's core values. The Institute's longstanding involvement in reflecting and acting on the concept of fairness is evident through the practices of its research staff and its day-to-day institutional commitments and mechanisms. Today, these practices are reflected in several roadmaps in which IRD is involved (environmental impact, gender equality, ethics in research, open science, etc.) and in particular in its approach to sustainability science. The RFI is not only about creating a level playing field for partners to work together, but also about understanding and compensating for existing inequalities to enable all partners to participate fully and benefit from the interactions between all stakeholders. The mechanisms for co-constructing knowledge and partnerships between the various stakeholders are at the heart of the Knowledge Communities (CoSavs) developed to support this approach. IRD's involvement in the RFI was therefore a logical consequence of its unique and historical position in the international landscape in the Global South, and of its interest in sustainability science methods and practices. It is against this background and with this goal of setting an example and improving the situation that IRD has called on its bodies, structures and agents to draw up its report (https://www.ird.fr/lird-precurseur-en-matiere-de-quite-des-partenariats).

Fair opportunities (before projects)	Fair procedures (project implementation)	Fair sharing of benefits, costs and findings	**3 areas**
Involvement of all stakeholders in project selection, relevance of research to the local context	Project mangement and stakeholder involvement, minimising negative impacts, recruitment and local procurement	Sharing of benefits and findings, and around research and innovation capacity building	**5 topics per area**

For each topic, the report describes the practices in place, the extent to which they have been formalised, the goals and potential action plans for progress on the topic. It also provides relevant documentation on the subject.

Structure of the content of RFI reports.

Sustainability science has an important part to play in this report, both in terms of acquired knowledge and new perspectives. A committee to monitor the improvement measures identified in the review of the current situation will shortly be set up, and IRD's Consultative Ethics Committee for Research in Partnership (CCERP) and Scientific Council will be asked to take part in a longer-term review of the approach and the role of IRD in the RFI.

Strengths and possible improvements

This important and intensive phase of reflection, combined with the consistent framework of the report, highlighted several of IRD's strengths in relation to fairness. These include:

- the high degree to which the systems and practices in general are documented and their transparency;
- the creation of the ethics mission, which will provide a structure for partnership relations and the necessary mediation mechanisms;
- partnership or capacity-building schemes in the South; schemes to support innovation in the South, which pay close attention to the views of partners;
- the strong commitment to implementing the Nagoya Protocol, in particular;
- obtaining the European HRS4R label, which supports the conduct of all research, regardless of its origin.

In terms of improvements, IRD was able to define priorities and propose a timetable of actions to:

- strengthen a culture of research impact (risks, spin-offs) in its teams and to think about designing its planning to take into account the concepts developed in the theory of change;
- improve the way it formalises the criteria and practices used to assess the actions it carries out, taking into account its partnership obligations;
- participate in monitoring and assessing the roadmaps it deploys on common challenges (the environment, youth and women, and open science).

KEY POINTS

Following a longstanding commitment to fair partnership, IRD has published its first report under the Research Fairness Initiative. IRD is using this report to embark on new actions related to the RFI and to strengthen its leadership at the global level. The exchange of good practices between organisations involved in the RFI and the knock-on effect of publishing the reports will accelerate the dissemination of fair partnership values within the global scientific community.

SDG summer school: sprinting towards sustainability science

Esthere Garnier,
Capacity Building Department,
IRD, Marseille, France
Leo Houdebine, Gaëll Mainguy,
Muriel Mambrini and Edward Stevenette,
Learning Planet Institute, Paris, France

Background

At a time when global changes are impacting the entire planet, there is an urgent need to transform lifestyles, ways of thinking and behaving. To do this, we need new knowledge and skills to deliver the solutions that will lead to more sustainable societies. Education systems must change, through pedagogical innovation, to create relevant learning content linked to sustainability science. This aim, part of the 2030 Agenda, is spelled out in SDG 4, which makes education a goal in its own right and a means of achieving all the SDGs. Learning differently and sustainably is the aim of the SDG Summer School, co-supported by IRD for the fourth time in 2021.

