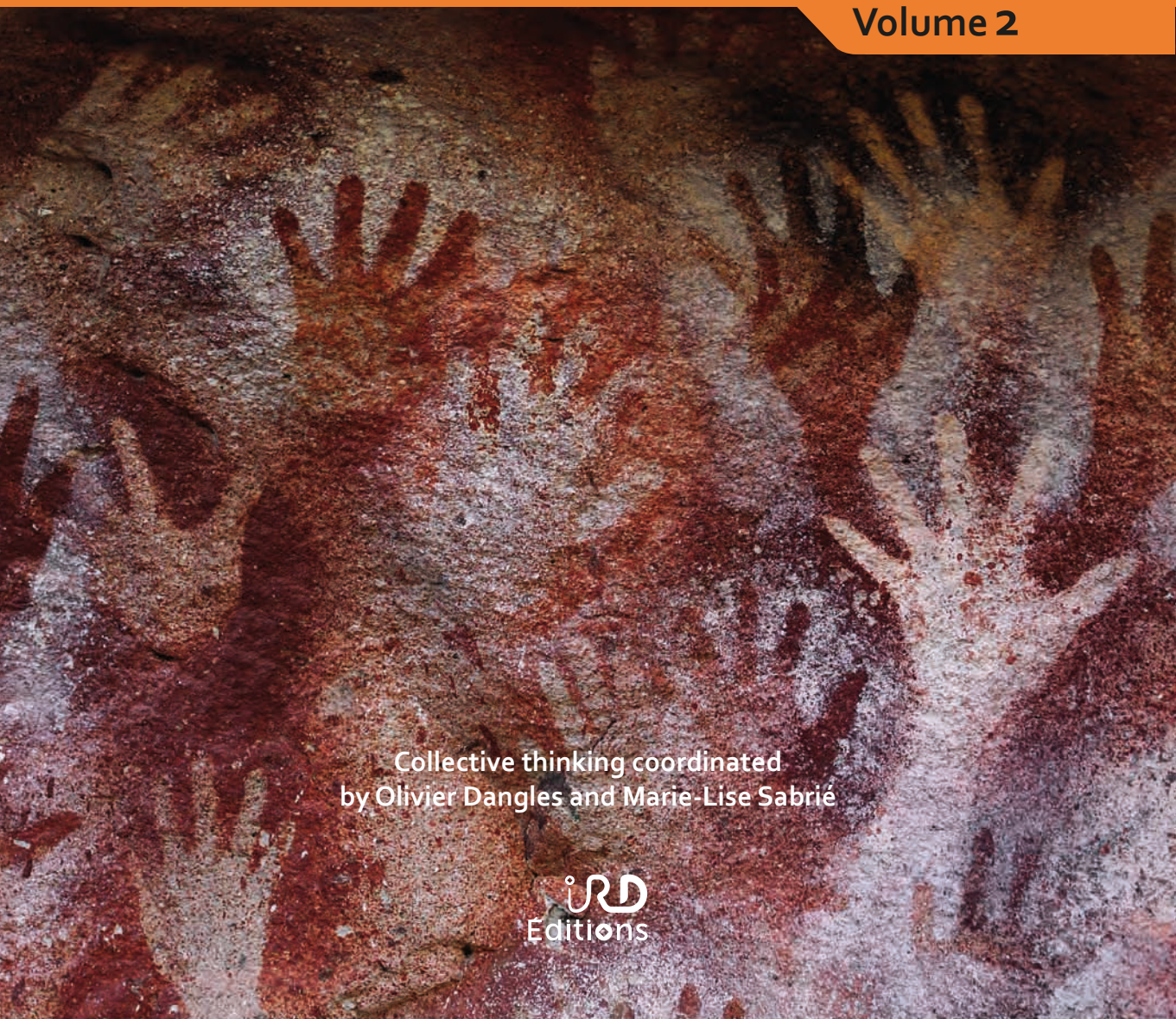
SUSTAINABILITY SCIENCE

UNDERSTAND, CO-CONSTRUCT, TRANSFORM

Volume 2



Collective thinking coordinated
by Olivier Dangles and Marie-Lise Sabrié

IRD Editions

SUSTAINABILITY SCIENCE

UNDERSTAND, CO-CONSTRUCT, TRANSFORM

Volume 2

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SUSTAINABILITY SCIENCE

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by Olivier Dangles and Marie-Lise Sabrié

IRD Éditions

French National Research Institute for Sustainable Development
Marseille, 2023

D2S follow-up of the articles: Claire Fréour and Magali Laigne
Editorial coordination: Marie-Laure Portal-Cabanel
Cover: Charlotte Devanz
Design and layout: Aline Lugand

Cover photo: Rock painting, Cueva de las Manos, Argentina.
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PDF version ISBN: 978-2-7099-3003-1

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* Vol. 1 (IRD Éditions, 2022) : https://www.editions.ird.fr/produit/685/9782709929820/sustainability-science
Vol. 2 (this book, IRD Éditions, 2023) : https://www.editions.ird.fr/produit/698/9782709930031/sustainability-science

RESPONSIBLE CONSUMPTION AND PRODUCTION

CLIMATE ACTION

LIFE BELOW WATER

LIFE ON LAND

PEACE, JUSTICE AND STRONG INSTITUTIONS

PARTNERSHIPS FOR THE GOALS

ALL ODDs

PREFACE

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

Since 2020, IRD has embarked upon a process of reflection on sustainability science and how it might serve as a unifying and collective approach to IRD's research themes and activities carried out in partnership with academic communities and research institutions in developing countries and French overseas territories. Placing sustainability science at the heart of scientific policy will enable IRD and its partners to produce the knowledge required for a holistic understanding of the challenges facing the Earth's habitability in the Anthropocene Era, to position their research within the 2030 international development agenda, to clarify their contribution to scientific diplomacy, and to reflect on the way their research is produced (carbon footprint, equitable partnership, etc.) and its impact on the societies of partner countries and territories. All these objectives are an integral part of our 2021–2025 Contract of Objectives, Means and Performance (COMP), signed last year with our two supervisory ministries.

However, the practice of sustainability science is not something that IRD's governance dictates. In line with the philosophy of the Knowledge Communities (CoSavs), the interdisciplinary and cross-sectoral collective intelligence platforms launched in 2020, our aim is to encourage IRD staff to reflect on their professional purpose and practices in a changing social and academic world. This reflection process is relevant to all IRD staff, who must work collectively and effectively to achieve the Institute's missions and the objectives set out in the COMP. It is also relevant to colleagues throughout the IRD world, in the countries and territories of the South but also in our joint research units, and more generally in the world of research and development (donors, NGOs, diplomats, etc.). It was with this aim in mind that we created the "Sustainability Science Reference Articles", which are published by IRD Éditions each year in a booklet and for which I have the pleasure of writing the preface.

The 2023 edition of the *Sustainability Science* booklet contains 42 articles written by almost 100 co-authors. It highlights the vibrancy of this multi-faceted approach, its influence throughout the IRD world, and the involvement of our colleagues in the Global South. I have personally reviewed each of these articles with care and interest. I have been able to gauge and assess the extent to which the conceptual and methodological frameworks of sustainability science are being strengthened and consolidated within our community, and how they are bringing together the different disciplines, research subjects and fields that make up the great diversity and distinctiveness of our Institute. The intercultural reflections of our IRD community are a rich source of information for any reader seeking a better understanding of the challenges of sustainability science, based on real-life experiences and examples of projects centred around the three pillars of "Understand", "Co-construct" and "Transform". These reflections come from authors with diverse profiles – PhD students, post-doctoral and young researchers, representatives, co-directors of international joint laboratories and administrative staff.

I am very grateful to all the authors and editors of these texts for their contributions. Thank you.

INTRODUCTION

Olivier Dangles and Marie-Lise Sabrié
IRD, Science Division

We have entered the era of "polycrisis". A civilisational tipping point, a period of major transition that is upending our certainties and calling on us to work together to find alternative paths to a better world. While a large part of the academic world has long kept its distance from the world's vicissitudes and society's most pressing needs, today the ever-increasing intrusion of global crises – health, environmental and political – into laboratory life is blurring the boundary between the researcher and the citizen. Manifestos, open letters to politicians, acts of civil disobedience: the list of committed and even militant initiatives is growing by the day. The introduction of energy-saving measures in laboratories is also part of this mobilisation of the research community.

Alongside these bottom-up actions by individuals or groups, research institutions such as IRD are looking at how their scientific policy, organisation and operations need to evolve if they are to produce science that is useful for improving the living conditions of the biosphere, particularly in the poorest countries. This kind of research is generally classified as engineering or applied science and is often "disparaged" by the academic world. But over the last twenty years or so, the production of knowledge in direct response to societal problems has given rise to a new field of interdisciplinary research, highly prized by leading international universities and the younger generation: sustainability science. A field at the interface of the sciences and the humanities, it is developing its own theories, concepts and methodologies, with one major objective: to identify sustainable solutions to major planetary upheavals. It is a science that responds to emergencies, at a time of intellectual, technical and technological effervescence, with a commitment that begs the questions "how far can we go in terms of commitment?" and "how do we protect the essential independence of research?" – and it encourages researchers to reflect on this.

It was against this backdrop that IRD launched this collaborative editorial project on sustainability science last year. In this second volume, researchers, engineers, technicians and diplomats continue to revisit their knowledge and practices and examine their subjects of

study, their expertise, know-how and interpersonal skills. As in the first volume published last year, this booklet is organised around the three major challenges of sustainability science: understanding the complexity of the world, co-constructing across disciplines and with society, and transforming our lifestyles and institutions. This three-part format encourages readers to explore the various texts without worrying about disciplinary boundaries, because it is primarily their specific subjects that provide a wealth of learning opportunities. Understanding the dilemmas linked to agricultural and food policies, gender and education, recognising that our attitudes transcend our abilities, transdisciplinary co-construction methods, and knowledge of the foundations of the theory of change are all cross-cutting issues in projects linked to sustainability science. These fundamental reflections are accompanied by examples of practical applications in the field (water management on the Bolivian Altiplano, the conservation of East African deltas, air pollution in South-East Asian cities, etc.) or in institutions (working differently at IRD headquarters, university training programmes, etc.). These wide-ranging viewpoints weave together the threads of an integrated approach to "doing science differently".

More than just words and ideas, this booklet is also a call to action for the world of research, a call for a paradigm shift in the way we engage with the issues facing humanity and the planet. Though largely ignored by the scientific community since their launch in 2015, the 17 Sustainable Development Goals (SDGs) are even more relevant today as a means of directing sustainability research towards clear targets that will help build a more sustainable world. Admittedly, this agenda needs to be analysed, criticised and improved, but for the time being it remains the best tool we have for bridging the gap between political decision-making and the knowledge generated by academic research. Time is running out. We need to move fast.

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.

Sustainable coexistence between humans and wildlife and the challenge of zoonotic diseases

Julio Benavides,
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Background

The rise in human activities in the natural environment is leading to increasingly frequent contact between humans and wild animals. Interactions with wildlife are sometimes seen as a conflict that needs to be mitigated, but they also bring benefits to people, in terms of tourism and psychological well-being, for example. These interactions are also a source of disease transmission, with major negative consequences for global public health and wildlife conservation. The development of integrated One Health approaches is a major challenge if we are to understand and limit this health risk.

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Further reading

Hopkins S. R. et al., 2021 – How to identify win–win interventions that benefit human health and conservation. *Nature Sustainability*, 4 (4) : 298-304.

Benefits and conflicts of human-wildlife interactions: the need for interdisciplinary science

A major objective of the United Nations Convention on Biological Diversity is to "live in harmony with nature". It is not uncommon to see birds or bats in gardens, seagulls eating out of litter bins at beaches, or monkeys begging for food in towns and at tourist attractions. Human-wildlife interactions are a source of many benefits. Wild animals in close proximity to humans bring benefits on which little research has been done to date, such as ecosystem services (for example, pollination or the control of insect proliferation by bats), economic activity linked to tourism and psychological well-being. Some wild species adapt to environments that have been reshaped by humans, such as urban areas, despite the consequences for their long-term survival, which are still poorly understood. However, the actions of wild animals can have a negative impact on humans, and vice versa. Countless initiatives and studies are under way to limit the impact of certain human activities, such as the expansion of agriculture, urbanisation, deforestation and hunting, with the aim of conserving wild species. Wild animals can also damage property, attack humans and transmit diseases, which can sometimes lead to negative attitudes in the communities affected. The implementation of effective coexistence strategies to maximise the benefits and minimise the conflicts associated with human-wildlife interactions is hampered by a lack of understanding of their causes, the diversity of socio-cultural contexts and the multiple ecological and socio-economic consequences. Developing appropriate sustainable strategies therefore requires an interdisciplinary understanding of these conflicts, multi-stakeholder dialogue and knowledge from a variety of fields, including ecology, social sciences, veterinary medicine, economics and public health.

The One Health approach to studying diseases at the human-wildlife interface

Increased interaction between humans and wildlife can increase the transmission of diseases from wildlife to humans (zoonoses) and from humans to wildlife (anthroponoses). However, little is still known about why these diseases emerge and how they circulate. This lack of knowledge considerably reduces our ability to implement effective strategies to preserve the quality of human-wildlife coexistence. Over the last 15 years, with a strong focus on the Covid-19 pandemic, the One Health approach – along with other approaches such as Eco Health (reinforcing the ecosystem approach) and Planetary Health (more focused on human health) – "recognises that the health of humans, domestic and wild animals, plants and the wider environment (including ecosystems) are closely linked and interdependent" (definition by the One Health High-Level Expert Panel). This approach shares the principles of sustainability science, such as equity, multi-stakeholder co-construction, transdisciplinarity and the implementation of solutions designed to contribute to the sustainable development of societies. The One Health approach to human-wildlife coexistence aims

Common marmosets *(Callithrix jacchus)* eating a banana offered by the inhabitants of Salvador de Bahia, Brazil.

to gain a better understanding of how human factors (e.g. deforestation, hunting) increase disease transmission, identify the human and animal populations that are most exposed and vulnerable, and assess effective strategies for reducing health risks, taking into account the socio-economic and cultural factors of the societies in which we work. This approach helps to answer open questions such as: what are the trade-offs between the many health benefits and risks associated with living in close proximity to wild animals? Can we limit the circulation of pathogens in wild animals that come into frequent contact with humans? What are the health and social consequences of wild species occupying urban environments?

The delicate coexistence between humans and wild primates in Brazil

In several major Brazilian cities, for example Rio de Janeiro, São Paulo and Salvador de Bahia, groups of common marmosets *(Callithrix jacchus)* or penicillata monkeys *(Callithrix penicillata)* are a frequent sight. These monkeys, endemic to Brazil but also transported and released by humans outside their natural ecosystem, can adapt to urban life and become invasive species in certain regions of the country. In cities, they are mainly seen as "cute", "hungry" and "funny" animals, who become accustomed to the food supply and make their homes mainly around

green spaces. However, this positive relationship does not come without consequences for human health, including hundreds of bites from the monkeys every year, posing a risk of transmitting diseases such as rabies, of which the common marmoset is a reservoir. Monkeys are also at risk of being infected by human viruses such as herpes, which are fatal to them, while diseases such as yellow fever can kill thousands of primates (e.g. howler monkeys, *Alouatta sp.*) and hundreds of unvaccinated people. Our team is working in Brazil to develop a One Health approach to limiting the health risks associated with this coexistence between humans and wild primates, which requires ongoing dialogue between public health, conservation and social science stakeholders and the populations in question. For example, we are working in partnership with public health authorities to gain a better understanding of how pathogens such as rabies circulate in common marmosets and to improve the care of patients bitten by these animals. We are also working with Brazilian researchers from a wide range of disciplines, including social sciences and primatology, to study the public's perception of monkeys. This work aims to address a major challenge, that of identifying solutions that limit high-risk contact and are compatible with the socio-cultural situation, while at the same time limiting negative attitudes towards these animals (e.g. the slaughter of howler monkeys because they carry the stigma of being a reservoir for yellow fever).

KEY POINTS

Our sustainable coexistence with wildlife requires us to limit the risk of disease transmission between humans and wild animals, which remains a major challenge for our society. To this end, the One Health approach is based on the concept of the interdependence of health between humans, animals and the environment, and aims to better understand the multiple ecological and socio-cultural components of this coexistence. The knowledge acquired will be used to identify effective and appropriate strategies for promoting coexistence that limits health risks. To achieve this, the One Health approach must strengthen the multi-stakeholder dialogue between public health, social and environmental sciences, and society.

Sustainability science put to the test of science

Anne-Gaëlle Beurier,
Sorbonne-Nouvelle Paris 3 University, UMR CREDA,
and Aix-Marseille University, UMR LPED, France

Background

Environmental concerns are placing high expectations and demands on scientists. Sustainability science holds out the promise of a science that documents, confronts and responds to ecological crises. It is based on interdisciplinary research, focused on solving socio-environmental problems rather than on dynamics specific to the academic world, and co-constructed with the stakeholders in these problems. For those who are not convinced of this, today's research frameworks regularly remind us of its importance. However, these new expectations are not always compatible with the professional standards of the various scientific fields. As this science is still in the process of being institutionalised, it is important to explore the difficulties and limitations that these new research practices and positions bring for scientists of all backgrounds.

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Further reading

Beurier A.-G., 2022 – La « recherche collaborative » en environnement : des pratiques innovantes aux dynamiques normatives. *Émulations : Revue des jeunes chercheuses et chercheurs en sciences sociales.*

Sustainability science challenges the institutional and organisational norms of research

Sustainability science is one of the new frameworks that are shaking up researchers' practices and professional standards. On the one hand, its institutionalisation gives scientists more room for manoeuvre in the way they do science, giving them a breathing space and legitimising practices that were previously marginal but are now considered necessary for tackling socio-environmental issues. In this respect, research posts in sustainability science at IRD, which have been open since 2020, have enabled a number of candidates with unique profiles to carve out a place for themselves in the professional academic world. However, this shake-up in expectations of scientific practice is taking place against a backdrop of shifting norms with which researchers have to contend, reducing the autonomy needed to practise science that is committed to solving these problems. These are mainly the demands for "scientific excellence" and the "relevance of research" to innovation and social impact. Researchers agree that the former exacerbates the rationales of competition, individuation, specialisation and hierarchisation of disciplinary approaches within academia. It also makes cooperation

Le Monde

ACTUALITÉS ÉCONOMIE VIDÉOS DÉBATS CULTURE LE GOÛT DU MONDE SERVICES

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TRIBUNE

Collectif

« Alignons notre pratique scientifique sur les enjeux impérieux de ce siècle »

Face aux crises globales qui se dessinent, des étudiants des Ecoles normales supérieures s'engagent, dans une tribune au « Monde », pour une recherche impliquée, davantage connectée à la société.

Publié le 11 mai 2022 à 18h00, modifié le 12 mai 2022 à 09h58 | Lecture 3 min.

Opinion piece signed by young researchers from the Écoles Normales Supérieures and published in *Le Monde* on 11 May 2022

(https://www.lemonde.fr/sciences/article/2022/05/11/alignons-notre-pratique-scientifique-sur-les-enjeux-imperieux-de-ce-siecle_6125674_1650684.html).

between researchers, and between scientific institutions, more complex, with each trying to stand out from the others in this great race. The second summation seems to be more in line with the approach taken by sustainability science, but some scientists regret the increasing standardisation and normalisation of what is understood as social "relevance" by scientific institutions. However, science/society relations vary with disciplinary backgrounds, institutional positions, epistemic cultures and the history of research co-construction practices. Consequently, the practitioners of a science geared towards solving socio-environmental problems, whose practices have often developed over a long period of time and on the fringes of their discipline and supervisory bodies, see standards being imposed as a result of this institutionalisation with which they do not necessarily identify. These tensions are all the more acute for young researchers and graduates from the social sciences and humanities (SSH), yet they are the ones who it is important to mobilise around sustainability science.

Sustainability science and young researchers

It is generally accepted that young scientists are more likely to be able to implement forms of research on which sustainability science is based. This is exemplified by the recent call from young researchers at the Écoles normales supérieures to "review our priorities when choosing our research subjects, by aligning our scientific practice with the pressing issues of this century" (see illustration). It seems that these young people, who have more interdisciplinary training than their elders, are more concerned about the environmental crisis with which they have grown up. Their status as new entrants to the academic profession would appear to protect them in part from an academic habitus that tends to favour the distinction between "scholars" and "politicians", making scientific neutrality an axiological pillar that is wary of commitment. However, a closer look at the professional integration of these young people shows that they are much less at ease with the new expectations of scientists. They are more exposed to the precariousness resulting from the growing trend towards contract-based research, which makes it more difficult for them to find the long-term workplaces and research areas they need to develop approaches to sustainability science. Current recruitment criteria, which vary from institution to institution and from discipline to discipline, are still based mainly on academic standing and the quality of their scientific publications. The investment involved in interdisciplinary work and multi-stakeholder co-construction around a socio-environmental issue requires a range of skills in addition to those already required to become a professional scientist. They are therefore still difficult to combine, to consider and to practise within the time frames of institutionalised research, and it remains costly for young people in search of academic legitimacy to invest in them.

Sustainability science and epistemological pluralism

Promoters of sustainability science are concerned about the lack of interest in this

science on the part of some SSH graduates. Among those who are taking an interest, it is intriguing to note that a number of former life and Earth scientists are switching to the "humanities". The reasons for this distancing are complex and depend in part on the standard-setting nature of certain research practices propagated by the process of institutionalising sustainability science. For example, taking up a position or a project in this field requires certain SSH disciplines to adopt more standardised forms of research evaluation and methods of co-construction with non-academic partners than those to which they are accustomed. However, this standardisation of the way in which their science is evaluated limits their possibilities for experimenting with forms of research that are more in keeping with some of their scientific practices and commitments. This unease is particularly acute among those involved in research into understanding class relations or any other form of domination within society. They view sustainability science with suspicion, because of the associated concept of sustainable development, which promotes corrective action against exploitative systems such as capitalism. Consequently, the co-construction of research should not become an ontological characteristic of sustainability science, but should always be subject to a *sui generis* reflection on the type of stakeholders with whom to partner and the resulting forms of politicisation.

KEY POINTS

The rise of sustainability science in France, as a scientific approach still under development, provides an ideal and necessary opportunity to reflect on our scientific positions and practices in response to the socio-ecological crises. The forms of research on which it is based are shaking up the organisational and institutional norms specific to the academic field. Given that it is still in the process of being institutionalised, it is important to investigate the academic constraints that it is displacing in the various scientific fields so that it does not become a vector for new ways of establishing standards, disciplinary hierarchies and status.

Crises and sustainability science: a public policy issue?

Florence Cassam Chenaï,
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Background

The "crisis" situations in 21st century societies are characterised by their complexity and their ambiguous relationship with time frames, over and above their chronic nature, which has resulted in them being described as "protracted crises". At the same time, sustainability science cannot avoid analysing these multifactorial phenomena, which have an impact on achieving the Sustainable Development Goals (SDGs). The production of knowledge about crises and the search for solutions also means taking an interest in how uncertainty is managed, which may seem irrational in a scientific environment. Furthermore, whatever the duration of a crisis, it is preceded by warning signals, followed by a peak in terms of the intensity of the shock and finally by a phase in which the effects of the crisis subside. This theoretical phasing of crisis situations, which in a given context can overlay different types of crises in different time frames, is nevertheless helpful when thinking about solutions.

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Further reading
http://www.lmi-macoter.net/les-cahiers-de-macoter/

Better understanding of crises with a view to action: at the crossroads between knowledge and policy-making objectives

The research community and the development community (donors, NGOs, operators, etc.) share the aim of understanding crisis systems, including their dynamics and stakeholders, from a holistic perspective. These two communities have different objectives, but all agree that there is a need to produce more knowledge on a subject that evolves over time and changes in its composition. One illustration of this desire to combine efforts using a multi-stakeholder approach can be found in the PASAS project (Platform for Analysis, Monitoring and Learning in the Sahel), financed by the French Development Agency (AFD) and entrusted to IRD in consortium with private-sector operator International Consulting Expertise (ICE). This operational knowledge production and management tool focuses on the Sahel region, which is itself affected by a wide range of crises. The challenges of understanding, from a sustainability science perspective, lie in taking stock of the knowledge that has been formally produced, in identifying subjects that have received little or no attention, and in gaining access to research and implementation sites for solutions that have been severely impacted by deteriorating security conditions. In this multi-faceted relationship between stakeholders, there is also the issue of mutual understanding: the simple fact of deciding to work together is not enough to overcome the limits around the objectives of the studies carried out (what is meant by "operational aim"?) or the language specific to researchers, which differs from that of development, diplomatic or even defence stakeholders (the "3D" approach advocated by France in the Sahel), and vice versa. Furthermore, the knowledge produced lies at the crossroads between the need to fill research gaps and the need to support decision-making and solution definition.

Multiplicity of stakeholders in response to crises: issues of legitimacy and power?

Co-constructing crisis prevention and response, by linking knowledge and solutions, once again introduces a multiplicity of stakeholders and time frames for action that are not always identical across the board, despite the efforts that may be made jointly to have a basis of shared analyses. Given the complexity of crisis systems, responses designed before, during and after a crisis inevitably call for coordination in decision-making and implementation. This raises issues of the legitimacy and power of the stakeholders involved. Questioning the mechanisms by which responses to crises are co-constructed should also be part of the research associated with sustainability science. Their development and history need to be documented, in terms of both the content of crises and their methods, with a view to long-term learning. Knowledge of the mechanisms involved is not enough to provide a concrete answer to the dynamics of power, which also change over time, but it can provide a better understanding of them from perspectives both internal and external to the crisis phenomena being analysed. Emotional, moral and ethical

factors are other aspects that need to be taken into account when studying crises. These extreme shock situations have an impact on every one of the stakeholders involved and affected. In this sense, the Covid-19 crisis is an illustration of the need to integrate emotional management and to take account of moral and ethical concepts when analysing the complexity of crises and the responses required.

How can uncertainty linked to crises be managed as part of sustainability science?

If we are to succeed in transforming societal practices in crisis contexts, we need to take into account how uncertainty is managed as an integral part of these phenomena. However, an analysis of the time frames of crises, with a pre-crisis phase, a shock phase and a post-crisis phase, provides some insights for public policy, as the responses to each of these phases are not usually the same. Firstly, the pre-crisis phase involves identifying signals and monitoring a given situation to identify endogenous and exogenous factors that may exacerbate existing vulnerabilities or risk factors. Secondly, the handling of the crisis situation itself should be based on a response plan drawn up in advance, so that a crisis management team and resources can be mobilised and the required actions can be taken. United Nations agencies operating in countries where the humanitarian situation is critical develop humanitarian response plans jointly with the various stakeholders making up the Humanitarian Country Team, providing

Faced with food crises in the Sahel, development agencies are supporting projects to make the best use of wadis in the Sahara-Sahel region. This example comes from the province of Kanem in Chad.

a roadmap to follow if the situation worsens. These plans are based on data/indicators developed to monitor the humanitarian situation in a given context. Thirdly, the post-crisis effects must also be taken into account as part of a public policy that also covers different time frames – immediately after the shock and then over the medium and long term – with a view to more far-reaching, transformative processes in crisis management. The development and implementation of public policies around crises, linked to sustainability science, should raise innovation issues in terms of both the content of these policies and their operating

methods and mechanisms, whether or not they are suitable in an increasingly uncertain environment (for example, talking about public energy policy in 2022 in the context of the war in Ukraine must include crisis management). Looking beyond uncertainty, the extreme nature of crisis management means that we need to think about death and dying, survival and the resilience of individuals, societies and institutions, taking into account moral and ethical frameworks. For example, the creation of the Covid-19 Ad Memoriam Institute at Paris-Cité University, supported by IRD, is a social and scientific innovation that aims to preserve the memory of the recent health crisis in a digital format open to all.

KEY POINTS

Linking the knowledge challenges of crisis management with those of sustainability science opens up a vast field of research in different territories and sectors, involving a variety of stakeholders in a holistic approach. Operationalising the production of knowledge and sustainable solutions around these issues requires, in terms of societal transformations, the development and governance of "crisis" public policies or policies that must take the crisis aspect into account.

Zoonoses and sustainable urbanisation in the Global South: understanding the risks to prevent them more effectively

Christophe Diagne,
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Background

The growing human footprint on natural habitats is causing significant environmental changes that are having a major impact on the nature of and changes in the relationships between hosts and parasites (a term that encompasses viruses, bacteria, helminths and protozoa that can be pathogenic), with, in particular, increased contact between humans and wildlife that are reservoirs for these parasites. These disrupted environments are conducive to the circulation of zoonoses (infectious diseases transmitted between animals and humans), particularly in regions of the Global South that are facing multi-sectoral challenges brought about by current anthropogenic changes. Intensive urbanisation is a prime example of this situation, where humans are both the protagonists and the victims of environmental disruptions. Preventing and managing zoonotic risks effectively and sustainably in these fast-growing urban areas is therefore a major priority for sustainable development.

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Further reading
https://doi.org/10.3402/iee.v6.30978

Rodent zoonoses: a major challenge for urbanisation in West Africa

Urbanisation in West Africa, as in the rest of the continent, is a rapid process that is difficult to control. It is often associated with high population density (the urban population is expected to triple to over a billion by 2050), weak public policies and very limited basic services (such as electricity and water supply, sanitation systems and access to healthcare). This process leads to the creation and/or expansion of precarious areas, where disturbed and unhealthy habitats exacerbate interactions between human populations and rodents. Rodents are recognised as key bioindicators of the anthropisation of habitats and are therefore an important taxon when it comes to health issues in the context of urbanisation – in addition to their socio-economic impact (resulting, for example, from damage to crops) and environmental impact (such as the reduction in biodiversity). They are reservoirs for around 40% of known zoonoses and have been responsible for major epidemics and pandemics throughout history. Zoonoses associated with rodents can be viral (such as smallpox), bacterial (such as plague), helminthic (such as schistosomiasis) or due to protozoa (such as toxoplasmosis). Some of these diseases can evolve into human-to-human transmission, causing more than 400 million illnesses worldwide every year. Furthermore, rodents are undoubtedly carriers of as yet undiscovered parasites that could be the source of new emerging diseases. Their strong preference for urban environments, their phylogenetic proximity to humans, their anthropophilic nature and the subsequent proliferation through global trade of certain

Magnolia Eco Health Framework: The 6 key principles of the Eco Health approach

(based on Orlando L. F. et al., 2022 – Ecohealth Villages: A Framework for an Ecosystem Approach to Health in Human Settlements. *Sustainability*, 14 (12), 7053.

invasive exotic species – such as the house mouse and the black rat – make rodents key players in the multiscalar spread of zoonoses. Recent research in a number of West African countries (including Benin, Niger and Senegal) has shown that rodents carry zoonotic pathogens (such as Lassa virus, leptospirosis, plague bacilli and the infectious agent of typhus), which are responsible for particularly harmful epidemics that are unfortunately often overlooked when it comes to planning for and/or managing them.

The Eco Health approach: co-constructed research for sustainable solutions

Within these socio-ecosystems, the risk of zoonotic infection is modulated simultaneously by the structure of the landscape (such as sanitation networks), socio-economic and cultural components (based on rodents' food consumption, the vulnerability of human populations, etc.) and the bio-ecology of rodents (e.g. spatio-temporal dynamics). The Eco Health approach (i.e. the ecosystemic understanding of health in all its environmental and societal dimensions) therefore appears to be the most appropriate for, firstly, understanding this zoonotic risk and, secondly, identifying and then supporting the implementation of appropriate actions to combat it. Implementing such an approach requires the development of collaborative and concerted research efforts based on shared objectives with local partners at the interface between science and society. By using an approach that is necessarily 1) interdisciplinary between the social, medical and ecological sciences (surveys, epidemiological monitoring, sampling, etc.), 2) cooperative with various non-academic stakeholders (such as the authorities, public funding bodies and private organisations) and 3) participatory with local citizens, the Eco Health approach provides a holistic understanding of the complexity of the eco-evolutionary mechanisms and societal factors at work in the circulation of zoonoses. The aim is to identify sustainable and operational levers for action at different levels (policymakers, medical organisations and citizen communities). An excellent example of this type of action is provided by community-based Environmentally-Based Rodent Management (EBRM) strategies (see Dobigny G. et al., 2022 – « La gestion communautaire des rongeurs dans les villes africaines ». In *Science de la durabilité*, Marseille, IRD: 42-45).

The aim of these strategies is to improve the environment to mitigate or prevent the proliferation of rodents by, for example, modifying the habitat and certain uses to reduce the attractiveness of breeding sites and refuge areas for rodents.

North Senegal: a textbook case for Eco Health research

North Senegal, with its "secondary" towns far from the major urban centres, is the driving force behind the urban transformation under way in part of the West African Sahel region. The growing human footprint in the region is reflected both in agricultural landscapes (such as agroecosystems) and in areas where major hubs for the exchange of goods and people are located (such as the towns of Saint-Louis

and Dahra). A research project is currently being co-constructed by a multi-stakeholder network of researchers and doctors (from IRD, Gaston-Berger University, the Pasteur Institute, etc.), local authorities (such as the Senegalese High Council for Health Security One Health) and community associations (such as the Association for the Development of Mbarigo [ADEMBA]), with the aim of: 1) identifying the determinants of human-rodent interactions during the urbanisation process; 2) identifying the ecological, sociological and landscape factors underlying zoonotic infections in urban habitats or those undergoing urbanisation; 3) anticipating zoonotic risks by identifying the most relevant actions to be implemented collectively. The aim of this project is to provide information – so that public policies can be used to develop sustainable, societal actions and practices adapted to local conditions – but also to produce a methodological framework that can be adapted to other West African socio-ecosystems, and even to other settings beyond this region. This project is part of the AfriCam programme, funded by the international PREZODE initiative.

KEY POINTS

One of the keys to meeting the challenges of sustainable cities is to curb the zoonotic health risks associated with the intensive urbanisation under way in regions of the Global South. In this context, the Eco Health approach appears to be fundamental in providing a holistic understanding of the multifactorial mechanisms and processes at work in the relationship between zoonoses and urbanisation. This integrated approach to health (combining interdisciplinary science, political decisions and community action) is primarily based on research carried out in partnership with local stakeholders, from the co-construction of projects through to the contextualised implementation of solutions, and provides a means of identifying the most relevant levers for integrated zoonoses monitoring.

Green spaces and concrete: can they exist side-by-side?

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Background

Goal 11 of the international development agenda – Sustainable Cities and Communities – focuses on rehabilitating cities and planning their development so that they can offer employment opportunities, access to basic services, energy, housing, transport and green public spaces for all, while improving the use of resources and reducing their environmental impact. However, while the proportion of the world's population living in cities continues to grow, green spaces are declining inexorably in many cities and often seem destined to disappear forever, despite being protected by international conventions or local regulations. Using the city of Dakar in Senegal as an example, this study examines the rationale, practices and results of the coexistence of natural and urban spaces and the contextual factors that influence it.

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Why talk about coexistence?

With the disappearance of natural areas in the wake of urban growth, the concept of coexistence refers to preserving or not preserving: 1) the spatial volume of natural areas; 2) their function as agrosystems (biodiversity reserves); 3) their ecosystem services, while ensuring that they remain sustainable. The term "coexistence" is preferred to "coviability" in order to emphasise the concept of shared habitat (*oîkos*), thereby overcoming the duality of urban space and natural space. This clarification seems necessary given the analysis of the factors behind the loss of natural areas in favour of built-up areas in many towns in the Global South. One of these factors is how the authorities in charge of planning view these natural areas, a view that prioritises economic benefits over ecological functions, without taking into account the economic, health and safety costs associated with the disappearance of ecological entities in urban areas. This now outdated view shows the extent of the work that needs to be done to update our knowledge and, consequently, the practices of the political bodies responsible for spatial planning.

Understanding the fragile nature of Dakar's natural areas

Consider, for example, the two largest natural areas in terms of surface area and popularity: the Great Niaye of Pikine and the Mbao forest, the green lungs of Dakar. Together, they cover 1,200 hectares and form the largest biodiversity reserve in the Greater Dakar area.

To understand the issues surrounding the survival of natural areas in this conurbation, we need to look at the changing status of the communities that are home to these natural areas. Pikine and Mbao are recent satellite towns, which have gone from being peri-urban areas to fully-fledged urban entities in the Greater Dakar area within the space of a few decades. Pikine was created in 1952 to rehouse displaced populations from Dakar's working-class neighbourhoods, and Mbao is a former Lebou village that became a municipality in 1996. With population growth and the attendant need for infrastructure leading to urban sprawl and densification, Dakar is encroaching on its last remaining land reserves. These natural areas, with their already problematic hydrogeological dynamics (salinisation, soil impoverishment), are caught in a double bind that seems to place their future on the shifting sands of disappearance.

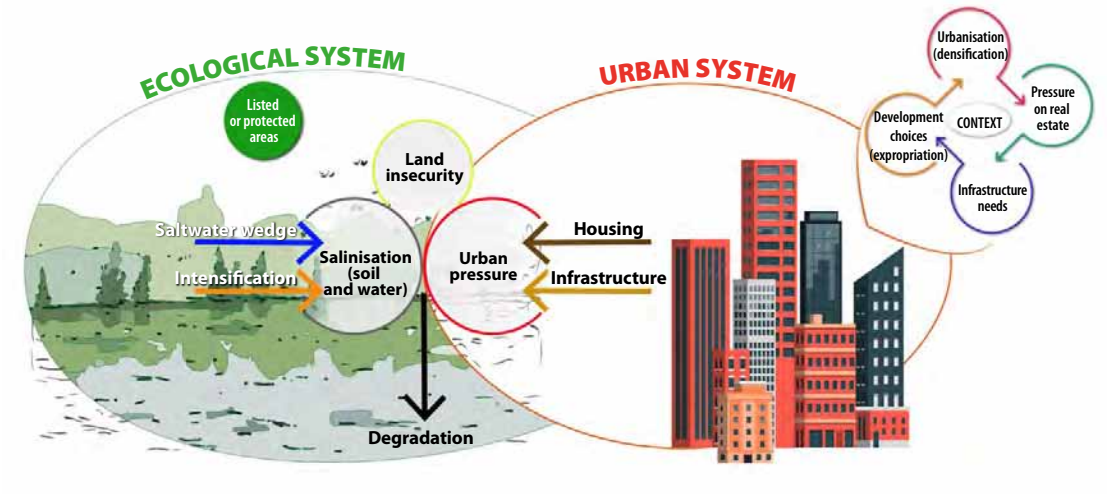
"Protected" areas despite everything

The paradox lies in the fact that these natural areas are either included in urban development plans or have their own development plans (action plan for the protection and urban development of the Niayes and Dakar's green spaces, among others). In reality, these green spaces are not being developed in line with the objectives of the plans that are supposed to "safeguard" them. The Great Niaye of Pikine has lost at least 84 hectares since the early 2000s, and the Mbao forest has lost 55 hectares. The list of infrastructure projects benefiting from the plans includes the Dakar golf

club, the national traditional wrestling arena, the Mbao Villeneuve development project, the Dakar-Diamniadio toll motorway and the regional express train. These are all state-run projects that have used the right of "expropriation in the public interest" or declassification decrees to operate in these areas. They justify their presence based on development plans proposed following environmental and social impact studies. Each time, the idea behind these plans is to turn the green spaces into multifunctional areas for crop production, housing (or transit) and leisure. However, it is precisely this planning approach that does not seem to work in favour of preserving green spaces, because it opens up loopholes that encourage expropriation. The result has always been the gradual disappearance of natural areas.

Changing the management paradigm?

It therefore seems urgent to review the concept of spatial planning, which mimics sustainability rather than actually practising it. This new approach raises the question not only of the discernible usefulness of green zones in an urban environment, but also of the unilateral management of development projects. Furthermore, the use of diagnostic tools (environmental and social impact studies) to justify the disappearance of green spaces remains a real legal obstacle to preserving these green lungs. The reason why the governance/management/use schemes for Dakar's nature reserves have not worked to date is that we need to move beyond the idea that natural spaces are somehow "alien" to human settlements. There is no reason why green spaces and concrete could not coexist if local stakeholders were given more say in the planning process. The development schemes currently in place only involve these stakeholders after projects have been identified. Nor does their role extend to the decision-making bodies that approve or reject projects following an impact study. This reality relegates local stakeholders to mere consultants. The role of the researcher could be to study the possibilities of integrating local stakeholders more effectively into development plans. In practical terms, this could mean studying the best practices of the users of these areas and proposing sustainable development plans based not on exogenous logic, but on the biophysical dynamics specific to these areas.



Urban system *vs* ecological system in Dakar.

KEY POINTS

Achievement of the "Sustainable Cities and Communities" Sustainable Development Goal (SDG) is being slowed down in many countries in the Global South by a dualistic view of "green" *versus* "concrete" and is coming up against many local constraints. In Greater Dakar, the major constraint to maintaining green spaces lies in planning practices that favour the tangible benefits of infrastructure over the more implicit, but no less vital, ecological role of urban green spaces. Those involved in spatial planning seem to be aware of this in terms of the legal protection measures that have been put in place. However, protection seems to be reserved for opportunities to declassify infrastructure that is judged to be structurally important enough to make use of several dozen hectares of green cover. Fruitful reflection could lead to green spaces being reconsidered as integral parts of the urban environment, in the same way as housing and other infrastructure.

Studying the evolutionary dynamics of the interaction between water and man in the past in order to plan for the future

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Background

Global change is altering the long-term evolutionary trajectories of socio-ecological systems, testing their capacity for resilience and adaptation. Against a backdrop of significant uncertainty linked to the interweaving of human and ecological vulnerabilities, planning policies involve choosing between different socio-ecological transition scenarios. These choices involve adapting to the local historical ways of living, while at the same time reinventing them. The study of socio-ecological trajectories falls within the scope of sustainability science: it is interdisciplinary, combining the knowledge of geographers, hydro(geo)logists, sociologists and ecologists, and building bridges with other disciplines such as urban planning. Firmly rooted in an understanding of the problems faced by local residents, it invites us to revisit the history of territories to shed new light on current controversies.

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Further reading

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Scientific lock: the question of the choice and relevance of the study baseline

Among the socio-ecological trajectories, the study of hydro-social evolutionary dynamics explores the interactions between human societies and water, and more specifically the role that water has played and continues to play in land use planning: water as a "resource", water as a "living environment", water as a "vector" for nutrients and contaminants, water as a "risk", etc. Studying the impact of global change on a local scale means analysing and documenting the spatial and temporal diversity of the hydro-social trajectories at work, through the interplay of scales (spatial interlocking) and impermanent frames of reference (temporal interlocking). This raises the question of the baseline from which to observe these evolutionary dynamics. Baselines are spatialised points of view providing a relevant basis for observing and modelling spatial and temporal changes in interactions with water. This question of the baseline is central, because it explicitly examines the biased loss of perception of change that occurs when each generation redefines what is "normal" or "natural" (the concept of a shifting baseline or "ecological amnesia"; Rodrigues et al., 2019). The study of hydro-social trajectories therefore calls for an examination of the choice and use of spatio-temporal baselines. This means developing a method for sizing and locating a sample of sites in a given study area.