Contact
esthere.garnier@ird.fr

Further reading
https://www.ecole-odd.fr

A school at the crossroads between SDGs 4 and 17

To meet the challenges of sustainable development head on, the Summer School has built its identity around three key elements: education (SDG 4), links with partners in the Global South (SDG 17) and interdisciplinarity. Learning together is about co-constructing solutions based on collective intelligence, whatever your scientific discipline, nationality, culture or value system. As learners journey through the school, they become aware of the diversity and value of each individual's background, knowledge and skills. They come to realise that no research question that seeks to address a sustainability issue can be answered by a single discipline alone. The concept of the SDG Summer School can thus be translated into the following andragogical objectives: (I) to create a collective by identifying each other's skills; (II) to overcome obstacles to cooperation by sharing a common goal; (III) to understand the global nature of the SDGs; (IV) to work in an intercultural and interdisciplinary way; (V) to strengthen their knowledge of biodiversity; (VI) to strive to produce interdisciplinary, humanistic and holistic research questions. These specific objectives are linked to core competences, which need to be identified, and to innovative working methods, which are provided during the school.

An innovative methodology

Three methods are used in the school. The first is collective intelligence. There are no traditional lectures; instead, the group draws on its synergies to produce collective ideas. This is work that is impossible to do alone. The second is interdisciplinarity. The assumption is that combining disciplines results in the group acquiring this interdisciplinary vision. This work requires getting to know each other through activities and games, building a sense of trust between participants. This is the only way to tackle the full complexity of the issues related to the SDGs. Together, participants create a continuum of knowledge and experience that is broader than it would be if they operated in disciplinary silos. Not only may their disciplines be complementary, but the working methods they each use provide a pool of knowledge that nurtures this interdisciplinarity and strengthens any response the group may propose. Lastly, the project-based approach involves choosing a theme and working method that encourage creativity, inventiveness and initiative.

The main stages of the SDG Summer School are:[1] three main opening lectures, a MOOC[2] and a three-day sprint with master classes on (I) scientific hypotheses, (II) the development of a research question and (III) the scientific pitch. Alternating between iterative work sessions in project mode and sessions with the mentors

1 • 2021 Programme: https://www.ecole-odd.fr/programme.html
2 • Mainguy G., What are the solutions for a sustainable world? https://www.learningplanetinstitute.org/en/solutions-for-sustainable-world#

Screenshot of the 2021 Summer School held fully online.

provided an opportunity to challenge and refine ideas and to flesh out the final research question. In all, a project steering committee, a selection committee, a jury, teachers, trainers, mentors, experts and seminar participants had the opportunity to take turns speaking or attend parallel workshops. It was a carefully orchestrated dance of "learning to achieve together".

SDGs 14 and 15 x One Health in 2021

During the Summer School, the participants created interdisciplinary research questions related to the theme chosen for 2021: SDGs 14 and 15 on terrestrial and marine biodiversity, at the crossroads with the One Health approach. Over the course of the three-day sprint, six groups of four to five young scientists each worked on developing research questions based on their own knowledge and skills. For example, one group, consisting of a biologist, a computer scientist, an environmentalist and a sociologist, asked the question: "To what extent can artificial intelligence help stakeholders control the emission of industrial waste to reduce marine pollution?" Another group, made up of an oceanologist, a waste biologist, an environmentalist and a computer scientist, asked the

following question: "Under what conditions can prickly pear cultivation be sustainable, serving biodiversity in arid and semi-arid areas?"

Successful digitalisation

The school was held for the fourth time in July 2021, after a 2020 edition that had successfully adopted a digital format due to the pandemic. Eleven facilitators received two days of training from the Centre for Interdisciplinary Research to support the 30 or so participants during the three-day sprint. Their role was to lead, facilitate, reassure, energise, moderate, sometimes fade into the background and, last but not least, motivate so that each group could come up with a unique, interdisciplinary research question that fitted the theme. On top of this, they had an almost magical box of activities and facilitation tools. On a technical level, the use of Zoom, Google Drive, Slack and WhatsApp ensured that no one was left on the sidelines, despite the sometimes poor connections.

What next?

Two areas of work are being explored to ensure that this SDG Summer School can be easily replicated. The first is creating a pool of facilitators trained by the Learning Planet Institute (LPI), which could repeat and expand the experience in the future. Second, the school's partners (AFD, Aix-Marseille University, LPI and IRD) are planning to distribute free video clips to explain the methodology for setting up this type of school. The goal is to capitalise on and spread the concept to countries in the South to stimulate the creation of interdisciplinary and intercultural projects, as these are the driving force behind change and sustainability science.

KEY POINTS

The interdisciplinary approach and revised andragogy are the two main thrusts of the SDG Summer School, placing otherness and sharing in the foreground. In this way, the group is committed to addressing concrete issues directly related to the SDGs. The participants take the time to listen to each other, to recognise each other's knowledge, and to break free from one's disciplinary stance. These are all challenges that, once overcome, facilitate interdisciplinary work. The support and innovative methods developed within the school, combined with this interdisciplinarity, encourage the emergence of new ideas that contribute to achieving the Sustainable Development Goals by 2030

Digital data and sustainability

Michel Labadie,
Department for the Development of Innovative Digital Uses,
IRD, Marseille, France
Jean-Christophe Desconnets and François Sabot,
Open Science Mission,
IRD, Marseille, France

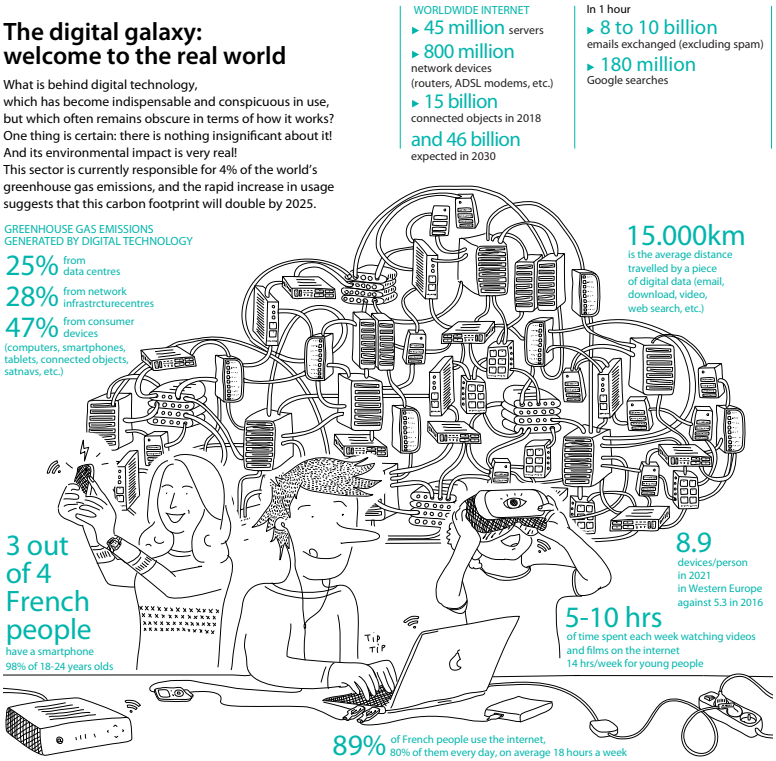
Background

Digital technology is a key driver in every transformation strategy, whether for governments, companies or the general public. This obviously includes the higher education and scientific research sector. This rapid increase in the use of digital technology, which rose tenfold during the Covid-19 pandemic, is often cited as a lever for reducing the environmental impact of our organisations, by limiting travel for example. However, for this reduction to be sustainable, the environmental footprint of our use of digital technology must be taken into account. IRD has chosen to make this concern central to its digital transformation strategy and its environmental roadmap.