Proposing a methodological approach to identify a study baseline

The methodological approach combines sampling methods from hydrology and sociology, and proposes three stages for identifying these "baseline" sites:

– surveys of a sample of local experts: geologists, hydrologists, historians, geographers, anthropologists and others, most of whom live in the study area. Their expertise and local practices help to identify "baseline" sites, because they are features of the way in which hydro-social interactions have evolved;

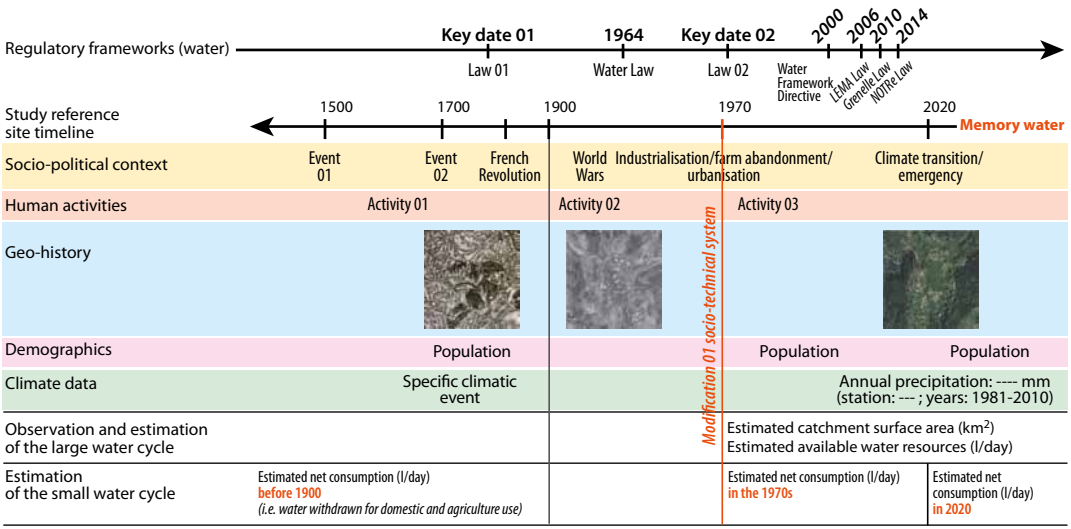
– a hydrological and hydrogeological observation and characterisation of the "baseline" sites cited during the exploratory surveys, which, through an initial analysis of the small and large water cycles, give an idea of how the environment functions;

– a study of socio-environmental controversies (river pollution, depletion of water resources, etc.) in the study area, revealing the problems experienced by local residents today, and the way in which the history of socio-hydrological interactions resurfaces in these controversies to shed light on the various transition scenarios.

Using new tools to study these "baseline" sites

The chrono-systemic timeline is a working tool used in the field of Long-Term Socioecological Research (Haberl et al., 2006). It is an interdisciplinary tool that combines qualitative and quantitative data with historical, ecological,

demographic, climatological and other related knowledge. It is also a transdisciplinary tool that can be used to support discussions with local residents on hydro-social trajectories. The figure below shows the work involved in constructing a chrono-systemic timeline for a baseline study site. This timeline highlights the hydro-social trajectory of a given baseline with a succession of socio-technical developments (for example, major hydrological changes such as the introduction of drinking water supplies or collective wastewater treatment). An analysis from the point of view of local residents provides an understanding of the role of these various developments in the transformation of types of housing and ways of living, with the aim of shedding light on future development scenarios.



This data can be used to produce a **simplified water balance over several periods** and to understand and quantify the uses made of water ressources in the reference location.

This approach can, for example, lead to a rethinking of modernisation through the prism of water and review of the boundaries of the spatial reference system.

An example of a hydro-social chrono-systemic timeline under construction.

KEY POINTS

To know where we are going, we need to know where we have been! This methodological approach, which focuses on identifying "baseline sites", is designed to provide a knowledge base that is fundamental to decision-making. By examining the relevance of choosing a (spatial and temporal) baseline from which to view changes and developments over the long term, this approach also raises questions about the sustainability of development choices.

Towards more sustainable use of fish aggregating devices

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Background

Sustainability science promotes the search for solutions to complex problems linked to major global issues. Sustainable Development Goal (SDG) 14 "Conserve and sustainably use the oceans" raises a major concern about waste discharged or abandoned in the environment. Although most of this waste originates on land, a significant proportion comes from maritime activities, particularly fishing, with harmful consequences for marine organisms and coastlines. Tropical tuna seine fishing contributes to this phenomenon by deploying thousands of drifting fish aggregating devices (FADs) every year, many of which eventually wash up on the shore. We therefore need to think about ways of preventing the loss and subsequent beaching of FADs, and thereby contribute to a more sustainable ocean.

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Further reading

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Drifting FADs and the problems associated with their use

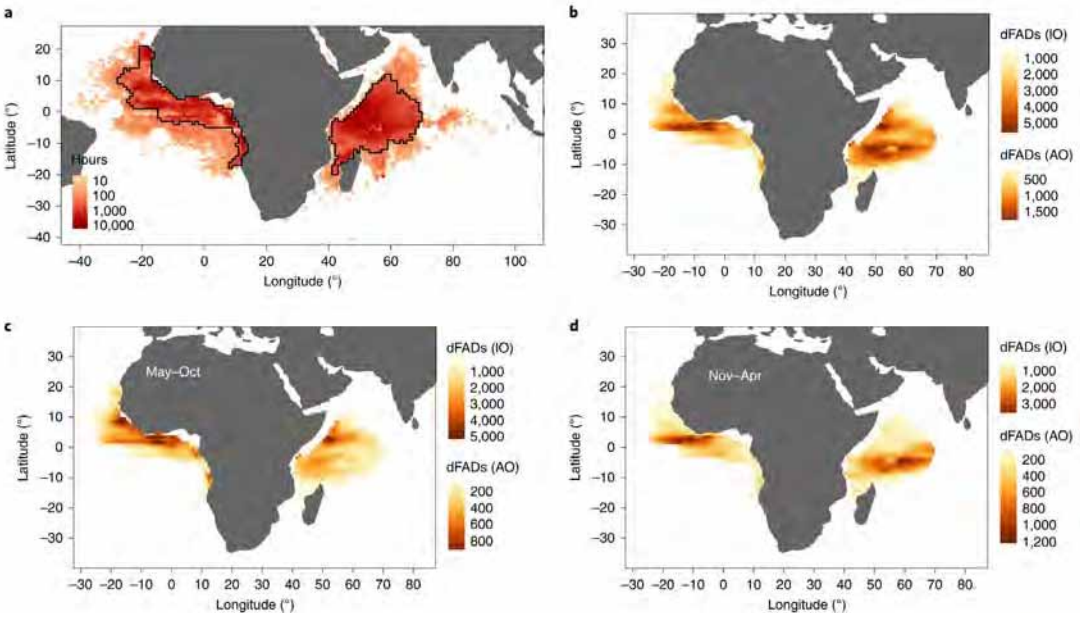
The drifting FAD is a piece of equipment that naturally concentrates fish and is used by fishermen to increase their catches. It usually comprises a rectangular raft measuring a few square metres, covered in fishing nets and attached to plastic floats. It also has a vertical structure comprising nets up to 80 metres deep, to which a weight is attached to anchor the net in the water column and make fish aggregation easier. A GPS buoy is attached to the FAD so that its position can be tracked remotely. Since the early 2010s, an echo-sounder integrated into the buoy has provided an estimate of the aggregated fish biomass. While the use of FADs has clearly increased the productivity of the tuna fishery, the practice has a number of negative consequences, including an increased risk of overfishing and accidental catches of species not targeted by the fishery. Furthermore, a significant proportion of FADs end up drifting away from fishing grounds and/or washing up on the shore, adding to the volume of marine litter.

Measures to reduce these problems

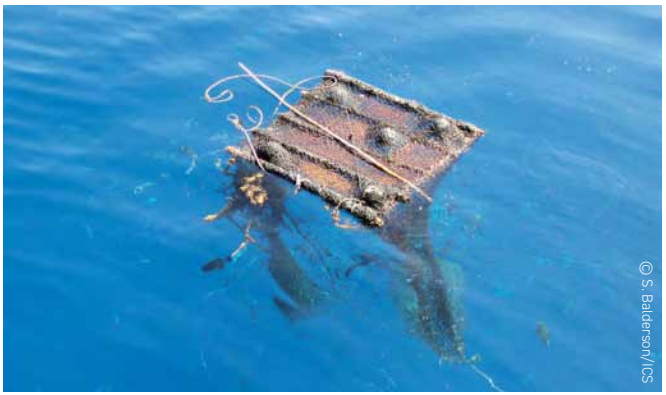
Regional management organisations for tropical tuna fisheries have put in place measures to reduce the problems associated with the use of drifting FADs, in particular limiting the total number of buoys used per boat, banning fishing with FADs in certain areas and at certain times, or requiring the use of "non-entangling" FADs (i.e. without open nets underwater to avoid killing sharks that become entangled in these nets). For example, current regulations limit the number of active buoys to a maximum of 300 simultaneously per boat and 500 in total per boat per year in the Indian Ocean. However, these measures do not specifically address the issue of reducing the beaching and loss of FADs. One solution would be to ban the deployment of FADs in areas where there is a high risk of beaching. By analysing the tracking data of tens of thousands of FADs, our research has shown that banning the deployment of FADs south of latitude 8° South in the Indian Ocean and in the coastal zone of the Gulf of Guinea in the Atlantic Ocean could reduce the FAD beaching rate in these two oceans by 20% to 40% (Imzilen et al., 2021; see illustration). As these areas are not heavily fished, this measure could be implemented with relatively little impact on fishing. However, such a ban regulation does not appear to offer the same protection for all the areas studied. The south-west of the Indian Ocean would benefit greatly from this measure, but the north-west would not, mainly because of the high variability of currents in this area. Here, implementing complementary programmes to recover FADs at sea might be effective.

FAD recovery programmes at sea and the associated challenges

With a view to proposing sustainable solutions to the FAD problem, we explored the possibility of setting up FAD recovery programmes in the Indian and Atlantic oceans (Imzilen et al., 2022). We examined the movements of more



a) Main fishing areas with the total number of purse seine fishing hours from 2012 to 2018.
b-d) Density of FADs and how far they drift in the Indian Ocean (IO) and Atlantic Ocean (OA).
(Imzilen et al., 2022).



On the right, a FAD caught on a coral reef on Alphonse Atoll in the Seychelles; on the left, a FAD deployed in the Indian Ocean.

than 100,000 FADs in these two oceans to see what happens to them. Our analysis showed that more than 40% of FADs drift away from fishing grounds and end up lost in the middle of the ocean or beached in coastal areas. In the Indian Ocean, FADs leaving the fishing zone from the east end up either beached in the Maldives or pass through the archipelago, drifting even further eastwards. In the Atlantic Ocean, FADs mainly leave fishing grounds along their north-west (10°-20°N) and south-west (2°-5°S) edges. Of these lost FADs, 20% pass relatively close (<50 km) to a port. Setting up programmes to recover these FADs from these ports could be an effective measure for reducing the loss and beaching of FADs. However, there are a number of major challenges to overcome if programmes of this type are to be successful. The equipment required to carry out a recovery operation (e.g. the size of boats), the type of collaboration to be put in place (e.g. collaboration with local fishermen and purse seiners and/or non-governmental organisations) and financing solutions (e.g. the development of a polluter-pays system applied during the deployment or manufacture of FADs) will all need to be defined if a programme is to recover as many FADs as possible while minimising costs and impacts on the fishery.

KEY POINTS

Recent studies carried out by IRD have proposed solutions to mitigate the risk of FADs being lost or beached: closing areas in which FADs are deployed and setting up programmes to recover FADs at sea. Implementing these solutions will, however, require political will and prior consultation between the scientists, managers, industry representatives and decision-makers involved in tropical tuna seine fishing. These various aspects are currently being actively discussed within the regional management organisations for tropical tuna fisheries in the Atlantic and Indian Oceans, in close collaboration with the authors of this article and other IRD colleagues.

Food and dilemmas

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Background

At the heart of sustainability issues is the question of decision-making for agriculture and world food, particularly in relation to changes in production and consumption patterns. This issue can be tackled using the concept of the dilemma – not widely used by the scientific community – to illustrate the various stages in the cycle. This provides an inspiring and innovative framework for organising multi-stakeholder actions. In the era of sustainability, this complex approach seems both necessary and long overdue if we are to open up a fruitful dialogue between science and society.

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Further reading

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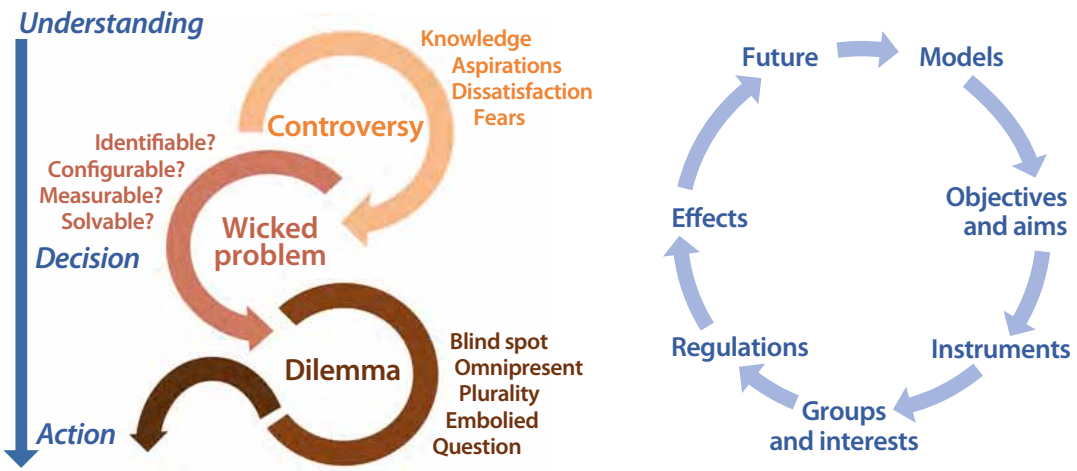
Broader, more far-reaching thinking

In these times of interconnected crises (environmental, energy, food, economic, migratory, etc.), taking action seems both somewhat futile and yet more necessary than ever. Agricultural and food issues are the focus of many challenges: dealing with emergencies, allaying concerns, meeting expectations (Janin et al., forthcoming), building adaptations and transformations, thinking about the way forward. A major shift in our production and consumption patterns to build resilience against shocks, uncertainties and crises involves two essential categories of action: time and space. The first involves linking the short and the long term without pitting them against each other. The ability to expand the time horizon, and even to plan ahead, makes it easier to deal with crises. It also means "thinking more broadly" (in a holistic and systemic way), while taking into account the specific characteristics of territories and societies. The second category of action, space, takes account of locations and distances, giving them a new relevance in an era of deglobalisation. The local, regional and national levels are once again becoming functional, desirable and even indispensable for action (whether by the state, businesses or citizens).

From controversy to dilemma

Producing food to feed the world at the time of the Agenda 2030 means facing up to numerous debates, doubts and pressures, with the risk of either discouraging all action or wanting to do everything without setting priorities. In fact, making an informed choice can quickly prove problematic. It all starts with debates: based on



The controversy/dilemma continuum (left) and the dilemma cycle (right).

knowledge (established, challenged, distorted, flawed, unequal, etc.), accompanied by aspirations and dissatisfactions (multiple, growing, legitimate or not), not to mention fears (real, imagined, reinforced, and so on). Because of this tangled web, certain debates can sometimes turn controversial. This moves us away from searching for solutions and building compromises. The expression "wicked problem" takes on its full meaning. It refers to something that is poorly identified, often a nagging issue, but also one that is difficult to set up and resolve. This wicked problem is likely to turn into a strategic dilemma (Rittel and Webber, 1973) if the need to act becomes pressing without identifying a way forward and then implementing it. The dilemma is often misunderstood, invisible and rarely explained, yet it is omnipresent. All the individual and collective stakeholders in the food system (individuals, producers, processors, developers, governments) are exposed to it and confronted with it. The dilemma is at once technical, political, moral and ethical, and it thrives on the complexity of the challenges and issues at stake in the era of transitions and sustainability. In return, it feeds on its own logic, opposing interests and on the fears, slowness and inertia that it produces. It therefore raises questions of responsibility, equity, accountability and legitimacy, and not just questions of efficiency.

The dilemma cycle

A dilemma can be broken down into several phases. The cycle is a good way of (re)presenting them. Each stage has its doubts, hesitations, negotiations and trade-offs. The first stage involves choosing between different socio-technical models (for food production, processing and consumption) and linking them together, taking into account the plurality of food systems. The second is to prioritise the objectives in a non-discretionary way (after debating or not, negotiating or not, reaching consensus or not). The third is to select and prioritise the various instruments for action (incentives and disincentives). The various protagonists involved will then have to arbitrate between groups and categories (of communities, of stakeholders) with non-convergent, opposing or even conflicting strategies and interests. This will be followed by a stage where the different regulatory methods (market and liberal, state, participatory and citizen) can be hybridised (or not) according to what is appropriate, possible and acceptable. The penultimate stage is even more strategic: it takes into account all the effects – positive and negative, immediate and future – inherent in any action. It is often on these effects that critical observations are focused and resistance crystallises. Lastly, to complete the cycle, time must be devoted to imagining the common unknowns of the future (what might happen, what we hope and wish for, where we are trying to go) and to anticipating how farming and food systems will develop together. From there, it is a matter of examining and testing the contexts, making the cycle explicit, embodying and reappropriating it, and encouraging decision-making.

KEY POINTS

"Sustainability" has a major impact on agricultural and food issues through the reconfiguration of models and modes of action that it implies. The concept of the dilemma provides a heuristic framework and an inspirational tool for co-constructing participatory actions at the various territorial and stakeholder ecosystem levels. The dilemma is not specific to the field of food and can be applied to health and environmental issues. It aims to ensure that appropriate and acceptable solutions emerge from the field, as close as possible to the stakeholders. It encourages actions to be taken "with full awareness of the cause", thereby strengthening sustainability.

Fine particle pollution: a beadcrumb trail through the SDG maze

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Background

Combustion produces the energy essential to human activity, but emits a range of pollutants, including CO_2 and fine particles. While CO_2 primarily impacts the climate system, the fine particles produced by combustion affect climate, health, ecosystems and society. These emissions, which have increased rapidly since the start of the industrial revolution, are now reaching levels that threaten the proper functioning of all the complex systems on which the sustainability of our societies depends. As these particles reach and affect all ecospheres (i.e. atmo-, cryo-, hydro-, pedo-, bio- and anthroposphere) during their life cycle, reducing their emissions contributes to many of the Sustainable Development Goals (SDGs).

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Further reading
https://www.ird.fr/black-carbon-la-face-sombre-de-lactivite-humaine

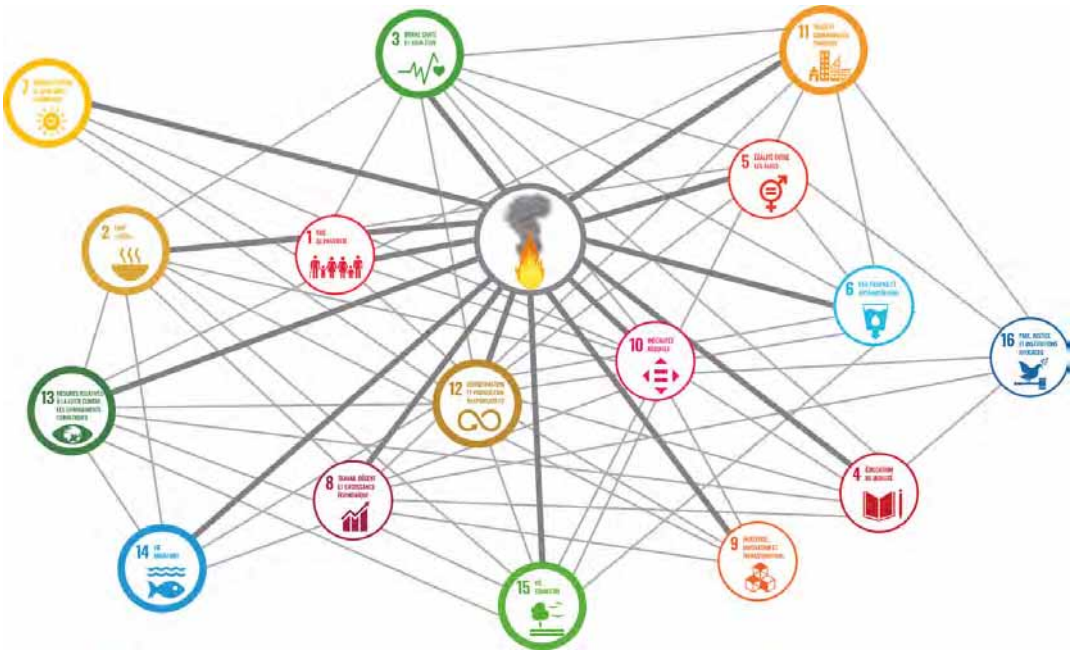
An age-old form of pollution that has evolved with society

Until the middle of the 19th century, energy was produced by burning biofuels (wood and charcoal). After that, the widespread use of fossil fuels led to a proportional increase not only in CO_2 and fine particle emissions from combustion, but also in population size, urbanisation, GDP per capita, literacy rates and life expectancy. So while the discovery of fire was the first milestone in the development of societies, the burning of fossil fuels has made us more numerous and, on the whole, more urban, richer, older and more cultured.

Following extreme pollution events in the 20th century, Western societies became aware of the need to reduce the collateral damage caused by energy production, which led them to pass laws guaranteeing air quality. As a result, energy-intensive and polluting production activities were gradually separated geographically from the consumption of the goods produced. This separation, which initially took place at country level, has now expanded to a global scale. Today, it is countries in the Global South, particularly in Asia, that produce most of the goods and suffer the consequences. Initially, this shift in production tools led to rapid economic growth in some developing countries, coupled with heavy industrialisation and urbanisation. Today, these transformations are leading to intolerable situations and heightened public awareness, resulting in growing socio-political tensions.

Pollution without borders: climate, health, ecosystems, societies

The principles of thermodynamics are stubborn. Oxidising fuels to extract thermal energy produces waste. Combustion particles from this waste have properties and a life cycle that enable them to reach and impact all ecospheres. They are formed in fire, circulate in the atmosphere, are deposited on the surface of the cryosphere, pedosphere and hydrosphere, ultimately becoming buried in sediments. Along the way, they affect the physics, chemistry and biology of various environmental and human systems. They know no geographical, thematic, ecosystemic or sectoral boundaries, least of all those of the SDGs. Following the breadcrumb trail left by these combustion particles not only helps to guide us through the maze of the SDGs and their targets, but also highlights their interconnections and their "integrated and indivisible" nature. This exercise advances the 2030 Agenda by improving the global environment and limiting climate change, delivering benefits for health, ecosystems and societies, with particular emphasis on: 1) improving health and well-being by reducing premature death due to noncommunicable diseases (SDG 3.4), reducing death and disease from dangerous chemicals and air, water and soil pollution (SDG 3.9), and strengthening the capacity of all countries for early warning, risk reduction and management of health risks (SDG 3.D); 2) preserving the global environment by improving air quality (SDG 11); 3) reducing marine pollution and increasing the resilience of marine ecosystems (SDG 14); and 4) preserving terrestrial and



The relationship between air pollution and the Sustainable Development Goals.

freshwater ecosystems and halting and reversing land degradation and biodiversity loss (SDG 15). Furthermore, describing the multiple impacts of this pollution by adopting transdisciplinary approaches is essential to identifying the benefits of reducing emissions of atmospheric pollutants in order to raise awareness among the various stakeholders (SDG 17) and advocate a revision of our production and consumption patterns aimed at reducing emissions (SDGs 7 and 12). Lastly, given the inseparable link between air pollution and climate change, the desire to improve air quality for immediate health reasons is a powerful lever for optimising the fight against climate change, and in so doing circumventing the cognitive bias of distancing ourselves from future issues that seem so far away (SDG 13).

Reducing emissions: from science about sustainability to science for sustainability

The challenge facing scientists is to move from a science about sustainability – aimed at improving our understanding of how physical, chemical, biological and social systems function and how vulnerable they are to increasing

pressures – to a science for sustainability – aimed at supporting sustainable policies and positive social transformations. The main characteristic of this science is to build, on solid scientific foundations (data-based evidence), scenarios of likely futures depending on the path taken.

Since moral responsibility towards future generations is a driving force behind commitment to sustainability science, researchers have a duty to provide the scientific evidence needed to find a balance and continuity between satisfying the needs of today and those of tomorrow. The main challenge is to challenge the dominant economic model based on fossil fuels, and to propose new equilibria and tools. This commitment to sustainability science with its goal of helping to reduce emissions must follow a sequence of stages that can be summarised as follows: 1) increasing our knowledge of the nature, sectoral and geographical origins of pollutants (what and where do we clean up?), and their impacts on physical, chemical, biological and socio-political systems (why clean up?); 2) using this knowledge to develop scenarios for positive change (how do we clean up?) and assess the potential effectiveness of desirable and acceptable options (how effective are they?); 3) raising awareness among communities and decision-makers of the risks associated with inaction (where is the consensus?); and 4) providing support to define the transformative solutions required to achieve the objectives identified, and to monitor the effectiveness of the measures taken (what are the solutions?).

KEY POINTS

Because fine particle pollution from combustion affects all environmental and human systems, the only way to find sustainable solutions is to take a truly cross-cutting approach that does away with borders: a cross-ecosphere, cross-disciplinary, cross-SDG, cross-border approach. The good news is that air pollution is a disease with a known cure: reducing emissions will bring immediate benefits for humankind as a whole. This makes it both a complex cross-cutting challenge and perhaps an ambitious test case for our ability to engage successfully in sustainability science by following this breadcrumb trail.

Food-friendly landscapes: moving beyond food sustainabilty

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Background

Research and initiatives focusing on the future of food are built around the concept of food sustainability. This concept is most often understood in its economic sense, looking at whether or not food production respects ecological carrying capacities. However, at a time when the reality and rhetoric of the crisis dominate political, social and environmental debates, is the concept of sustainability sufficient? Can it counter the drama of apocalyptic visions of a collapsing world? Does it provide a clearer picture of the systemic and social transformations that are needed if the planet is to have a food-secure future? It is now more necessary than ever to develop a vision that recognises the contributions of sustainability to the food system and looks beyond it.

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Further reading
http://www.paloc.fr/fr/agenda/paysages-alimentaires-conviviaux-pour-aller-au-dela-de-la-durabilite-alimentaire-6946

Kichwa women from the Lamas region (Peru) preparing *juane*, a rice-based speciality.

What does food sustainability mean?

The concept of sustainability, as we have come to understand it, refers to a vision of the world that separates humans from non-humans, and culture from nature, with nature primarily relating to the idea of biodiversity and ecosystems. But people in the West, supposedly the representatives of culture, have rejected the holistic vision of ecosystems, placing themselves, for the most part, outside them. Expressions such as "the gifts of nature" or "aligning with nature" express this separation. In this vision, ecosystems are "giving", and must be observed and managed to ensure that they continue to do so. Corporate approaches to sustainability, such as "ecosystem services", are tools for managing a resource that ultimately exists to serve modern lifestyles. This utilitarian approach to sustainability implies a form of status quo: while it may, at best, enable a few transitions to be made, does it really provide a

transformative awareness of ecology and food? The concept of a food-friendly landscape offers a way of sensitively addressing this question. It provides an opportunity to revisit the concept of sustainability by combining it with those of "friendliness" and "food landscapes" to develop an inclusive, critical approach to it.

Friendliness

By friendliness – or its Latinate equivalent "conviviality", which combines the Latin terms *cum* ("with") and *vivere* ("to live") – we mean interdependence, mutual respect for each other and the natural world, and taking responsibility for our lifestyles and commitments. Friendliness sees humans and non-humans as intrinsically intertwined in complex networks and relationships, struggling for both their individual and shared existence, while recognising that tension and conflict are as much a part of friendly (or convivial) relationships as mutual respect and collaboration. While sustainability is about the primacy of humans and their ways of life, friendliness is about the primacy of networks comprising human and non-human, organic and inorganic, tangible and intangible entities. While sustainability institutionalises environmental concerns and often delegates solutions to experts, friendliness, by broadening the scope of involvement to include activism, local thinking, the arts and humanities, and people with other areas of knowledge, brings a sensitive dimension to bridging the gap between different ways of thinking about and experiencing the world.

Food landscapes

The concept of a food landscape usually refers to the physical, social and institutional environment that supports food production and consumption in a given place. A food landscape is therefore composed of a whole host of anchor points that make food accessible to a certain group of people: markets, food shops, cookbooks, restaurants, fishing ports, producers, gastronomic media, culinary schools, community kitchens and food regulatory institutions can all be considered as components of these landscapes. The definition we propose is a relational one, focusing more on how people relate to each other and to the environment, physically and symbolically, through food practices. Food landscapes are the social spaces in which food-related practices, values and representations intersect with the material realities that underpin people's relationships with food. It is at the crossroads between the physical, the imaginary and the symbolic that food landscapes help to give the lives of people and social groups a firm footing in the world.

"Food-friendly landscapes" forum

On 20 and 21 June 2022, the cross-sectoral "Food-friendly landscapes" forum was held at the Institute of Advanced Studies in Paris. Organised in partnership with the PALOC joint research unit (IRD and MNHN), the event brought together scientists, activists, artists, chefs and a diverse audience to discuss the concepts of friendliness and food landscapes. Each of the participants described, in their own way,

their experiences, activities or work, the common thread of which was a determination to resist the exploitation of the natural world that goes hand in hand with the creation of knowledge in the West. The importance of time for listening, learning, imagining and opening up to others was also discussed, as was the subjectivity and intelligence of other species, opening up possibilities for new forms of collaboration and co-creation that extend beyond humankind. Through critical dialogues between science, the arts and peasant and/or indigenous thought, the concept of food-friendly landscapes has proved fertile for demonstrating how art, the humanities, cookery and activism in the agricultural and food sectors can complement, extend and challenge accepted ideas about our relationship with the environment and food.

KEY POINTS

The concept of food-friendly landscapes lies at the crossroads between the social sciences, the arts, cooking and activism. It provides an opportunity to revisit the concept of sustainability and combines it with those of "friendliness" and "food landscapes" to develop an inclusive, critical approach to it. Friendliness refers to a principle of close interdependence between living beings, geared towards fairer and more sustainable social orders. Food landscape refers to a social space in which the materiality, practices and representations associated with food intersect. Combining them in this way gives rise to a critique on two levels. The first aims to make up, at least in part, for the "cultural deficit" in sustainability, in other words, the fact that humanists, scientists from "developing countries", civil society, artists and other cultural workers have not been at the centre of discussions on what sustainability is and could be. The second is an invitation to rethink our relationship with food, the environment and "living things" in general.

Sustainable gathering, an example of reciprocal contribution between people and nature

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Background

The socio-ecological crisis is partly linked to the unidirectional relationship that industrialised societies have with nature, in which humans extract resources, generally without any accountability. Many conceptual frameworks have attempted to formalise the human-nature relationship with a view to putting forward proposals for action to achieve greater sustainability, in particular through ecosystem services or the contributions of nature to society. This latter concept looks to integrate cultural diversity and the many different relationships between people and nature. More recently, the concept of reciprocal contribution has been developed based on the relationships between different indigenous peoples or local communities and the nature that surrounds them.

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Further reading

Comberti C. et al., 2015 – Ecosystem services or services to ecosystems? Valuing cultivation and reciprocal relations between humans and ecosystems. *Global Environmental Change*, 34 : 247-262.

Ojeda J. et al., forthcoming – Reciprocal contributions between people and nature: A conceptual intervention. *BioScience*.

Reciprocal contributions

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) has called for a transformative change in policies and practices that actively engage with Indigenous Peoples and Local Communities (IPLCs) and take account of their knowledge to protect/preserve biodiversity. Local knowledge systems on nature are diverse, adaptive and resilient, having emerged from lived experience of close interactions with the environment over many generations. IPLCs draw on these knowledge systems to develop practices that can contribute directly or indirectly to maintaining, conserving, developing or sustainably managing landscapes and their biodiversity. They possess knowledge that is essential for restoring ecosystems, and this is recognised by the Convention on Biological Diversity. In 2015, Comberti et al. proposed the term "ecosystem services" to recognise that "humans often contribute to the maintenance and enhancement of ecosystems" and to close the loop on the reciprocal relationship between humans and nature. These contributions by societies to nature are actions that change ecosystems to improve the services they provide while maintaining reciprocity over time. The idea of reciprocity is central to the definition of these contributions, in contrast to the unidirectional relationship between nature and humans, which is strongly rooted in Western science. Recently, the concept of "reciprocal contributions" has been defined as "actions, interactions and experiences between people and other components of nature (considering people as part of nature) that result in positive contributions and feedback loops that accrue to both, directly or indirectly, through different dimensions and levels" (Ojeda et al., forthcoming). Reciprocity is not just an action or interaction between societies and their environment, but also the values and experiences that underpin these relationships and ensure their sustainability.

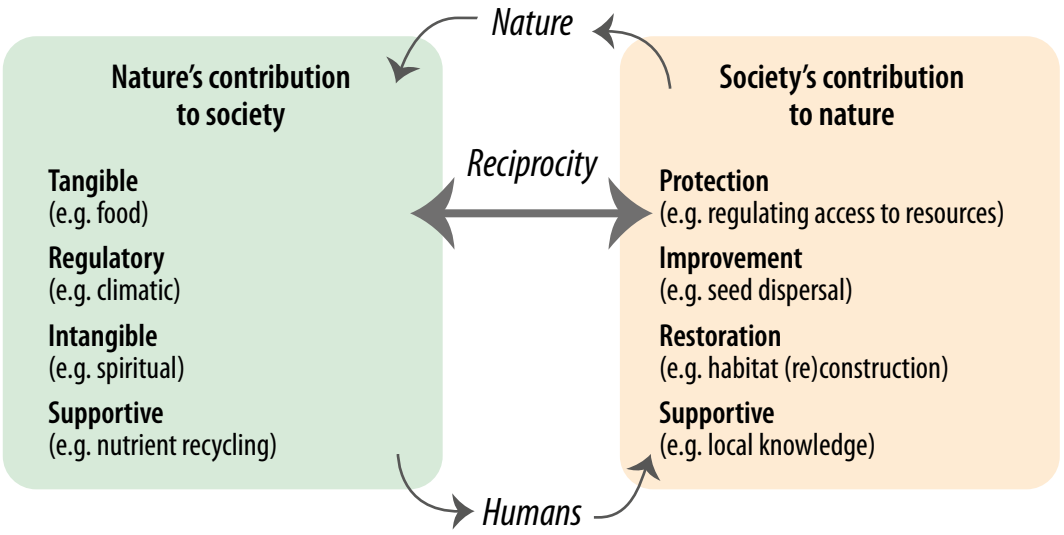
An example of reciprocal contribution: gathering wild plants

Gathering wild plants is a common practice throughout the world among urban and rural dwellers of different ages, cultures, genders and socio-economic statuses, at the interface between social and ecological systems. Choosing which species and plants to gather, and how and when to do so, depends on cultural, socio-economic and ecological contexts. Wild plants are of particular importance to people in developing countries, who depend heavily on the natural resources around them for their livelihoods. These plants are gathered for use as food, spices, animal fodder, medicines, craft and construction materials. Gathering them provides both supply and cultural services. They contribute directly to ensuring food security, improving health, supporting local economies, fostering social cohesion and maintaining co-evolutionary relationships with the natural environment. In turn, gatherers provide services to ecosystems, for example by pruning fruit trees, dispersing seeds, encouraging forest regeneration and avoiding picking in certain places or at certain times of the year. These practices help to avoid depleting plant resources or hindering their reproduction. In

addition, the local people monitor how these resources vary (production, phenology, resistance to change, etc.) in space and time and how these resources respond to their practices, and they actively share this knowledge. The social and moral standards of the gatherers help to prevent the over-exploitation of natural resources, as is the case for wild plants when they are harvested for self-consumption. Research into the gathering of wild plant species for self-consumption shows that direct negative impacts on biodiversity are extremely rare. Despite these observations, many, including the community of gatherers, are concerned that gathering is, or could become, unsustainable if it increases in popularity and the demand for wild plants grows.

From local to global

Relationships between societies and nature, which give rise to reciprocal contributions, are rooted in a particular context and are most visible at the local level. When the demand for plants expands beyond the local level, the social mechanisms for passing on reciprocal values and knowledge about low-impact practices rarely work. Threats of over-exploitation therefore most often emerge as a result of extra-local demands. If gatherers are in a vulnerable socio-economic situation, taking into account the long-term availability of plants can be overtaken by market pressures, leading to over-exploitation. To encourage large-scale sustainable commercial gathering where the



Loop in the reciprocal relationship between humans and nature
(based on Comberti et al., 2015).

harvesters are not the direct users of the resources, the concept of reciprocal contributions could be adapted to cover multiple geographical scales, communities and stakeholders throughout the value chains. Some international organisations are already proposing sustainability certificates for commercial gathering, based on ecological and socio-economic criteria, which guarantee reciprocal, equitable and sustainable contributions within these globalised socio-ecological systems.

KEY POINTS

The concept of reciprocal contributions between people and nature recognises indigenous peoples and local communities as environmental custodians with an important role to play in nature conservation. It can also help to develop public policies that support reciprocal contributions within their territories as an effective means of conserving biodiversity while guaranteeing the well-being of communities and sustainable livelihoods. Using the concept of reciprocal contributions could also help reshape institutions so that the practices and standards used by local communities are recognised and can help refocus public policies at supra-local levels. By examining the role of the plurality of knowledge (transdisciplinarity) and the link between local and global levels in nature conservation, reciprocal contributions provide a major conceptual framework for sustainability science.

Crises and sustainability science: contingency and necessity

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Background

In the worlds of the media, intellectuals and scientists, two issues are increasingly coming together, one directed at humanity (the crises), the other at the world of knowledge (sustainability science). Researchers must take advantage of these transformations in the way the world and science work to say that crises benefit from being deciphered through the lens of sustainability science and that, conversely, sustainability science can be transformed by these "borderline" events. This is a perfect illustration of a science that is intimately in touch with the world's tensions, anxieties and disruptions, and with the way we see the world.

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Further reading
https://pasas-minka.fr ; http://www.lmi-macoter.net/les-cahiers-de-macoter/

Diversity in crises

"Crisis" is an intuitive term that runs the risk of becoming blurred by its increasingly indiscriminate use. Initially, it defines an exceptional event, limited in time and causing (or likely to cause) a level of disruption that is seen as negative. However, some "crises" seem to broaden this definition. For example, the climate crisis is proving to be less and less time-bound, at least within a generation, and the Covid-19 crisis is likely to be much less rare and exceptional than we imagined when it first occurred: epidemics of zoonotic diseases are clearly on the horizon. Security crises are unique in that they are magnified, if not determined, by other series of crises (climatic, health, but also social and political). In other words, we are dealing with a series of crises that are cumulative and, moreover, multifactorial.

Crises – a textbook case for sustainability science

More specifically, understanding security crises in all their diversity (in terms of causes and structural and cyclical dynamics) requires the pooling of a variety of viewpoints and expertise and implies listening to the views of stakeholders, both those involved in and those affected by these crises. This requirement is even more

Tabarey-Barey refugee camp, Tillaberi region, Niger, 2016.

pressing than for any other research issue because of the profusion of analyses they give rise to (agencies, NGOs, donors, consultancies, research centres, universities), all forming part of a crisis market (with its own budgets, careers and favourite subjects). The result of this profusion is to play down the "needs of the people", relegating them to standardised visions and approaches, mainly promoted by international aid agencies and adopted locally, and to diagnoses/recommendations that are rarely original and often redundant.

From this perspective, the security crises affecting the countries of the central Sahel (Mali, Burkina Faso, Niger) in particular are a textbook case of how researchers' analyses need to be incorporated into sustainability science. There are three key ways in which security crises are anchored firmly in sustainability science. 1) These crises give rise to issues that need to be considered at their interfaces, because neither the causes nor the means of dealing with them can be attributed to a single explanatory factor, nor do they lead to a single solution: conflicts between farmers and breeders, for example, intersect with tensions between descendants of captives and nobles, and between local communities and government representatives. In so doing, the researcher is explicitly focused on "problem-centred" thinking, rather than on disciplinarily determined thinking. 2) As a result, only interdisciplinarity can lead to an understanding of these issues: for example, the renewed interest – sometimes under pressure from armed terrorist groups – in other justice practices (what we might call "customary" or "traditional") appeals to legal experts, historians, sociologists and anthropologists. 3) Given the abundance of diagnoses made and solutions put forward, analysing crises means starting from people's feelings and needs: surveys show that the "primary need" expressed is, generally and vitally, the need to live and work in safety. If we look at how security crises are described, the analysis focuses first and foremost on issues of survival, clearly existential needs that go hand in hand with more traditional needs that are also put to the test, such as health care, education, work and food. These three points are all requirements of sustainability science.

What can sustainability science learn from this?

As well as being at the heart of the philosophy of sustainability science, working on crises allows the discipline to evolve, even at the margins, or to define its boundaries more precisely. There are three aspects to this. 1) Collecting data on security crises is not without danger and puts our methods to the test: second-hand data (for example, data collected by organisations that keep records of security incidents and then used by researchers) may be preferable; obtaining first-hand data requires patient work, a knowledge network – which means giving preference to working with investigators who know or even come from the communities under study, rather than experienced data collection technicians – and a great deal of care. This raises questions about one of the approaches promoted by sustainability science, which strives to be as close as possible to the needs of local populations. 2) The issues studied are unique in that they are both anchored in time (for example, conflicts over

access to resources or the spread of Islamic fundamentalism) and unstable, constantly changing under the researcher's very eyes (such as the reconfiguration of local alliances between "communities" and between armed groups, or political changes within countries). The knowledge produced as a result of these situations is therefore not only contingent, but must also be sufficiently "agile" to take account of the changing nature of the contexts.3) Sustainability science, which takes problems as its starting point and proposes solutions, is being put to the test to exert influence on public policy. This is not only because the timetable is incompatible with the researchers' conclusions – this is one of the difficulties faced by IPCC experts in political forums such as the Conferences of the Parties (COP) – but also because the research is coming up against relatively unprecedented processes of delegitimisation which, even if they remain in the minority, challenge sustainability science: the fact of being referred to as what one is rather than what one says; the fact of having to take sides on political choices concerning the subject studied. The issue is not so much that of science being used for political ends (the "usual" process) as that of its content being invalidated by the immediate disqualification of the person expressing it, in this case the scientist.