Contacts
dduni@ird.fr
mso@ird.fr

Further reading

Derakhshannia M. *et al.*, 2020 – Data lake governance: Towards a Systemic and Natural Ecosystem Analogy. *Future Internet*, 12 (8) : 126.



Greenhouse gas emissions generated by digital technology (source: ADEME).

What we know

Digital technology is opening up new practices that are transforming the way we work. However, to work properly, we know that digital technology is resource hungry: building equipment such as mobile phones, computers and servers requires rare-earth and precious metals, running data centres and networks requires electricity and water for cooling. To avoid repeating the mistakes of the past, when fossil fuels were used to accelerate economic development, digital technology must be used with due consideration for its environmental impact. In 2018, digital technology was responsible for 3% of global greenhouse gas emissions, roughly the same as emissions from air travel. Some studies predict that within a few years, these emissions will reach a level equivalent to that of private car transport (https://theshiftproject.org/).

Even though producing and storing research data is not the main cause of the acceleration of digital transformation, IRD has chosen to put environmental responsibility firmly at the heart of its commitment to sustainability science. Promoting sustainability science to build pathways towards a more sustainable society also means considering the sustainability of research practices. This issue is naturally part of IRD's digital strategy.

Working towards FAIRS research data

Creating a policy for managing the data produced by IRD and making it openly available falls more broadly within the scope of research data governance at the Institute. This approach must include an environmental responsibility dimension. It is aligned with the national strategy for open science and involves a process whereby scientific outputs are gradually brought into compliance with the FAIR principles: Findable, Accessible, Interoperable and Reusable. The "reusable" principle is an important goal for IRD: it is key to fostering interdisciplinary approaches and addressing thematic challenges, but it also poses an environmental risk if no consideration is given to appropriate data retention practices (what data should be retained? for how long and on what medium?).
It is in some ways an illustration of the friction between SDG 17 (partnership for the Sustainable Development Goals) and SDG 13 (action against climate change). Consequently, in an effort to remain mindful of the environmental footprint of the data produced by science, IRD is keen to add Sustainable to these principles. This means expanding the FAIR principles by adding a fifth that covers the environmental dimension. It aims to minimise and assess the environmental footprint of retaining and distributing digital outputs through the use of FAIRS (Sustainable/Sensitive to the environment) data.

How to develop FAIRS data?

In an effort to further develop the concepts of open science, the FAIRS principles will provide recommendations and practices on how to include the environmental cost of storing the data produced. Several work streams have been identified:

- developing a policy and recommendations for data management and retention: To be shared and implemented, data management rules and good practices need to be widely publicised. This work is included in IRD's Open Science roadmap and in projects to implement storage tools such as DataSuds;
- mapping research data storage and providing tools: Implementing technical solutions that are less resource-intensive requires an understanding of where the data are hosted. This inventory must be aligned with the data management strategy. The use of the latest technologies will make data management more efficient (e.g. data lakes);

- measuring the environmental impact of IRD's digital tools: Governance has encouraged a process of building dashboards to monitor activity within IRD. The aim is to develop indicators to measure the environmental impact of IRD's tools;
- collaborating on processes within joint research units (UMRs): Several structures within IRD, aware of the need to reduce their environmental footprint, have already undertaken work to reduce their infobesity (reducing the use of email, limiting printing, etc.). Supporting them in their efforts is essential to maintain momentum within IRD;
- supporting partners in countries of the South: As most of IRD's research is conducted in developing countries, promoting the implementation of data management solutions in the countries where the data is collected is essential. Beyond the issues of partner sovereignty, these tools will help to limit data transfers over resource-intensive computer networks.