KEY POINTS

As an intellectual and pragmatic requirement, sustainability science cannot fail to seize upon crises, especially security crises, and make them a privileged object of research (and not just a methodological constraint). This need – reinforced by the analogies between the "crises" object and the "sustainability science" approach – must also take into account contingencies, not all of which are predictable. In this respect, thinking about the causes of crises, particularly security crises, provides a testing ground for the principles of sustainability science, in particular its ability to anticipate needs, renew its research questions and adapt to the demands of the field.

Socio-ecological metabolism for thinking about the sustainability of society-environment interactions

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Background

Social metabolism, or socio-ecology, is a conceptual framework posited by Karl Marx and developed a century later by ecological economics. It proposes a way of looking at the environment as the product of interactions between a biophysical sphere – whose processes govern the transformations of matter – and a socio-political sphere, which shapes how these flows of matter are arranged in the environment. This perspective leads to a view of nature as the totality of reality and not as a lost Eden that needs to be rediscovered. Such a vision has major implications for sustainability science. It challenges us to think about the use of space in its many dimensions: biological, geographical, technical, economic, cultural and political, but also to transform it.

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Background to socio-ecological metabolism

At the root of socio-ecological metabolism (*Stoffwechsel*) lies Karl Marx's definition of human labour: "The labour process [...], the activity that creates use values, is appropriation of the natural world for human needs, it is the universal condition for the metabolic interaction between nature and man, and as such a natural condition of human life it is independent of, equally common to, all particular social forms of human life." This definition reminds us that human labour is a physical reality embedded in nature; it is the exchange of matter between man and nature. However, human labour is also a social relationship of production, which is extremely variable in time, space and the different sectors of the market economy. Labour is therefore at the heart of the concept of socio-ecological metabolism, since it is the physical flows of matter shaped voluntarily or induced involuntarily by human labour as organised by the economic relations of production that link the social and biophysical spheres (see illustration).

Analytical implications

Socio-ecological metabolism highlights the contradictions between economic functioning and production conditions based on natural resources. The analysis of these contradictions builds on classical Marxist theory, which was essentially concerned with the contradictions in the market sphere of the economy between the rate of exploitation and the rate of profit. Socio-ecological metabolism addresses a second contradiction of capitalism, which concerns the antagonism between production and the ecological conditions of production, in particular land, fresh water, space and raw materials. Here, the problem lies in the appropriation and destructive use of space and other natural resources for economic production. This antagonism between capital accumulation and ecological reproduction is likely to give rise to shortages of raw materials, space, and so on, which take the form of economic crises that hit different social groups and countries of the world in very different and unequal ways. A strong geopolitical foundation is needed to account for North-South inequalities and the impact of historical trajectories on the metabolisms specific to different territories at different scales. Socio-ecological metabolism is thus part of the "spatial turn" in the social sciences, which means that geographical space, territorial ecology, places of extraction, economic production and power, as well as the distances travelled by goods and people, are all of paramount importance in understanding the flows of matter involved in society-environment interactions. While this spatial turn is essential for thinking about the sustainability of interactions between society and the environment, the Marxist legacy nonetheless encourages us to maintain a global vision and interweave spatial scales rather than making an empirical catalogue of each specific local situation. On a global scale, we need to understand the economic dynamics of capital accumulation regimes and the associated global extraction of raw materials, which also accumulate in the environment in the form of waste, pollution and greenhouse gas emissions. On a territorial scale, the aim is

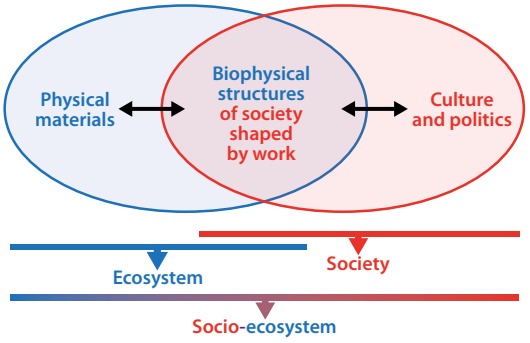
to study how these global historical regimes are reflected in concrete terms in a spatial mosaic of society-environment interactions, the sustainability of which depends on the ability of natural resources drawn on locally and imported from other territories to reproduce. This interconnection through trade, both its physical and economic aspects, brings territories into the scale of the global economy and thus enables spatial scales to be nested.

Epistemological implications

The socio-ecological metabolism approach requires the epistemic cultures of different disciplines to be combined to reflect the social and biophysical duality of the flows of matter. This involves developing radical interdisciplinary approaches, hybridising methods and concepts from biogeochemistry and ecology (biophysical dimensions of flows), history, geography, political science and economics (social dimensions). The risk of this kind of hybridisation is that it leads to confused definitions, misunderstandings and vague concepts. To avoid this, it is essential to develop clear definitions and strong interdisciplinary dialogue. This means being able to contradict, debate or question not only the new methodological approaches used to produce scientific results or analyses, but also the conceptual frameworks used. From an epistemological point of view, this means equalising and positioning conceptual frameworks in relation to each other, considering whether they are complementary or incompatible when it comes to describing part of reality, and comparing their respective power to explain the phenomena we are interested in.

Social and political implications

This epistemological positioning calls for the disciplinary, methodological and epistemological biases from which scientific activity produces statements to be made as explicit as possible. This kind of reflexivity implies considering scientific activity as part of reality: it does not separate itself from reality to observe it but is a dynamic part of it. Scientific statements and discoveries, especially those produced by sustainability science, are likely to change reality at the same time as they describe it. Scientists must therefore find a balance between, on the one hand, maintaining a rigorous stance aimed at objectivising reality using methods that can be falsified and approaches that can be reproduced and contradicted and, on the other, observing that objectivity does not mean neutrality. Scientists cannot separate themselves from reality and, as such, they are part of the power relationships that shape both society



Socio-ecological metabolism
(based on Haberl et al., 2006).

and the environment. Sustainability science must not forget that describing the world is tantamount to beginning to transform it. The question now is in what direction(s).

KEY POINTS

The conceptual framework of socio-ecological metabolism aims to link a social sphere to a biophysical sphere without reducing one to the other. With this in mind, the preferred object of study is the set of material relationships that exist between geographically and historically situated societies and their biophysical environment, along with the causes and consequences of these interactions. This vision has major implications for sustainability science: it provides a way of thinking about the ecological contradictions of the economy, while at the same time ensuring that the spatial dimension is given the attention it deserves if we are to devise new ways of inhabiting the world.

Soil health: a holistic and transdisciplinary approach

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Background

Over 30% of the world's soil and 70% of European soil are considered to be degraded and/or in poor health. In agricultural areas, 80% of this degradation is due to intensive farming practices. This degradation raises issues of food security and the preservation of biodiversity, particularly for tropical soils, which are the most fragile. Introducing more sustainable farming practices such as agroecology is seen as one possible way of rehabilitating soils. However, this approach requires the ability to qualify and quantify the condition of soil, which explains the recent emergence of the concept of soil health.

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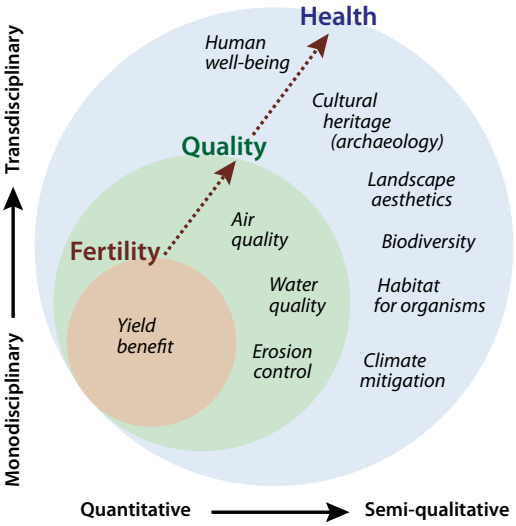
Further reading

Janzen H. H. et al., 2021 – The "soil health" metaphor: Illuminating or illusory? *Soil Biology and Biochemistry*, 159: 108167.
Rochelle L., 2019 – *De la fertilité des sols à la santé de la terre*. Thèse, université de Namur.

What is soil health? A brief history of the concept

The concept of soil health is linked to developments in our relationship with soil (see illustration). The dominant agronomic view initially considered soil as a simple support for plant production (the concept of soil fertility). This view was partially superseded in the 1990s by a more environmental approach, with the concept of soil quality. This is based on a functionalist approach to soil linked to the conceptual framework of ecosystem services. Between 2000 and 2010, more attention was paid to the biotic component of soils, and the concept of soil health has been increasingly used since then. There is no established consensus on the concept of soil health, but most definitions are based on the definition of soil quality, leading to confusion between the two terms. However, the concept of soil health also conveys a more holistic, ecological and sustainable approach to the "soil" system, and it is worth highlighting this. By 1990, a number of scientists had recognised the transformative potential of the concept of soil health, associating it with "sustainability", "alternative or sustainable agriculture", "resilience" and the health of the ecosystem as a whole.



Soil functions and services
(based on Janzen et al., 2021).

Criticisms and views on the concept of soil health

The concepts of soil quality and soil health, and even soil fertility, remain controversial within the soil science community. The main criticism is that these simplifying concepts do not take into account the inherent complexity of the soil ecosystem, which is characterised by the interaction of its biotic component (soil hosts one quarter of the earth's biodiversity) with its physical and chemical component. Soil health, as a metaphorical concept, is criticised because it likens soil to a supra-organism, downplaying its mineral component. The idea of assessing soil quality or health is also criticised because, while it is possible to assess air or water quality, soil quality is more subjective. There is no such thing as a universally healthy soil: its condition depends on the use to which it is put (crops, livestock), the service it is intended to provide (carbon sequestration, crop production), the type of soil, and so on. However, the term "soil health" has given soil a higher profile in society (see https://www.fao.org/soils-2015/news/news-detail/

en/c/277682) and politics (see European Union, *Soil Strategy for 2030*) and has led to a fruitful interdisciplinary (soil science, agronomists, ecologists, social sciences) and transdisciplinary (academia and agriculture) dialogue. Health is a useful metaphor that transcends groups and cultures, because it is widely recognised that healthy soil is the basis for healthy food. This metaphorical concept may be viewed by the scientific world not as a problem, but as an opportunity to co-construct an operational concept with stakeholders in the agricultural world.

Societal significance of the concept of soil health

There is a particular focus on the human component of soil health, echoing many popular views on soil, and it is often compared to the human body. Health conjures up a semantic field that includes the terms "to care" (in line with recent conceptual and methodological developments around care), "to regenerate", "to nourish" or "to look after", terms that are not found in other more technical or productivist views on soil. This notion of care directly raises the issue of the impact of farming practices on soil health. Viewed in this way, soil health refers to the balance of the soil environment, emphasising its living component and making agriculture a goal to strive for in order to ensure the sustainability of the production system and, by extension, the entire food system. This approach means recognising the societal significance of this concept and questioning our modern society's relationship with living things and the productivist and reductionist aims of the agro-industrial system. Soil therefore brings together the life of the soil and the cultural and social dimensions of agriculture in one fell swoop.

Pooling scientific and farming knowledge to assess soil health

Because the concept of soil health is so familiar to the farming world, it facilitates dialogue between the concepts and knowledge of scientists and farmers. This dialogue is happening in a favourable and relatively recent context of transdisciplinary openness, particularly as part of the widespread agroecology movement, which sees it as a necessary way of tackling contemporary socio-agroecological challenges. Today, we need to highlight the practical relevance of this wide-ranging knowledge and to cultivate this diversity of knowledge through ongoing experimentation with agricultural practices adapted to each environment (the concept of context-specific solutions). Dialogue between different forms of knowledge involves not only recognising the legitimacy of each of these forms of knowledge (Kebede Y., 2023 – "Recherche en agroécologie: notre attitude plus que notre aptitude détermine notre altitude". *In*: *Science de la durabilité*. Marseille, IRD, vol. 2: 100-103), but also co-constructing a common language and shared objectives, within a given context. The assessment methods and indicators must be chosen in such a way that they can be shared with the farming community and used to monitor the state of soil health over the medium and long term in order to assess the

impact of practices (for example, https://view.genial.ly/6113dcd5814045odac525bc5/presentation-biofunctool). From this perspective, the concept of soil health cannot be defined in a standardised and universal way; it is a situated and contextualised concept and needs to be co-constructed so that relevant indicators can be defined that are adapted to local conditions.

KEY POINTS

Assessing soil health is a central issue in the agroecological transition. Despite the debates surrounding this concept and the absence of a consensus definition, it is proving to be a catalyst for change in the way we understand the "soil" ecosystem and in the process of co-constructing knowledge. We propose a contextualised approach to soil health, involving a vision of soil as a socio-ecosystem and leading to transdisciplinary dialogue to support farmers in their practical experimentation with agroecology.

Strong sustainabilty as a paradigm for brinding economics and sustainability science

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Background

The concept of sustainable development is rooted in the rise of environmental issues in international institutions. In the 1987 Brundtland Report, sustainable development was defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Economists have adopted this concept in their models, proposing that the stock of capital (human, financial, physical and natural) must remain constant to enable the production of goods and services that guarantee human well-being over time. This conceptualisation, known as "weak sustainability", has been widely institutionalised, notably with the production of "genuine savings" indicators[1] and the regular publication of World Bank reports (Changing Wealth of Nations). However, another conceptualisation, known as "strong sustainability", is also possible.

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Further reading

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Strong sustainability as a conceptual and operational challenge

The weak sustainability approach focuses on the sum total of capital, including social, manufactured and natural capital (see illustration A). Quite soon after the concept of weak sustainability emerged, another school of thought proposed a different way of defining sustainable development. This second school of thought believes that natural capital is different from other forms of capital, and that it must be protected to maintain the integrity of the biosphere. This proposal reflects two criticisms of the definition of natural capital in weak sustainability. The first is its "substitutability" for other forms of capital, since it is the total stock that must be constant. Broadly speaking, we might imagine destroying natural areas if we build a school or a production plant in their place. The second criticism relates to how we value this natural capital, which must be commensurate with other forms of capital and therefore requires a monetary valuation of the flows of ecosystem services that provide benefits to human societies. The proposal for strong sustainability addresses these two criticisms. Firstly, natural capital is defined as the functional characteristics of ecosystems and the integrity of the environment that must be maintained over time. This is similar to work on defining planetary limits, which determine critical thresholds for different aspects of the environment, beyond which the habitability of the biosphere is compromised. This definition therefore does not provide for any substitutability between different forms of capital, but defines a system as sustainable only if it operates within these sustainability thresholds. The strong sustainability approach makes achieving a healthy state of the environment an essential condition of sustainability (see illustration B). This approach can be applied to the Sustainable Development Goals (SDGs) (see illustration C), where achieving sustainability is based on the healthy state of the four environmental goals (see illustration D). Strong sustainability can be integrated into national accounting through the valuation of abatement, preservation and restoration costs, which differs from conventional financial valuations and is useful as an operational tool to inform public decision-making.

Strong sustainability as a boundary object to bring the sciences closer together

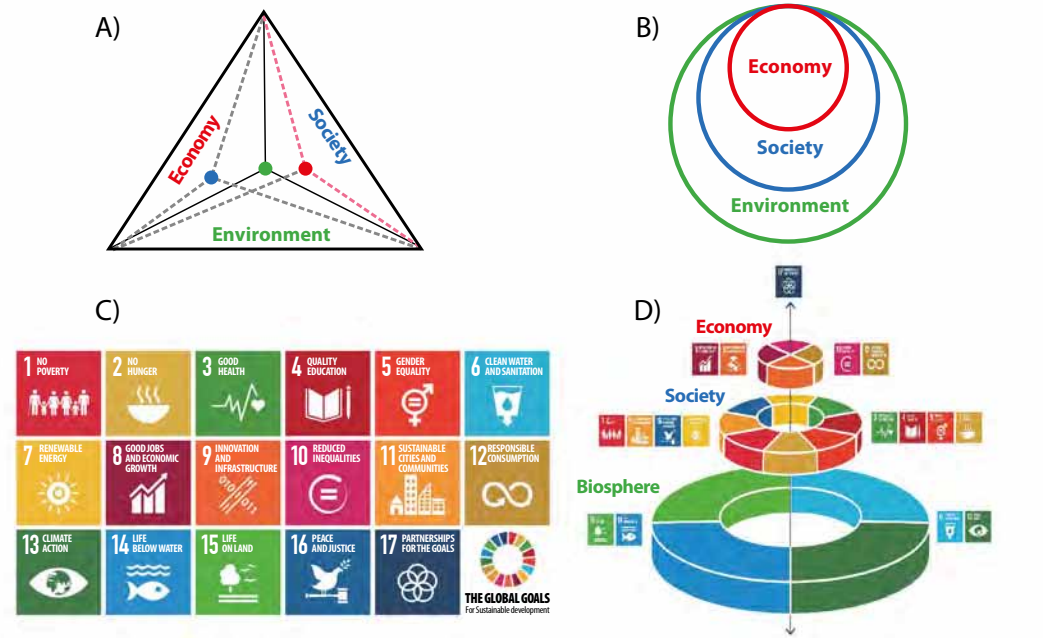
An important issue in operationalising this concept of strong sustainability is the definition of thresholds that must not be exceeded or environmental objectives that must be achieved. This is where the other sciences involved in sustainability come into play. Whereas the weak sustainability approach allows economists to produce models and indicators virtually in isolation, the strong sustainability approach is intrinsically interdisciplinary. Developing environmental objectives is a frontier issue that requires a dialogue between disciplines. Many ecologists, who might be described as pragmatists, have jumped on the weak sustainability bandwagon by developing tools for valuing

1 • Defined as the sum of a country's investments in manufactured capital and natural capital.

ecosystem service flows, without necessarily considering the framework within which these valuations would be used in economics to aid decision-making. Although monetary valuations of ecosystem services provide useful information for making decision-makers aware of the importance of protecting the environment, they have not yet led to a paradigm shift in favour of sustainable development. Strong sustainability also needs ecologists and all the natural sciences to qualify and quantify the integrity and functionality of the environment, at different levels, and to recommend definitions of environmental objectives to be achieved or maintained. Social sciences and humanities must also be called upon to describe other aspects of this boundary object, including the production of legal standards, the adoption and governance of environmental objectives, and the production of biocultural indicators that include values other than those relating to ecosystem functionality. The role of economists here would be limited to providing a framework for transforming this information into indicators that can be compared with other information needed to inform development policies, in the form of a dashboard or an assessment of the costs involved in achieving these objectives, for example.

The need for transdisciplinarity to build strong sustainability pathways

To ensure that the right environmental objectives are defined and adapted to each territory and each development scenario, the strong sustainability approach must not only bring together different scientific disciplines, but also include non-academic stakeholders. The first to be affected are the decision-makers who define development policies and institutionalise them in the form of legal standards. These can be interpreted as shared values that contrast with the sum of individual preferences currently employed in neoclassical economic frameworks. Nor can environmental objectives be defined solely by the natural sciences. This is primarily because these objectives have to be defined at administrative levels (municipalities, regions, states) that do not exactly overlap with the study of ecosystems, but also because of the uncertainty involved in defining these objectives. Some advocate the objective of returning to a state of the environment prior to human intervention (Anthropocene/industrial revolution), while others consider that humans have in fact been changing land use for thousands of years, so an objective based on an environment untouched by human intervention makes no sense. This new research agenda to help define environmental objectives could be based on the Sustainable Development Goals and on scientific frameworks such as planetary limits or the Environmental Sustainability Gap, a conceptual framework that recommends assessing a country's environmental sustainability in terms of achieving good ecological status through the sustainable use of natural resources, the critical load of pollution on ecosystems, biodiversity and human health and well-being.



Approaches to sustainability (based on Wu, 2013):
A) the weak sustainability approach, B) the strong sustainability approach,
C) SDGs prioritised according to sustainability (D)
(Sources A and B: Wu, 2013; sources C and D:
https://www.stockholmresilience.org/research/ research-news/2016-06-14-the-sdgs-wedding-cake.html).

KEY POINTS

Defining sustainable development always poses a problem when it comes to formulating development pathways in concrete terms, at all levels. Strong sustainability, based on the definition of environmental objectives to be achieved as boundary objects, proposes a conceptual framework that enables some economists to embark on a new scientific, transdisciplinary and co-construction-based approach. In its unique position, IRD has begun to lay the foundations for a common understanding of research into sustainability science, by bringing together a community of researchers around Knowledge Communities and by having a strong institutional network.

Space geodesy to observe changes in the Earth's habitable conditions

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Background

As we enter the Anthropocene, the need for tools to observe the rapid changes in the Earth's habitability conditions is more urgent than ever. The international agenda for sustainable development is based on a host of indicators for monitoring the achievement of the Sustainable Development Goals (SDGs), many of which cover vast geographical areas that need to be measured using appropriate tools. Over the last few centuries, geodesy – the science of measuring the Earth – has developed a range of techniques/measures and an international framework for harmonising them. From monitoring various types of natural hazards and their impacts to measuring the consequences of global warming, space geodesy has become a key cross-cutting discipline in sustainability science's arsenal. It is playing an increasingly important role in society by helping to shape the spaces, movements and locations of a wide range of stakeholders and sectors.

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Further reading

Paganini M. et al., 2018 – Satellite earth observations in support of the sustainable development goals. *The CEOS Earth Observation Handbook*. www.copernicus.eu

Space geodesy: evidence for the environment, security and development

Geodesy measures the Earth, including its horizontal and vertical distortions. One of the main purposes of geodesy is to estimate the geocentric coordinates of a set of points on the Earth, thereby creating a global reference frame. These coordinates are calculated from observations made by permanent stations on a range of satellites and extremely distant celestial objects. In 2015, the UN recognised the need to maintain an accurate and reliable global geodetic reference frame (GGRF) over the long term, accessible to all for the sustainable development of societies. The GGRF is in fact the essential foundation for mastering "geolocalised" information, which has become a strategic challenge in the face of rapid environmental change, including for adapting to and predicting climate change. Its main weakness today is the lack of geodetic stations in the southern hemisphere. Space geodesy is therefore a valuable approach for achieving many of the SDGs (see illustration). When it comes to global warming and the associated risks to people, space geodesy can be used to monitor rising sea levels, the amount of melting continental ice and the redistribution of surface water. The launch of the Galileo satellite positioning system by the European Union, the Copernicus satellite Earth observation programme for nature and biodiversity conservation, and the very long series of data from altimetry satellites, which has now been available for more than thirty years, are all examples of a strong commitment to the ongoing development of space-based observations. Many locally elected officials are already using these data and the resulting geodetic products (forecasts) to factor changes in the coastline and changes in the mass of aquifers into their land management policies, or to prevent geophysical risks in continental areas.

Sea levels: observe, explain, prevent

The shifting mass of the ocean and the complexity of the thermal interactions that drive it and those it maintains with the atmosphere make it a major contributor to the mechanisms and changes in the Earth's climate. There is therefore no shortage of reasons for developing space-based techniques for observing the ocean, such as altimetry (surface topography). For example, the now widely recognised acceleration in the rise in mean sea level of +3.28 mm/year (±0.3) has been determined using high-precision altimetry since the Franco-American Topex/Poseidon mission in 1992. The global challenge of rising sea levels alone justifies the need to continue this type of space mission, especially given the major upheavals expected over the next 20 years and by 2100 (see the IPCC reports). The data provided by the Jason satellites, and now by the Sentinel satellites (Europe/United States) have truly ushered in the era of operational oceanography, supplying data to numerous international climate study programmes and monitoring and warning systems, with data available in near-real time.

This has led to the development of application services based on space and in situ data (meteorology, transport, fisheries, biology and resources) which, from a societal point of

Geospatial data and Earth observations used to support official statistics for monitoring the UN Sustainable Development Goals
(source: https://www.earthdata.nasa.gov/learn/backgrounders/sdg).

view, are becoming essential for the sustainable management of the oceans (for example, the Mercator project, https://www.mercator-ocean.eu) Supporting a series of space missions capable of monitoring the oceans for several decades and promoting the operational use of geodetic data (oceans and continents) are therefore major international challenges. France has a unique position in this field as it has territory in most of the world's seas and a long tradition of scientific and technological activity (oceanography, geodesy, space), particularly in its overseas territories.

Geodetic infrastructures spread across the southern hemisphere

However simple the principle of altimetry may be, implementing it is still complex. Positioning satellites with a high degree of accuracy relative to the surface (<1 cm in some places) while at the same time using a terrestrial reference frame that is universally adopted and internationally recognised (i.e. the International Terrestrial Reference Frame) requires the use of networks of observatories, permanent stations or ground antennas that can be deployed across as wide an area as possible and positioned with a high degree of accuracy (1 mm objective). While we should first mention the major role played by CNES (satellites and altimeters), IGN (ground monitoring) and SHOM (the French Naval Hydrographic and Oceanographic Service) in oceanography and geodesy, several research bodies including INSU, CNRS and IRD are now working together to explore how to set up new geodetic and environmental observatories in the southern hemisphere. There is already a site in Polynesia, but it needs to be modernised and, if possible, duplicated in the Indian Ocean (on La Réunion, for example).

KEY POINTS

Space geodesy is a key discipline for achieving the SDGs. Accurately measuring changes in the habitability of the Earth system requires common geodetic references to be established and maintained. Climate change, with its consequences for ocean-atmosphere interactions in particular, is a major challenge for the scientific community. There is an urgent need to expand geodetic infrastructures in the southern hemisphere, while at the same time developing education, training and public awareness of the challenges posed by the effects of climate change. Here again, space geodesy has a central role to play, through the visual and educational value of its maps and images.

Studying territorial dynamics in the Anthropocene

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Background

The global environmental crisis shows that human societies are not external to the environment, but rather they occupy a special place within it. The complexity of the processes linking human systems and natural ecosystems is the key to understanding the concept of the Anthropocene, which, while signalling the start of a critical era of systemic disruption, emphasises that social systems have never been autonomous. This article looks at the dynamics of interactions between society and the environment, using the example of the semi-arid Nordeste region of Brazil, a vast area with a long history of anthropisation, where demographic changes and urbanisation in recent decades have transformed social and territorial dynamics.

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Further reading
www.ird.fr

Courtyard of a family farm. The type of fencing is indicative of a sheep or goat farm. On the left, a semi-buried water storage tank. In the background, the *caatinga*, a dry forest; Tauá, Ceará, Brazil (2020).

Studying the Anthropocene

A large proportion of studies on the environmental crisis focus on understanding biogeochemical disruption on a global or regional scale. Integrating the anthropogenic dimension most often involves categorising human activities by major economic sector (transport, industry, construction, agriculture) with a view to measuring their current and future impact on the environment. Another approach is to look at "natural" risks on a case-by-case basis, analysing their effects on social organisation using explanatory models (inequalities, vulnerability, segregation, environmental justice, for example). A complementary approach is to look at contemporary lifestyles, in other words routine activities, both group and individual, and the way in which they interact with the environment. This makes it possible to place the study of the Anthropocene within an individual-society continuum in the ordinary life of contemporary societies and their local interactions with the environment. One potential

approach concerns the contemporary disruptions to modern life, namely demographic and urban transitions, because they have changed lifestyles and the way space is organised, and because they are putting intense pressure on the biosphere. To begin thinking about the intensity of the environmental impacts of human societies, it is necessary to: 1) bring together the scientific disciplines of the Earth, life and social sciences; 2) incorporate different timescales into the analysis, from the pre-anthropic era to the present day, with a view to developing a systemic analysis of the environment without giving priority to the environment or society; 3) adopt a territorial approach, because the territory is defined as the materiality of socio-ecosystems; and 4) define a common research medium for linking time frames, materiality and the variety of interactions specific to each socio-ecosystem.

An interdisciplinary approach for the semi-arid Brazilian Nordeste region

This analytical framework has been used within the young SANA combined team ("The Semi-Arid Brazilian Nordeste in the Anthropocene") and the ANR Tasab project ("What can a territory do when faced with the global Anthropocene crisis? Socio-environmental dynamics in the Brazilian semi-arid region"). Despite its status as one of Brazil's "problem" regions, because it is exposed to the disastrous effects of cyclical droughts, the semi-arid region is undergoing rapid change, experiencing unprecedented demographic growth and intense changes in land use. To understand what is at stake in this volatile environment, we need to explore the material links between the people and the environment, through a multidisciplinary analysis of the territories from two perspectives. The first concerns the social sciences. It covers several spatial scales, mainly in contemporary times. It is based on the idea that demographic and geographical changes over the last 50 years, including the demographic transition and the urban transition, have led to profound changes in both settlement patterns and lifestyles. These developments have produced specific territorial configurations and spatial points of reference that define society's relationship with the environment and its place in it. The second perspective is that of the life and Earth sciences. Human territoriality in the Anthropocene – and in the socio-historical context under study – is putting pressure on vulnerable ecosystems and their resources. The forms this pressure takes need to be described not only in terms of risks, but also in terms of their evolutionary dynamics over the long term, from several decades to several millennia. By bringing these two perspectives together, the Anthropocene can be described as a socio-environmental territorial dynamic that feeds into forward-looking thinking on ecological transition.

A mosaic of semi-arid regions

The study of the mosaic of territories in the semi-arid Nordeste region of Brazil combines various disciplinary approaches centred on soils, which are essential interfaces for interactions between societies and the environment. Combining, on the one hand, pedologists and

palaeoecologists to study pollens and sediments on water reservoirs and surrounding soils, and, on the other, human and social science surveys on agricultural practices and settlement phases through collecting life histories, the analysis focuses on how the mutual relations between people and the environment have evolved, by detailing how their daily activities manifest themselves locally. Studying two municipalities undergoing rapid change in different contexts reveals a variety of uses of resources and adaptations by local people to the various constraints of a tension-filled environment. In Tauá, a predominantly rural municipality prone to accelerating desertification, a hybrid rural farming model combines agro-sylvo-pastoral family farming that includes food commercial cash crops and small-scale sheep/goat rearing on forest plots. One of the challenges of sustainability is to understand the soil nutrient cycle and the lifestyles and consumption of household units. In Crato, with its wetter climate and interface with a metropolitan area, the effects of urban growth on the rural environment and the resulting forms of peri-urbanisation need to be viewed in a context that encompasses the history of land use and the climatic and environmental changes in the area, which are representative of changes in Brazilian society over the last few decades.

KEY POINTS

Documenting society-environment relationships in a developing country in the Anthropocene era necessitates adopting a dual perspective to understand the fundamental changes in social and territorial frameworks and to assess the local conditions associated with the global environmental crisis. An approach structured around the society/climate/vegetation/erosion nexus aims to deepen our understanding of current social and environmental dynamics and shed light on them through a diachronic analysis of geographical spaces that are characteristic of contemporary territorial dynamics, providing a starting point for reflecting on the ecological transition of societies.

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.

Urban vulnerabilities to climate change: a case study from Bolivia

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Background

Pooling concepts and data to achieve a single objective is the key to interdisciplinarity, involving dialogue and the flow of information between scientists from different disciplines and social stakeholders. For this dialogue to be useful for policy-making, the work must be carried out at a level that is appropriate for territorial management, one where decision-making is possible and that is close to concrete action. In addition, the whole research process must be transferable to the management team, so that it can be understood and reproduced at other sites. A research-action programme is tackling these issues in two Bolivian cities where climate change is an emerging challenge.

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Further reading
https://scioteca.caf.com/handle/123456789/1811

Content of the research project

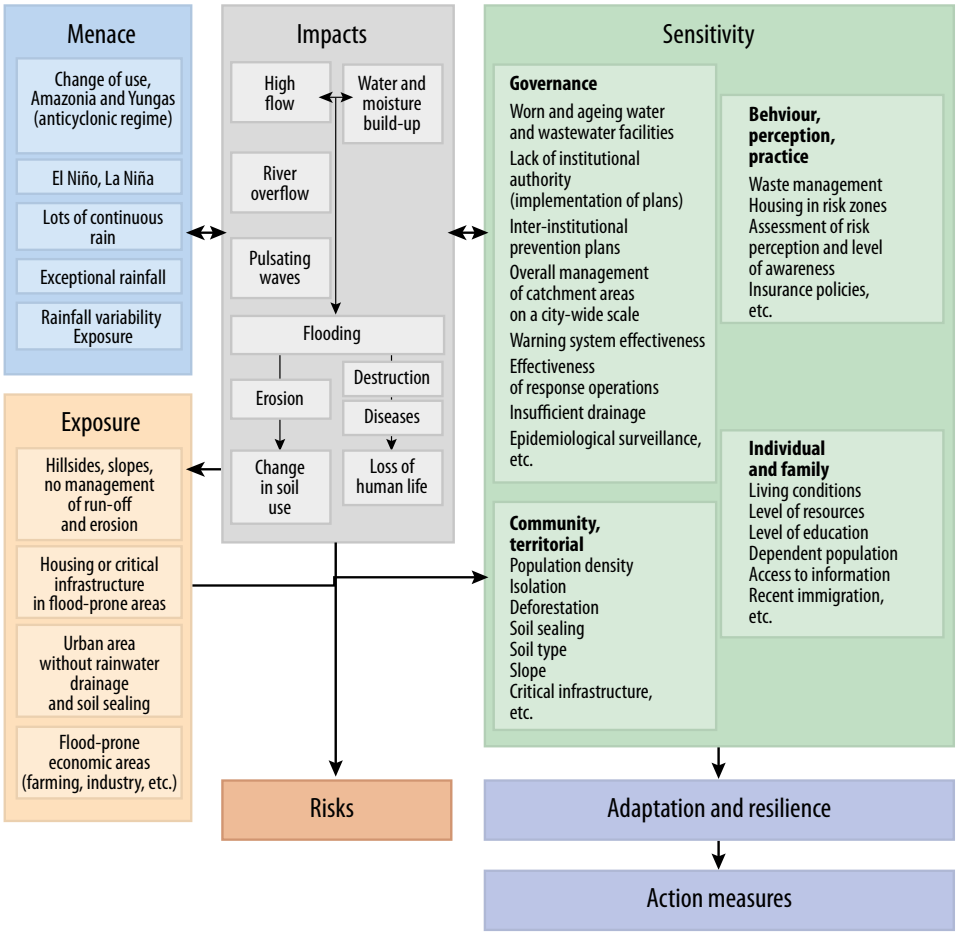
A large number of Andean towns, particularly in Bolivia, are extremely diverse in terms of their physical and environmental characteristics (altitude, climate, type of soil, system of basins and slopes), social and economic features (inequalities between neighbourhoods, varying degrees of identity) and urban planning (high levels of concentration, areas of individual housing or areas of densification and expansion, presence of unconsolidated housing). This heterogeneity creates a variety of impacts and responses to climate change, requiring a cross-sectoral and interdisciplinary approach. As part of a programme[1] designed to strengthen the capabilities of key stakeholders in two Bolivian cities, La Paz and Tarija, the environmental department of the municipalities concerned, two research centres and two NGOs worked closely together to tackle the new challenges of climate change. The programme focused on four areas of study. Firstly, hydro-climatic modelling at a highly detailed scale (1:50,000 for 10, 30 and 70 years) showed: 1) stable rainfall, but an increase in extreme events; 2) a significant increase in temperature differences of up to 7°C; and 3) the importance of the Zongo valley, situated between the tropical zone and the Altiplano, in regulating the climate of the cities of La Paz and El Alto. This modelling, together with workshops with city stakeholders,[2] was used to rank the threats and define the physical, social, economic and political vulnerability of the cities. This programme resulted in the development of integrated risk diagrams (known as "risk chains") – through participatory workshops at which all the variables associated with the threat, exposure, impact and vulnerability are listed, along with the linkages between these four components – for four prioritised threats: flooding, landslides, dwindling water resources and heat waves. Then, using these diagrams as a basis, a series of indicators for diagnosing and monitoring vulnerability to climate change and a detailed mapping of these indicators (at the level of the 649 basic territorial organisations, each of which is the minimum management unit) were developed. Lastly, an adaptation plan was drawn up, including 10 priority projects and 100 or so measures designed to strengthen the resilience of towns and cities, together with the funding for these projects.

A methodology combining scientific rigour and stakeholder priority

From a methodological point of view, the added value of this programme is the constant connection that has been established between the modelling carried out by hydro-climatologists, the design of risk chains by geographers, the work carried out by sociologists on risk indicators and perceptions, the financial evaluations carried out by economists, and finally the search

1 · The programme is entitled "Index of vulnerability to climate change in the cities of La Paz and Tarija" (2019-2022) and is funded by the European Union's Latin America Investment Facility (LAIF) programme, the French Development Agency and the Andean Development Corporation (Corporación Andina de Fomento).

2 · Nearly 30 institutions involved in studying or managing the city took part in the workshops: university laboratories, international bodies, NGOs, public institutions such as town hall departments and certain ministries, private bodies such as chambers of industry and commerce or the engineers' association, and neighbourhood associations.



**Example of how to build a risk chain for "flooding" events.
A few examples of variables are listed here.
The method then attempts to connect these variables, both qualitatively and quantitatively, to assess risk priorities and possible courses of action.**

for projects prioritised by the social stakeholders, which are likely to become the basis of a resilience policy created by the town hall management team. A constant flow of information back and forth between these various stakeholders, in particular the neighbourhood associations who know the terrain best, proved to be fundamental to achieving consistent results

as part of an integrated approach. From a scientific point of view, this study highlighted the importance of the impacts of climate variability in cities with extreme conditions (altitude and drought), combined with geographical and social variability that need to be understood on a detailed scale if targeted actions relevant to municipal management are to be proposed. The inclusion of management stakeholders in the scientific programme from the outset ensured that the proposals for action were validated in the field and consistent across six areas: "green, high-altitude town", "integral conservation of Zongo's ecological heritage", "conservation of fragile high-altitude Andean ecosystems", "urban drainage", "development of a new water culture" and "creation of a climate change resilience centre".

Limits of operational application

A programme of this kind also challenges the limits of scientists' involvement in controlling climate change through programmes whose implementation is often the responsibility of development cooperation agencies or NGOs. Even if this project resulted in a realistic adaptation plan, what guarantee do we have that the plan will be properly implemented? To what extent do scientists have a responsibility in this implementation phase? Should the dogmatic approach of sustainability science not also consider scientists participating in and overseeing the implementation of their findings and recommendations? If so, how might this be done? Methodological frameworks such as theories of change could help to assess these limits.

KEY POINTS

Current data and forecasts on climate change suggest that the impacts will be more intense and specific in urban areas, but also less discernible to the general public and politicians. Working with the risk chain methodology proved to be educational as it enabled the participative construction of summarised diagrams, the elements of which were then prioritised by the local people or experts. This makes it easier to define the actions to be taken and their cost. However, there is still one aspect that scientists do not control: the implementation of research results. This depends on political will and institutions, which are often too unstable in the most vulnerable countries. Solutions to combat climate change are long-term endeavours, which go beyond political visions that are often more short-term.

Nature as an interdisciplinary object

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Background

Marine protected areas (MPAs) have gained in popularity in recent years as a means of experimenting with sustainability and new management methods involving a variety of stakeholders. The changing functions of protected areas go hand in hand with the promotion of new governance frameworks that are relevant when multiple stakeholders are involved. Promoting these frameworks also reflects a desire to work towards less conflictual and more collaborative management, involving public administrations, local populations, non-governmental organisations (NGOs) and environmental protection associations, the private sector, and so on. Theoretically, these governance frameworks are based on shared authority and responsibilities to ensure that the knowledge and expertise of the legitimate stakeholders associated with the protected area are taken into account.

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Further reading

Siniscalchi V., 2008 – Économie et pouvoir au sein du parc national des Écrins. Penser la nature, définir l'espace. *Techniques & Culture*, 1 (50) : 40-59.

Lavigne-Delville P., 2011 – Vers une socio-anthropologie des interventions de développement comme action publique. *Social Anthropology and ethnology*, université Lumière Lyon-II.

From a multi-stakeholder perspective to an interdisciplinary approach

The issue of MPA governance, and particularly the analysis of multi-stakeholder management methods, reveals the "operationalisation" of co-management agreements involving a range of different types of institution, along with institutional and legal pluralism and the mobilisation of several normative repertoires that may be complementary, contradictory or in competition with each other. Natural areas have become less neutral, less consensual and more exposed to conflicts of use, power, strategies and diverse interests (Siniscalchi, 2008). Governing a protected area means first and foremost mediating conflicts, sharing power, undertaking negotiations, allocating or restricting spaces and rights, and taking into account the symbolic dimension of nature. The issues raised by protected areas can only be understood through a combination of concepts, tools and analysis methods from different disciplines.

Interdisciplinarity to understand the complexity of the "nature" object

In a context and in fields that are strongly influenced by normative conceptions of co-management, an interdisciplinary approach is appropriate for deconstructing preconceived ideas and truly questioning the issues raised by the governance of MPAs. Environmental phenomena are "complete social facts", in other words, facts that are part legal, part economic, part religious, and even part aesthetic, part morphological, and so on. As such, they need to be approached from a combination of political, historical, cultural and socio-economic perspectives. This approach is all the more necessary when the stakeholders in question have different ideas about and relationships with nature. When managing the Bamboung MPA in Senegal, two approaches to governance regularly clashed: the one advocated by the associations/communities – for whom the MPA's shellfish resources, after conservation, should be exploited for the benefit of local communities – and the one defended by the Senegalese government, which imposes a conservation sanctuary where exploitation is not possible.
An interdisciplinary study of the governance of MPAs reveals, in addition to the environmental aspects, the socio-political changes brought about at local level by Community-Based Natural Resource Management concerning questions of belonging, identity

Preliminary General Assembly of the Bamboung MPA in Senegal, December 2012.

and autochthony, and their consequences in terms of rights, access to resources and citizenship. In the Bamboung MPA, access to space has been redefined in the interests of "participatory" management. By structuring the project around the criterion of autochthony, exclusive management for the benefit of the residents of the 13 surrounding villages was encouraged without taking into account the historical uses and users of the maritime area in question, which in turn exacerbated claims that certain social groups had been excluded to the benefit of others. An interdisciplinary approach also helps us understand the political dimension of conservation measures, the conflicts of interest and power they generate, and the transformation dynamics of the role the State plays in implementing public environmental policies. Demands for MPA management by the public conservation authorities reveal the ambiguous relationship that the authorities have with the ideologies and international standards that regulate the field of marine and coastal conservation, since they involve a transfer of control from the public authority to the field. Lastly, the interdisciplinary perspective takes a critical look at MPAs as both abstract and empirical spaces where the State and the community meet. It provides an ideal opportunity to explore the reconfiguration of these relationships in a context where citizens are involved in an ongoing process of exercising public authority and asserting their rights in the production of "statehood" and control over the benefits of conservation.