KEY POINTS

IRD is mindful of its environmental impact and has therefore incorporated environmental awareness into its work, particularly in digital projects. This approach operates across sustainability science's three pillars (Science, Development and Support) and in partnership with the higher education and research ecosystem. To ensure maximum buy-in to the process and to make it sustainable, emphasis is placed on being especially sensitive to research data. IRD is proposing to include the sustainability of digital practices as one of the main principles of open science so that FAIR (Findable, Accessible, Interoperable, Reusable) data becomes FAIRS (Sensitive to the environment/Sustainable) data.

Artificial intelligence for sustainability science

L. Berti Equille,
UMR Espace-Dev, Montpellier, France
A. Drogoul and J.-D. Zucker,
UMR UMMISCO, IRD, Bondy, France

Background

The emergence of artificial intelligence (AI) and data science is transforming not only our societies, but also the way research is conducted, structured and understood in other scientific disciplines. Sustainability science, which aims to find sustainable solutions within planetary boundaries, is one such discipline because of its reliance on data and models. But what can AI do today? What impact might AI have on sustainability science and the SDGs? These are important questions for IRD researchers, many of whom are already using AI in their own research.

Contacts
laure.berti@ird.fr
alexis.drogoul@ird.fr
jean-daniel.zucker@ird.fr

Further reading

NISHANT R. *et al.*, 2020 – Artificial intelligence for sustainability Challenges, opportunities, and a research agenda. *Int. J. Inf. Manag.*, 53 : 102-104.

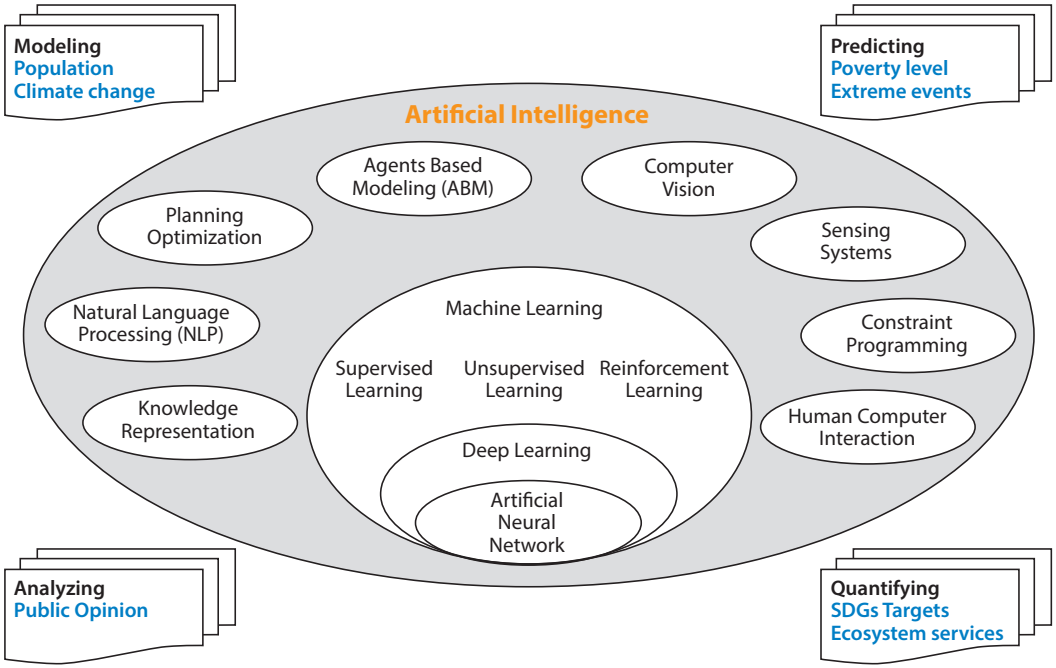
AI today and its success in many different areas