Moving beyond interdisciplinary approaches to promote the co-construction of knowledge

By highlighting the complexity of environmental issues, the analysis of MPAs also reveals the way in which nature has become the object of a multitude of interventions. The State, NGOs, universities and other funding bodies are all jostling for position in these natural areas, where local communities are beginning to ask: What is the point of research? What value does research have in these surveys? Can we continue to treat social facts as things when they raise crucial issues, such as the management of natural resources? In countries where ecological issues are a major concern and where the consequences of climate change are already being felt, this debate is more than a foregone conclusion. While social utility is clearly accepted in the English-speaking world, among French-speaking anthropologists the debate is less clear-cut and the question of "application remains highly suspect in most cases" (Lavigne Delville, 2011). The challenges posed by local communities should prompt us to think more deeply about the need to extend interdisciplinary approaches, which must include the co-construction of knowledge at the local level. This co-construction approach has the advantage of enhancing endogenous conservation knowledge, which has long been marginalised and which can be used to develop sustainable solutions.

KEY POINTS

The governance of protected areas can only be understood through interdisciplinary approaches that help overcome normative visions and encourage an overall consideration of the interconnection of natural, social and political phenomena. Acknowledging the complexity of "nature" as an object and the crucial issues it currently poses in the Anthropocene context, are necessary to develop research that is more inclusive and more focused on implementing solutions. Sustainability science offers real prospects in terms of ensuring consistency and interconnectivity between the production of knowledge and the applicability of related solutions.

A shared fieldwork area: fertile ground for interdisciplinary research into cities in the Global South

Stéphanie Dos Santos [1], Coffi Aholou [2], Bérénice Bon [3], Stéphane Cartier [4], Cécile Cornou [5], Yawo Mawufe Dotsu [6], Jérôme Duminil [7], Gabriel Feltran [8], Romain Gate [9], Helen Gurgel [10], Anouar Hechmi [11], Jean-François Léon [12], Valeria Mardonez [13], Laurent Marseault [14], Anastasie Mendy [15], Raphaël Onguene [16], Jean-Emmanuel Paturel [17], Risa Permanadeli [18], Yosra Saadi [19], Alexis Sierra [20], Valentin Valette [21], Irène Valittutto [22] and Marie-Hélène Zérah [23][1]

Background

One of the raisons d'être of the IRD's Knowledge Communities (CoSavs) is to build interdisciplinary groups around major sustainability issues. However, the recognition and promotion of interdisciplinarity, and even the pressure for it, come up against a number of issues relating to the links between disciplines, which often restrict the effective practice of interdisciplinarity. This is why the CoSavs' first "Sustainable Cities" summer school brought together 27 members from 10 countries and a wide range of disciplines (life sciences, earth sciences, social sciences and humanities) for a collaborative and pragmatic debate on the practice of interdisciplinarity in the study of the sustainability of cities of the Global South.

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Further reading
https://www.cosavvillesdurables.xyz/?PagePrincipale

An urban ecosystem – a jigsaw puzzle of heuristic spaces

Cities are generally characterised as complex ecosystems by their socio-spatial heterogeneity, involving high levels of inequality, and the fragmentation of their spaces, resulting in a diversity of issues and interactions around the question of their sustainability. Taken together, these areas form a jigsaw puzzle, with each piece raising its own set of scientific questions and generating its own heuristics. This is the premise on which we started our work, by choosing to share two areas selected for their cross-disciplinary nature and the diversity of potential research objects.

Two pieces of the jigsaw as a shared fieldwork area

Two sites were chosen in the city of Tunis, the capital of Tunisia, representing two pieces of the puzzle: the industrial port area and the Sejoumi sebkha (flood depression). The industrial port area was chosen to analyse the issue of risks from a number of angles: the concentration of economic issues, urban manufacturing methods, interactions between technological and environmental threats, air and water pollution, health issues, and possible conflicts of interest between major projects and the urban fringes in particular. This area also represents the "open city", ready to trade with the rest of the world through its port activities. The area around the Sejoumi sebkha was selected because it represents the "interface city", that is, the edge of the city, located in an urban-rural area, with self-built and working-class neighbourhoods and a wetland (home to a bird sanctuary) at the centre of a usage conflict. Biodiversity issues, household pollution (liquid and solid waste), agricultural and industrial pollution, and local residents' health issues were all factors in this decision. Two civil society associations helped to give our group of researchers a solid grounding in the real-life situation of each of these areas: the Association of Friends of Mégrine for the industrial port area and the Association of Friends of Birds for the Sejoumi sebkha.

A shared fieldwork area as an opportunity to say and do things together

Sharing these two sites was a fantastic opportunity for co-learning on several levels. Firstly, it allowed us to engage in a dialogue that was less restricted than an academic one, and

1 • **1**: LPED, IRD, Abdjian, Côte d'Ivoire; **2**: CERViDA, UL, Lomé, Togo; **3**: CESSMA, IRD, Paris, France; **4**: PACTE, CNRS, Grenoble, France; **5**: ISTerre, IRD, Grenoble, France; **6**: CERViDA, UL, Lomé, Togo; **7**: DIADE, IRD, Montpellier, France; **8**: CEE, CNRS, Paris, France; **9**: LEDa, UPD, Paris, France; **10**: LAGAS, UnB, Brasilia, Brazil; **11**: GDT, UM, Tunis, Tunisia; **12**: LAERO, CNRS, Toulouse, France; **13**: LFA, UMSA, La Paz, Bolivia; **14**: CAE Opteos, Montpellier, France; **15**: UCAD, Dakar, Senegal; **16**: UD, Douala, Cameroon; **17**: HSM, IRD, Abidjan, Côte d'Ivoire; **18**: ICSRS, Jakarta, Indonesia; **19**: IPT, Tunis, Tunisia; **20**: Médiations, SU, Paris, France; **21**: PRODIG, IRD, Tunis, Tunisia; **22**: PRODIG, CNRS, Paris, France; **23**: CESSMA, IRD, New Delhi, India.

Collaborative map of locations of attention
(https://www.cosavvillesdurables.xyz/?Cartographiedesterrains).

therefore more likely to have a transformative effect. This practice meant that the city's sustainability could be examined using an experimental and inductive approach, based on research objects observed in the field, rather than through the prism of each discipline. This approach avoided the classic disciplinary ethnocentrism of "I, in my discipline, am interested in examining such and such an aspect". For example, working on different spatial or temporal scales, or on concepts that are common but not defined at the outset, was aided by tangible discussions, focusing on specific objects. In addition, working together in a shared site provided an opportunity to learn about the methodological approach that others used, sometimes to the extent of "doing things together". Discussions on concepts (crisis, environment, forcings, limits, risk, etc.), know-how and proof protocols specific to each discipline helped to avoid a hierarchical ranking of disciplines, which is one of the obstacles to achieving a trusting and respectful dialogue between researchers from different disciplines.

Field objects as indicators of diversity

As a result of the diversity of our group, the on-site observation of each researcher revealed the multiple, sometimes antagonistic, questions and surprises of the different pieces of the jigsaw that make up these two sites, some of which certainly led to some conflicts of interpretation and therefore of analysis. For example, the map of the locations that attracted our attention (see illustration) shows that we are not all seeing the same things in the same places. It should be noted that for some people it was not possible to indicate a point, because their analysis scale was larger. A polygon representation was more relevant for them. Marking the site with a point or a polygon illustrates the diversity of perceived issues and therefore of approaches. This diversity helps to describe a set of urban spaces that are part of the overall fabric of the city; discovering each of these parts is then a means of interpreting this urban fabric. In addition, the objects observed during these field studies were able to turn our tacit or implicit preconceptions of sustainability on their head, with car wrecks being a prime example. Although analysed by some as a source of pollution or waste, by others these research objects are no less integral to the value chain and processes that contribute to the city's informal economic fabric. These car wrecks are characteristic of the paradoxes of sustainability: a one-dimensional view of sustainability would not have allowed waste to be analysed as also contributing to the sustainability of the city. This diversity was a way of collectively examining the relationships and frictions between the major challenges of urban sustainability, and therefore the kind of trade-offs that need to be made (e.g. environment *vs* employment).

KEY POINTS

Carrying out interdisciplinary research on sustainable cities calls for a multi-faceted approach that requires methodological co-construction ahead of time. A shared fieldwork area is a powerful tool for implementing this approach. It creates the conditions for inductive co-construction of the shared research object by encouraging a transformative dialogue. It then helps with defining an operational conceptualisation of the sustainable city, a step that should be done in the first phase of setting up a project. In all cases, the earlier it is carried out, the easier it will be to establish a dialogue between disciplines.

Agroecological research: "Your attitude, not your aptitude, will determine your altitude"[1]

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Background

At the intersection of agronomy, cultural practices and political movements, agroecology is a field of research which well illustrates the challenges of sustainability science. Of particular interest is the need to integrate traditional/indigenous and scientific knowledge systems, allowing for greater diversification of alternative agricultural systems which contrast with the normative structures of the industrial model. This represents a challenge for researchers, who are not always trained in the complexities of incorporating non-scientific knowledge systems. Moreover, co-constructive approaches involving all relevant parties necessarily represent a challenge to the researcher's habitual position, namely their central role in defining research questions and how they are to be addressed. In what ways do researchers now need to adjust their stance? What are the pitfalls to be avoided?

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Shifting perceptions of traditional knowledge

Traditional or 'indigenous' knowledge is defined as the sum total of knowledge, know-how, practices and representations maintained and developed by peoples with a long history of interaction with their natural environment. In many cases, traditional knowledge has been passed down through the generations in the form of oral traditions. Such forms of knowledge are often unfairly maligned, perceived as being inferior, archaic or even less serious than scientific knowledge. This pejorative view of popular wisdom has been exacerbated by the snobbery of many scientists, academics and teaching institutions, despite the fact that it has been unwaveringly contested by the very people dismissed as "backwards," whose social struggles have been minimised by such condescending attitudes. Traditional knowledge encompasses unique, localised forms of knowledge which illustrate the cultural diversity of our world; it is the cornerstone of an approach to sustainable development which is attuned to local conditions. In agroecological research, traditional knowledge forms the essential basis of the process of co-innovation. This requires us to take full account of contextualized indigenous knowledge, in addition to scientific knowledge, in order to co-construct research programmes commensurate with the needs of local communities. How best to integrate systems of traditional and scientific knowledge is a research topic in its own right, and one which raises various ethical questions that need to be discussed with the people who actually contribute to the traditional knowledge, not an external ethics committee.

Agroecological research has not got off to a good start

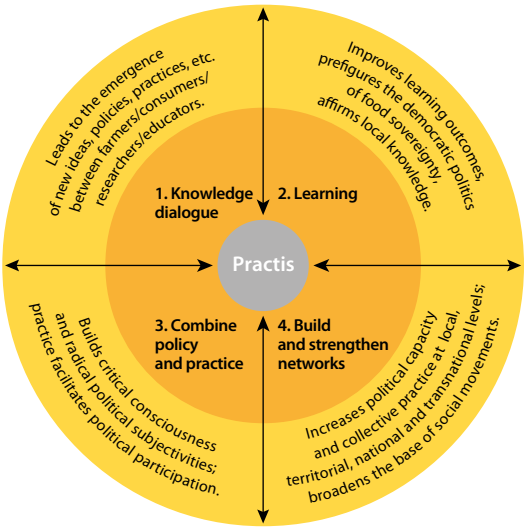
Although interdisciplinarity and transdisciplinarity are now established priorities in many research contexts, the importance of taking traditional knowledge into account is often mentioned, but generally remains a marginal concern. Better engagement with traditional knowledge will not be possible without more effective dialogue between the different disciplines represented within research institutions, nor without a thorough rethink of the way researchers are assessed. Bibliometric analysis of the publications issued by IRD researchers working in the field of agroecology in the decade 2010-2019 reveals that, of a total of 408 publications, only 8% were published by two different research units from within IRD, 1% by three different units, 3% by two discrete IRD departments (Simonins C., Brauman A., 2020 – *Agroécologie à l'IRD : état des lieux et analyse SWOT des recherches en agroécologie à l'IRD.* Report published by the IRD's Ecobio department, specifically the Agroecology working group). Moreover, at the international level, a recent analysis conducted by a Ceres2030 consortium (https://ceres2030.iisd.org) focusing on 100,000 agricultural research publications

1 • Quote from the american writer Zig Ziglar (1926-2012).

found that over 95% of these studies were unable to provide any solutions for reducing food insecurity, particularly that suffered by smallholder farmers (*Nature,* Editorial, 2020). One of the key findings of the Ceres 2030 team was that "most of the studies analysed only involved researchers without any participation from farmers." Since the same causes inevitably produce the same effects, agroecological research cannot hope to be effective without first thoroughly rethinking the practical organisation of disciplinary research, and making changes at various levels: 1) at the level of major research funders, who bestow astronomical sums upon a handful of research projects, which too often become unwieldy behemoths with highly dubious cost-benefit credentials; 2) within research institutions, whose researcher evaluations encompass their impact on communities and society, albeit with assessment criteria which remain primarily focused on scientific excellence within their chosen discipline (number of publications in high-impact journals, number of projects funded). Another recent study (Fini et al., 2022) found that the more effective a multidisciplinary researcher is, the less likely he or she is to receive recognition from his or her peers; 3) at the level of the countries and communities who are still generally characterised as "beneficiaries," where greater critical clarity and more exacting standards are required in terms of the real benefits they can expect to derive from such research; and finally, 4) within educational institutions, the majority of whom continue to train students in monodisciplinary approaches, despite the fact that young researchers are increasingly expected to put forward transdisciplinary research projects with real societal impact.

Participatory research-action: practical considerations and pitfalls

In the field of agroecology, participatory research-action is becoming the method of choice for most research projects. Nevertheless, and although this approach is born of the best intentions, its practical implementation remains problematic. There are a certain number of pitfalls which need to be avoided if we wish to make the transition to



Transformative agroecology requires a didactic approach which places praxis front and centre, while also leaning upon the four pillars (orange circle) in order to further the political objective of food sovereignty (yellow circle)

(adapted from Anderson C. R. et al., 2019 – From Transition to Domains of Transformation: Getting to Sustainable and Just Food Systems through Agroecology. *Sustainability*, 11 [19]).

truly radical, equitable forms of coproduction. In her work with indigenous communities in the Ecuadorian Amazon, sociologist Nina Isabella Moeller identified four limitations to the participatory research-action approach, which are applicable to other research contexts in the South and must be taken into consideration by all participatory research projects: 1) false pertinence (the uncontested hypothesis that a project and its objectives are pertinent for the communities involved, although they have not been consulted in advance); 2) received wisdom about what constitutes participation (the terms of participation are defined in advance by project-leaders, with non-compliance and non-participation regarded not as signs that the project itself is poorly-constructed or lacking in pertinence, but rather as shortcomings on the part of the participants); 3) the myth of equal opportunities (history and past interactions between actors, particularly asymmetrical North-South power dynamics, are often simply ignored instead of being acknowledged and dealt with, which hinders the creation of genuine relationships of trust); 4) the sidelining of other forms of knowledge (knowledge not compatible with the project paradigm is silenced and pushed aside, which means that opportunities for more profound intercultural exchanges and dialogue are simply lost).

KEY POINTS

As an essential component of sustainability science, agroecological research requires us as researchers to change the way we work. We need to adopt an attitude of humility, respect and genuine interest in others, recognising the partiality of our own scientific perspective and the fact that we are steeped in scientific paradigms and belief systems which can never claim to be definitive and all-encompassing. True transdisciplinary research requires us to take other forms of knowledge seriously, an imperative which is as much ethical as it is methodological. In the words of Indigenous Australian activist Lilla Watson: "If you have come here to help me you are wasting your time, but if you have come because your liberation is bound up with mine, then let us work together."

Moving towards land degradation neutrality

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Background

Land is the foundation of all continental ecological processes. Land degradation is characterised by a partial or total loss of vegetation cover, and a corresponding decline in soil fertility, productivity and/or biodiversity. This undermines the resilience capacities of ecosystems and populations. It is estimated that over 70% of the world's ice-free terrestrial ecosystems are in a degraded state, with a fifth of all land (over 2 billion hectares) now regarded as being degraded. Achieving land degradation neutrality is one of the 179 targets (Sustainable Development Goals, SDG 15.3) featured in the UN's 2030 Agenda for Sustainable Development. An opportunity to apply the three pillars of sustainability science: "understand, co-construct, transform."

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Observing and quantifying the health of the land: the importance of interdisciplinary research

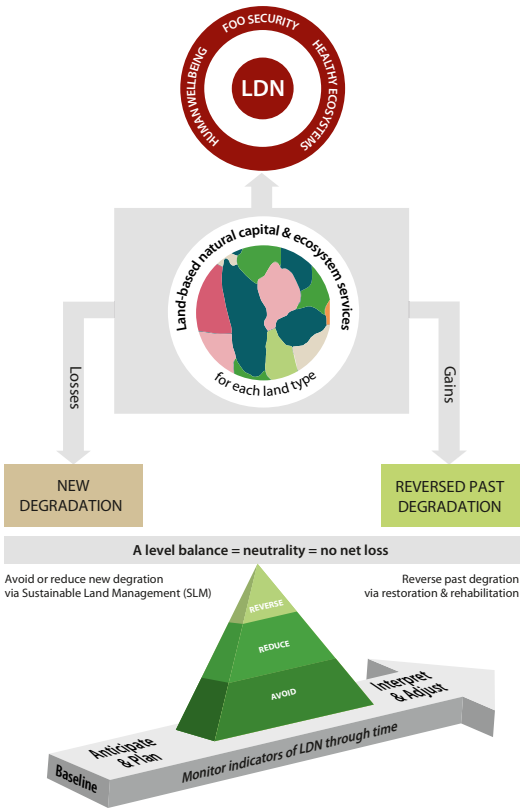
The intensification of poorly-regulated agricultural production with scant regard for environmental conditions, along with the over-exploitation of natural resources to meet the ever-increasing needs of a growing population, are the principal causes of land degradation. Climate change, and its current and future consequences, will only serve to exacerbate this anthropogenic pressure on the land, not least on account of the increasing regularity of extreme weather events (droughts, rains). Documenting the scale of land degradation is a major priority in order to identify pertinent solutions. Since the first years of this century, considerable efforts have been made to quantify land degradation, particularly in arid zones. Remote sensing is one means of estimating the evolution of land degradation over vast areas and long periods of time. For example, numerous studies have highlighted a recent trend for regreening in the Sahel region, although this does not necessarily equate to a full restoration of natural soil functions or the services which ecosystems provide to local populations. Farmers do not always see a positive correlation between re-greening and ecosystem restoration, since periods of drought may encourage the development of hardy plants which are of less use to local populations (Herrmann & Tappan, 2013). Furthermore, the results obtained by remote sensing need to be backed up with measurements taken in the field in order to highlight localised heterogeneity in precipitation, regreening and land usage. Last but not least, the current state of technology does not allow us to track the evolution of soil health down to the fine level of individual family smallholdings, and yet it is precisely at this level that solutions to combat degradation are being deployed. Observing and quantifying all of the social, economic, ecological and agronomical dimensions at both the global and the local levels (down to individual plots of farmland) represents a major priority in order to bridge the gap between science and decision-makers.

Co-producing research with all actors

One way of making more informed decisions is to prioritise the coproduction of research, with a view to improving the state of available knowledge.

"The coproduction of research is a process of collaboration between multiple stakeholders, including academics, who aspire to generate useful knowledge to inform decision-making." (Page et al., 2016). The process can be divided into three phases: 1) co-designing of the research; 2) co-development (scientific integration, knowledge development); and 3) co-publication of results to maximise the impact of the research. In order to avoid land degradation, to reduce the speed of degradation and, where possible, to restore degraded land, it is essential to effectively plan interventions and ensure that they are focused on areas where they are most consistent with the needs of local populations, at the right time and on the right scale (plot, landscape), driven

by a jointly-defined set of priorities. The process of coproducing research may be of use to decision-making and, more generally, may help the research community to evolve and make an active contribution to the transformations required to achieve sustainable development.



Conceptual framework for land degradation neutrality (LDN) as per SDG 15.3

(adapted from Orr B. J. et al., 2017 – *Scientific Conceptual Framework for Land Degradation Neutrality. A Report of the Science-Policy Interface.* CNULCD, Bonn, Germany).

Uniting all actors in pursuit of land degradation neutrality (LDN)

A political objective ratified in 2015 by over 200 UN member states, achieving land degradation neutrality (SDG target 15.3) is a new paradigm designed to halt the continuing destruction of healthy land. LDN is defined as "a state whereby the amount and quality of land resources, necessary to support ecosystem functions and services and enhance food security, remains stable or increases within specified temporal and spatial scales and ecosystems" (*United Nations Convention to Combat Desertification*, 2015). The idea is to balance out losses and gains in order to arrive at a situation whereby healthy, productive land is no longer in decline. To achieve this, more effective dialogue is needed between decision-makers, technical and financial partners, development agencies, civil society organisations, professional bodies, academics and consumers in order to identify concrete solutions to the many challenges involved: food security, biodiversity, attenuation of and adaptation to climate change, and of course general well-being. One key priority must be to reconcile scientific knowledge, traditional knowledge and political visions. All parties should remain true to themselves and their unique skills, but all must agree upon shared objectives which must be constructed over the long term, with "spaces" for dialogue at different levels. At the territorial level, "living labs" are of particular importance for all stakeholders, as they provide forums in which users can share their reactions and ideas, as well as offering spaces in

which to conduct experiments and involve users in the innovation process. A good example is provided by the Ferlo-Sine Living Lab "Trajectories towards carbon neutrality and sustainable development along an agro-sylvo-pastoral gradient in Senegal", launched under the banner of the FairCarbon priority research programme (PEPR). The lab's goal is to test different scenarios for carbon neutrality, looking at their impact in terms of land degradation (see diagram) using an agro-sylvo-pastoral gradient which represents land usage within the parts of the Sahel affected by the Great Green Wall project. The best scenarios, co-constructed with local populations, will be presented and debated with local governments, NGOs, central government agencies and local people, in order to put together a territorial action strategy for achieving carbon neutrality by 2035.