Artificial intelligence (AI) is defined as "the set of theories and techniques used to create machines capable of simulating human intelligence". Its use has become indispensable for all sciences needing to scale up (increase their processing capacities as the volume of data increases) to extract knowledge or build models from masses of data. AI has been interdisciplinary since its inception, just like cybernetics, which played a key role in its emergence. It has absorbed and advanced theories and techniques from many fields, including computer science, statistics, epidemiology, economics and biology. But one of the undeniable reasons for the meteoric rise of AI is linked to its success over the last ten years in reproducing and even surpassing human capabilities in an ever-increasing number of tasks. This is largely due to the success of Machine Learning and, more specifically, Deep Learning, which gives AI models the ability to be unbeatable at the game of Go, to excel at driving cars, to diagnose cancer from medical images and to detect galaxies. In the words of world-leading expert Andrew Ng: "If a human can perform a mental task in less than a second, it's likely a computer aided by AI can take over that task".
And this process often involves building classification or prediction models, which are automatically learned from data.

There are many ways in which AI can be applied to sustainability science (Nishant *et al.*, 2020): to quantify, analyse and monitor biodiversity, air and soil pollution or changes in climate; to plan how sustainable cities or traffic will be managed; to model solutions for energy transition or for the conservation of natural or water resources; to predict and reduce the risks of disasters, etc. But AI is not just limited to Machine Learning. It also offers ways and means of putting interdisciplinarity "into practice" through the wide range of formalisms it employs (mathematical, logical, rule-based, agent-based, etc.) and of generating and exploring "possible" scenarios (knowledge creation in ways that are neither inductive nor deductive, but generative) for different uses because of the various modelling scales (spatial and temporal) that it combines. Furthermore, the tools that AI develops as part of participatory approaches foster collaboration between various scientific communities, in fields as varied as economics, climatology, oceanography and ecology.

Using AI to achieve the SDGs

AI4Good, AI4SG, AI4Climate, AI for Climate Action are all names for the many initiatives and movements currently under way, whose aim is to build international communities of knowledge and expertise that use AI to address climate and social issues. These joint research and development efforts on theoretical, methodological and applied aspects place the SDGs squarely at the heart of the fields in which AI is used and are already demonstrating its very great potential in many sectors. AI applied to



The fields of AI in the centre and some examples of applications at IRD in the four corners.

the SDGs requires interdisciplinarity with the added benefit of adhering to the FAIR (Findable, Accessible, Interoperable, Reusable) and CARE (Collective Benefit, Authority to Control, Responsibility, Ethics) principles. These principles apply to data as well as to AI outputs and developments such as predictions, estimates, classification results, clustering results, simulations, models, knowledge representations and their computer code. Furthermore, one of the advantages of AI is that it lends itself to rapid operational deployment in many technical areas related to sustainable development. It has been positioned for several years as a key technology for transition, adaptation and crisis management, drawing on data from several disciplines. For example, it has been used to estimate the amount of carbon sequestered by forests from LiDAR data, providing a means of estimating tree heights; to assess and predict poverty from satellite images in places where social and economic surveys cannot be conducted; and to create near-real-time maps and disaster evacuation strategies using data from social media platforms and aerial photographs.

Lastly, the strength of using AI to help achieve the SDGs lies in its ability to take into account different scales of time and space by leveraging data of various types (text, images, audio, video, etc.). It also has the potential to provide methodologies that can be replicated and automated at low cost and used to answer a variety of thematic questions, while taking into account externalities, socio-technical aspects of solutions and human expertise. Myriad initiatives provide evidence of these benefits, as does the "actionability" of AI for the SDGs. These initiatives also raise more general questions about the role of AI in society (and societies) and about the role IRD wishes to play in this international drive to use AI, as a legitimate stakeholder and contributor in partnerships in the Global South.

KEY POINTS

AI has the potential to be a key enabler in the development of sustainability science. AI is, by construction, interdisciplinary and takes an approach that favours the modelling of complex systems by providing tools to strengthen dialogue between experts and to co-construct knowledge on sustainability science models. Furthermore, through learning, it enables the construction of innovative tools for the SDGs. We have a great deal of room for improvement and a role to play in making IRD a leading contributor to the international drive to use AI to help achieve the SDGs.

Together for climate action

Nicolas Gratiot,
IRD, UMR IGE, Grenoble, France
Géraldine Sarret,
CNRS, UMR IsTerre, Grenoble, France

Background

One of the targets of SDG 13 (Climate Action) is to improve education, awareness-raising and human and institutional capacity on climate change adaptation. Participatory workshops and serious games, designed to bring together a community of stakeholders to solve challenging problems using a fun interface, can be useful tools in achieving this.

Contact
nicolas.gratiot@ird.fr

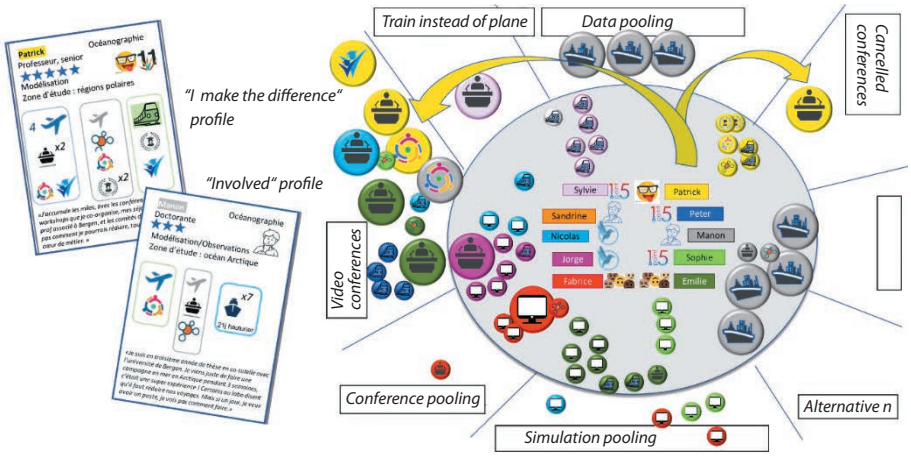
Further reading
https://materre.osug.fr

My Earth in 180 Minutes: a participatory workshop for climate action

As part of the Labos1point5 initiative and in light of the fact that nearly two thirds of the carbon footprint of our research laboratories is directly linked to the choices made by our staff, a group of researchers from IRD pondered the following question: how can we make our community of scientists aware of the need to reduce our carbon footprint and think together about alternatives to air travel, less intensive computing and more frugal field missions? To address these issues in a fun and friendly way, and avoid a moralistic tone, they created an online participatory workshop called "My Earth in 180 Minutes". This workshop includes a collaborative game phase that features research teams made up of characters (inspired by real life) with various profiles, such as the "what's-the-pointist" ("what's the point of reducing my footprint if others aren't doing anything?"), the hummingbird ("I'm aware of the issue, I've changed my individual practices"), the "bulldozer" ("my fame and my work justify my travel, full stop") and the "activist" ("I'm involved in collective action for climate change"). Playing the part of characters whose opinions we do not necessarily share helps us gain a better understanding of the different possible points of view and identify levers for changing behaviour. Based on these characters and the stringent extraction of greenhouse gas emissions carried out by the research teams, the players set out on the game board the requirements and constraints for carrying out meaningful science while changing their practices and limiting their carbon footprint.

50% reduction in greenhouse gas emissions: an achievable target

The goal of the workshop was to reduce GHG emissions by 50% by asking questions about travel (by air, car, train, boat) and activities (field missions, modelling, conferences, etc.). Each game during the role-playing phase was recorded, providing valuable material for analysing behaviour and resistance to change, breaking down our certainties, and stimulating our imagination to invent the academic world of the future. At the beginning of November 2020, some 50 people took part and more than 150 observers shared their views on the inventiveness and acceptability of the solutions proposed by the players to reduce their carbon footprint. The good news was that every team managed to reduce its emissions by at least 40%, and three quarters of them came up with scenarios to reduce their emissions by more than half, a target that has galvanised the international community. One of the key solutions for achieving the targets is the use of video conferencing to replace certain field missions, attendance at conferences and thesis juries. Some players pointed out that just a year ago it would not have been so easy for them to imagine video conferencing as an alternative to travel. The Covid-19 pandemic has already made us rethink our old habits.



Example of character cards (left) and the play board at the end of the Modelling team's game (right). The team identified alternative scenarios, moving tokens from the centre to simulate the reduction in emissions (-52.3% of tCO2eq in this game).

The benefits of this participatory workshop

So, what are the benefits for the players and more broadly for higher education and research? The first benefit is awareness of their own work-related carbon footprint and that of the scientific community in which they work. This greater understanding during the workshop is consistent with the rigorous quantification of CO_2 emissions carried out by research units, which is nowadays made easier by the 1point5 GHG tool developed by Labos1point5. Following the introduction of "nutriscores" for the agri-food industry, why not a "climate score" for the academic world? A second benefit is that it allows everyone to think about and come up with practical ways of limiting emissions: video conferencing, of course, but also sharing field missions and streamlining activities that consume fossil fuels. New ideas emerged from every game. These alternatives to our current practices not only impose restrictions on us, they can also have positive effects: rethinking our relationship with time and how we organise our work-related activities (particularly when travelling); identifying a shared objective for the team; innovating when it comes to collecting data from the field; taking advantage of the increasing usability of digital tools to create new ways of collaborating, while remaining watchful of the rebound effect and the need for digital frugality.

The increase in the number of online conferences has also resulted in greater fairness and improved representation of the research community, particularly from the Global South. The "My Earth in 180 Minutes" workshop, which was designed and then launched during the two Covid-19 lockdowns in France, epitomises this hybridisation towards digital technology in both form and content, but without leaving out the human element.

But perhaps the greatest benefit is seeing the discussions shift from individual to group-based considerations. All the teams who took part demonstrated how important collective intelligence is to winning. One participant, paraphrasing the American psychologist and philosopher John Dewey, said: "My Earth in 180 Minutes made me realise the full potential of this participatory workshop. I was really impressed with this excellent approach to 'liberating [...] the creative and transformative potential of the human race'."

Beyond the game: reconnecting with researchers' social contract

Other ideas emerged during the awareness-raising and debriefing phases of the workshop. For example, some researchers would like to use it to reduce other practices such as the overuse of plastic, eating habits that are still too meat-heavy, energy efficiency of equipment and the fight against device obsolescence. In addition, the scenarios created during the role-playing phase provided new material for understanding more about the psychological barriers to change, group dynamics and the balance required between individual initiatives and collective action. Assuming the workshop succeeds in proposing credible and innovative solutions to quantitatively reduce our carbon footprints in the virtual world, the next challenge is to use it to transform our laboratories in the real world. Could a what's-the-pointist turn into a hummingbird?

KEY POINTS

Although there are still many challenges, this experience shows that there are solutions to changing our travel patterns, reducing our emissions and collectively rethinking a more sustainable approach to scientific research as part of a joint effort to limit climate change. Researchers in the 21st century must change their behaviour and become aware of the balance they need to strike between their freedom to question and their responsibility to society. Promoting collaborative initiatives such as participatory workshops and role-playing games will create buy-in among researchers and generate real and lasting systemic change.

SUBJECT INDEX

GEOGRAPHICAL INDEX

SUSTAINABILITY SCIENCE
UNDERSTAND, CO-CONSTRUCT, TRANSFORM

Over seventy authors from throughout IRD - scientists, heads of department, project officers and members of civil society - share their knowledge and skills in sustainable development research.
In these pages, their different views form an interdisciplinary and cross-sectoral insight into sustainability science, and provide the reader with food for thought on this emerging approach.

IRD Institut de Recherche pour le Développement FRANCE