KEY POINTS

A key component of sustainable development, the fight to end land degradation and desertification (and to achieve neutrality by 2030) will require closer collaboration among all actors, at the international as well as the local level. Sustainability science provides a framework for building and operationalising this collaboration.

Utilising the critical zone concept in interdisciplinary research

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Background

Representing the interface between the atmosphere and the world's surface, governed by a complex and interweaving array of physical processes, biochemical processes and human activities on various scales, the critical zone is home to the vast majority of terrestrial life. It is a complex entity best comprehended by means of interdisciplinary research. Although various disciplines of earth sciences and life sciences have begun to join forces, interactions between environmental sciences and the human and social sciences are less advanced. Using the example of water management in El Alto, Bolivia, this study demonstrates how geosciences and social sciences can strike up a productive dialogue and generate new, useful knowledge, proposing solutions to mitigate the impact of climate disruption and human activities.

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The critical zone of El Alto studied from a geoscientific perspective

Located in a semi-arid part of the Andes, El Alto is Bolivia's second most populous city. In this zone, the availability of water resources is at the heart of various challenges such as climate instability, tensions between different water uses and the pollution they cause. Within this context, and from a geophysical perspective, it is fundamental to quantify and qualify this essential resource by modelling the flows of water and contaminants, as well as the availability of surface and subterranean water. Utilising the critical zone concept, researchers are able to detect contaminants and track their migration through the waters and soils of the drainage basin, predicting their future impact on socio-ecosystems. For example, surface water flows are intermittent in this semi-arid, high-altitude climate, and some rivers contain exclusively treated and untreated waste water during the dry season. The hydrographic network downstream of human activities is contaminated with various nutrients (nitrogen, phosphorous, carbon), coliform bacteria and pharmaceutical

The task of securing the drinking water supply in the Katari drainage basin requires some major changes to the way waste water from human activities is managed, since it is often simply pumped out without being treated, sometimes in direct proximity to inflow valves.

residues. DNA sequences associated with antibiotic resistance (sulfamethoxazole) have been found across the entire basin, and even in Lake Titicaca. Furthermore, the city of El Alto sits atop a sizeable aquifer contained within Quaternary-era rock formations composed of fluvio-glacial sediments. This aquifer is replenished primarily during heavy rains in January and February. It is already being affected by contamination from the city, and downstream of El Alto we find greater concentrations of nitrates and chlorides, as well as sulfamethoxazole. However without a clear understanding of the sources of these contaminants or the different soil and water uses, it is impossible to determine the recommended management practices which are both environmentally sound and commensurate with socio-economic realities on the ground.

The need for a geographical perspective

For the geographers working in this zone, analysing the vulnerabilities in the water supply in order to plan ahead for future crises is first and foremost a matter of studying water availability and potential threats to this availability. Pollution generated by local people, particularly the release of largely untreated domestic, industrial and agricultural waste water, both upstream and downstream of El Alto, has a major impact on the water found in the aquifer beneath the drainage basin. Mapping this pollution also serves as a means of raising awareness among stakeholders, and considering potential solutions. Mapping begins with the creation of a geolocated database of activities, which are then sorted by criteria including source (heavy industry, pharmaceutical and chemical industry, mining, industrial agriculture etc.), size, location in relation to waterways and wells, aquifer replenishment points, or upstream/downstream of water resources. Although it does not include undeclared activities – which account for up to 80% of total activity in Bolivia – this census of formally-declared activities, compiled by the La Paz chamber of commerce and industry, constitutes a valuable base from which we can work, and which can be enriched with data gathered in the field. Undeclared activities tend to be influenced by spatial dynamics, springing up close to declared activities for reasons of complementarity and logistical synergy. Approximate though it is, this mapping exercise thus provides a broad outline of the location of polluting activities, which can be improved as stakeholders continue to use it and build on it.

Cross-pollination of knowledge: 1+1 = 3

The data and results generated by researchers in geosciences and social sciences regarding land usage and trends, the geolocation of pollution sources and their circulation within the aquifer, at different temporal and spatial scales, can now be shared and analysed using the critical zone as a conceptual framework. The advantage of this approach is that it allows for a more detailed understanding of vulnerabilities in the available water supply. The aim is no longer to ascertain the quantity of water in the aquifer, but rather to determine whether or not this water is available for use in human activities, based on the circulatory dynamics of the water and associated contaminants. Pooling results from different

disciplines in this manner can help us to better understand and anticipate the feedback mechanisms at work in the water cycle, with creeping anthropogenic pressures on the one hand and climate change on the other (see illustration). It also allows us to create *scenarios* which better reflect the reality of societal interactions with the critical zone. Furthermore, cross-analysing these data enables us to provide stakeholders (ministries, water agencies, municipalities) with more finely-targeted, and thus more effective, solutions. This targeted approach makes it easier to achieve a fair compromise between resource exploitation and conservation in the long term, identifying milestones for a road map for future actions which will be acceptable to all. Examples might include: optimizing the aquifer's replenishment zones, introducing regulations to guarantee the quality of the water in these protected zones, identifying waste water categories which need to be treated etc. Actions conducted in a spirit of consensus may be more readily accepted, since they focus on the shared interests of the different users of the resource. Finally, involving stakeholders with results also provides a means of mobilising them to facilitate research work, for example by helping with population census operations and ensuring access to key measurement points (community wells), or even setting up observation networks and participatory management methods. This inter-disciplinary research raises a number of exciting questions still to be explored: how can the concept of the critical zone and its inclusive management help us to translate results produced by different scientific disciplines into a single, unified result? And by the same token, how can we transfer the benefits of these results to stakeholders with diverse interests, encouraging them to seek out solutions which are not only sustainable, but also acceptable to all? And in return, how can stakeholders facilitate the development of our understanding of the critical zone?

KEY POINTS

One of the strengths of the critical zone as a concept is its capacity to unite researchers from different disciplinary fields in pursuit of a shared objective, with a view to improving our understanding of this zone by taking full account of the multiple interactions between the environmental milieu and human society. It thus serves to bring various questions, results and solutions into focus, some of which may be directly pertinent to stakeholders. It falls to the latter to resolve the problems arising from environmental-societal interactions, which are starting to be felt severely in El Alto, in a high-altitude region with a semi-arid climate which is under pressure from multiple angles.

In defence of militant research: understanding and action in socio-hydrological territories

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Background

Sustainability science is driven by a dual ambition: to understand and offer responses to global challenges. Approaches prioritising the co-production of knowledge and solutions occupy a central place in this movement, but it is now time to abandon the well-meaning fantasy of detached neutrality and recognise the importance of such approaches as political arenas. The analytical frameworks provided by the study of science and technology (Bonneuil & Joly, 2013) and development anthropology (Olivier de Sardan, 1995) may be useful in this respect. This article explores one potential approach to reconciling a suitably critical stance with a clear commitment to supporting the sustainable transformation of socio-hydrological territories, which can be defined as the sum total of relationships which exist between human populations and water resources, as well as the spatial contexts within which these relationships operate.

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In defence of political co-production?

Sustainability science has emerged as a possible response to a dual expectation, or tension, between society at large and the academic sphere: the need to find solutions to complex problems stemming from the interface between nature and human society, while also recognising and respecting the plurality of knowledge. Interdisciplinarity and co-production are combined under the banner of "transdisciplinary" processes, wherein research plays a role which Indian economist and philosopher Amartya Sen defines as "informed agitation," a term which encapsulates both the researcher's duty to produce knowledge and the moral obligation to take a political stance against structural inequalities and power imbalances which benefit a minority at the expense of the majority. Social sciences have an essential role to play here, particularly when it comes to unpicking the risk that co-production approaches might actually serve to reinforce dominant interests, or, on the contrary, the opportunity they provide to foreground marginalised viewpoints. But sustainability science also requires researchers in the social sciences to move beyond their traditional analytical stance (which some would call condescending, or at the very least comfortably detached) and become actively involved, bringing their analytical capacities to bear upon the aforementioned approaches, understood as political arenas.

Serious game designed to illustrate the twin challenges of water resource management and agricultural development, and to identify fair and sustainable improvements.

Militant research: striking the right balance

Long before the notion of co-production came to prominence, the concept of participation (by stakeholders, in all their diversity) in research activities and development projects was a subject of considerable debate. Discussions on this topic tended to be somewhat dichotomous in nature. On the one side were the champions of participatory approaches, heralding their idealistic dimension and the underlying potential to further the emancipation of the most marginalised populations and social groups. On the other side, staunch opponents denounced what they saw as a new form of tyranny (Cook B., Kothari U., 2001 – *Participation: The New Tyranny?* London, Zed Books), a well-meaning discourse which in fact served to perpetuate, or even exacerbate, pre-existing structural inequalities. Diametrically opposed though they may seem, these two perspectives actually share a certain "globalising" dimension, i.e. the desire to impose an analytical framework which is generic and applicable in all situations, and which does not actually allow for any real understanding of the construction and implementation of participatory approaches, specific forms of co-production rooted in specific realities. Naturally, participatory approaches introduce (or are founded upon) certain constraints, but in no way do these constraints compromise their transformative capacities. The real challenge is to define precisely what these constraints are, by whom they are introduced and to what ends, and of course what consequences they engender for a research approach which is both militant, which is to say committed to a fairer and more sustainable future, and more reflexive.

The contribution of critical social sciences

To this end, the analytical frameworks offered by sociological studies of science and technology and development anthropology represent particularly interesting perspectives for an institute whose guiding purpose, as its name suggests, is to conduct research into matters of development (sustainable development, of course!), utilising various partnership-based research structures. What unites these two fields of research is their focus on the day-to-day discourse and practice of research partners, as well as development more broadly. Both fields utilise the terms "involvement" and "brokerage" to describe the strategies of alliance deployed by different actors in order to defend their viewpoints and interests. These notions are of direct relevance to co-production and, more broadly, the interface between science and decision-making. These notions also serve to highlight the fact that researchers are (also) faced with stakes of their own, just like any other actor: methods of co-production thus begin to resemble political arenas, shining new light on research activities and results, as well as some of their emerging and non-independent (and thus partial and contingent) properties.

Reflection and action in socio-hydrological territories: plurality and exploration

Research into water management is particularly conducive to such approaches, confronted as it is with debates over the need to more effectively account for the interactions between

water and society, within the framework provided by interdisciplinary approaches such as socio-hydrology, designed to offer solutions to the challenges of sustainable water management. Nonetheless, a dual process of de-centring is required here. Firstly, it implies a shift towards a more reflexive attitude, recognising the plurality of ways of "thinking about water" and acknowledging that scientific manners of framing water issues are not neutral, and that they inevitably influence results and proposed solutions. This is not so much a matter of integration, but rather of more effectively combining and reconciling different conceptions and perceptions of socio-hydrological territories (i.e. the relationships between water and society, and the spaces in which these relationships unfold). The second shift must be a push for greater engagement, putting research at the heart of participatory approaches rooted in specific socio-hydrological territories and conceived as exploratory rather than prescriptive arenas. Among the potential approaches at our disposal, serious games (see illustration), when combined with a clear understanding of the socio-political stakes of water resource usage, can open up interesting perspectives. Examples can be found in existing initiatives co-created by researchers and non-researchers, which have succeeded in changing old ways of thinking about the construction of water retainment infrastructure in the flood plains of Cambodia, without going so far as to challenge their long-term pertinence – rooted in a political will for agricultural intensification. The reflexive, exploratory nature of co-production is essential to the emergence of an approach to development research which is ethical and humble as to the change it can help to bring about.

KEY POINTS

Sustainability science prompts us to rethink the role of the researcher within society. As one actor among many, each with their own knowledge and understanding of what is at stake, the researcher may be viewed as a sort of informed agitator. Nevertheless, the scientific framing of questions necessarily involves certain choices, and thus incorporates a political dimension which may be more or less explicit. It is therefore essential to adopt a reflexive perspective on sustainability science in action. The study of science and technology and development anthropology provide analytical frameworks which can help us to understand what is at play in the arenas of co-production where knowledge and solutions are forged. Moving beyond the realm of discourse and injunctions, paying more attention to day-today practices can help us to anchor sustainability science, and thus to maintain a certain sense of humility with regard to the role and position that research and researchers might occupy in the socio- environmental transformations at work in the developing world.

Nutrition-sensitive aquaculture for more sustainable aquatic food systems

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Background

Access to varied, nutritious, safe and affordable food is an essential priority in the fight to end malnutrition. Food of marine origin – fish, invertebrates, seaweed and other aquatic plants harvested or cultivated in freshwater or saltwater ecosystems – constitutes the world's most commercially-traded food group. Although it represents an essential source of nutrients, this food group is largely absent from the food policy discourse. Global fishing quotas have remained relatively stable over the past three decades, and aquaculture now produces more biomass than fishing. Nevertheless, in order for aquaculture to continue providing healthy food and a means of subsistence to the world's growing population, its production methods will need to be environmentally, economically and socially responsible and sustainable.

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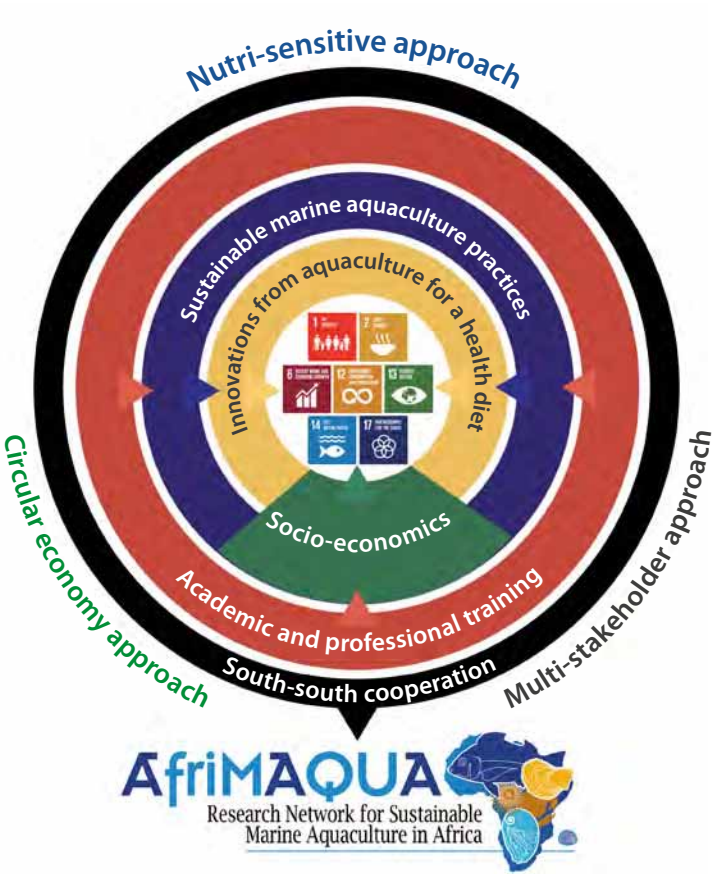
Products of marine origin in the food system

In spite of their undeniable importance for health and well-being, particularly for vulnerable groups such as pregnant and breast-feeding women and children, aquatic foods are generally overlooked in debates and decisions regarding food systems, which tend to focus primarily on agriculture and livestock. For example, SDG 2 expresses an ambition of achieving "zero hunger"[1] by 2030, but it does not mention fishing or aquaculture and its list of targets contains no specific recommendations regarding production systems for food of marine origin, despite the fact that fish accounts for 17% of animal protein and 7% of the total dietary protein consumed worldwide. In many countries, fishing and aquaculture policy is dictated exclusively by economic considerations, often with an emphasis on high-value products destined for export, with scant regard for their contribution to food security and well-being. There are many potential ways to shift this paradigm, including efforts to ensure that fishing and aquaculture are better included in decision-making processes concerning food systems, supporting the role of small-scale fishing and aquaculture in the food supply, and championing nutrition-sensitive aquatic food systems, to name but a few.

A nutrition-sensitive approach

Nutrition-sensitive food production is an approach which seeks to ensure the production of a varied food supply which is affordable, nutritional, culturally appropriate and safe, as well as being sufficient in both quantity and quality to meet human dietary requirements in a sustainable manner. In the specific case of food of marine origin, this means no longer regarding fishing and aquaculture exclusively as means of producing food, but also as means of creating well-being. This requires us to take socio-economic, environmental and cultural dimensions into proper consideration. In other words, the aim is to improve the nutritional contribution of fishing and aquaculture without compromising the essential functions of ecosystems, other food systems and means of subsistence. Adopting a nutrition-sensitive approach means promoting the sustainable diversification and intensification of aquatic food production, evaluating the nutritional content of different foodstuffs in the context of aquatic biodiversity (selecting, capturing and producing species not solely on the basis of their yield, but also with reference to their nutritional content), encouraging sustainable, nutritionally-efficient eating habits, feeding aquatic species with sustainable and nutritious fodder, e.g. foodstuffs rich in Omega 3, vitamins, minerals etc.

1 • Eliminating hunger and malnutrition by 2030, by guaranteeing universal access to safe, nutritious food in sufficient quantity, by establishing sustainable and resilient food production systems and agricultural practices.



Research, training and cooperation within Limaqua.

The Limaqua international joint laboratory

Although it has grown rapidly in recent decades, Africa's aquaculture industry – primarily focused on freshwater aquaculture – represents just 3% of global production. The continent's marine aquaculture industry is thus one of the smallest in the world. In this complex context, the Limagua international joint laboratory (the interdisciplinary laboratory for sustainable, nutrition-sensitive aquaculture in Africa) is running a research and training programme aimed at tackling the nutritional and sustainability-related challenges facing marine aquaculture. Based in South Africa, Limaqua is focused on laying the groundwork for a centre of excellence for

sustainable, nutrition-sensitive marine aquaculture in the interests of food security and nutrition, reducing poverty and contributing to wealth creation in the region (see illustration). This laboratory comprises an interdisciplinary team of South-African and French academics specialising in fields such as biology, biotechnology, socio-economics, food science and human nutrition, all united in the pursuit of a shared response to an essential research question: how can sustainable marine aquaculture contribute to food security and nutritional stability, while also working to reduce poverty and generate income? With this in mind, Limaqua is working: 1) to develop sustainable marine aquacultural practices for priority species, drawing upon research into sustainable farming technologies, sustainable nutrition, animal health and well-being in different farming systems (i.e. the One Health approach) and interactions between aquaculture and the environment; 2) to develop an integrated approach to marine aquaculture, particularly by means of participatory workshops devoted to the co-construction of scenarios conducive to the development of nutrition-sensitive aquaculture; and 3) to develop innovative aquacultural products for healthy eating, including the various uses of by-products.

KEY POINTS

Nutrition-sensitive aquaculture is one of several approaches designed to capitalise on the potential of foods of aquatic origin, in the interest of ending malnutrition. It seeks to boost the nutritional efficacy of aquacultural production without compromising the essential functions of ecosystems, other food systems and means of subsistence. In this context, the international joint laboratory Limaqua, based in South Africa, is running a research and training programme aimed at tackling the nutritional and sustainability-related challenges facing marine aquaculture in this region, informed by the principles of sustainability science.

Co-constructing scenarios for Indian Ocean deltas

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Background

River mouths are socio-ecosystems which play an essential role in coastal biodiversity and productivity. They are also exposed to various dynamics of degradation (erosion, salination, decline in biodiversity, pressure from urban expansion, agriculture, industry and mining, pollution) and territorial projects which often prove to be conflictual. The Sud Deltas international research group (GDRI) is a network devoted to comparing environmental dynamics and tensions associated with the development of river deltas in the western Indian Ocean, discussing potential pathways for these territories, in pursuit of a more equitable distribution of the costs and benefits of upstream dams.

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Fairer sharing of water downstream of dams

River deltas downstream of large dams are among the biggest losers in a division of water resources which prioritises hydro-electric power production and the water supply to cities and industrial agriculture, at the expense of the ecological productivity of coastal wetlands. More than 20 years ago (in 2000), the World Commission on Dams warned of the negative impact of dams on deltas. In the meantime, public policies and international environmental standards have evolved in a bid to identify the environmental flows capable of attenuating the harmful effects of dams. Although certainly no panacea, these flows could nonetheless reduce the impact of upstream water retention infrastructure. However, the environmental flow model has been criticised for being overly technocratic, and sometimes directive. The challenge we now face is to make it an inclusive tool capable of encompassing the needs and visions of local actors (cf. the focus on socio-environmental flows found in the Brisbane Declaration: Arthington et al., 2018). Dam overflow discharges can no longer be regarded simply as technical decisions to be taken by energy companies, technical agencies and their financial backers. Freshwater discharges are about far more than the volume of water which is sent downstream to the sea, as flooding reshapes the aquatic landscape and can have major consequences for the ecological productivity of deltas. But not all actors and residents present within this territory share the same interests, nor do they have the same degree of control over water discharge. They have different sensitivities and experiences regarding the landscape and its functions, and plan for floods differently. Envisaging a consensual flooding scenario which satisfies residents, technicians, scientists and politicians is therefore a challenge, but a challenge which can be overcome by regular observation of flooding rhythms, with each actor bringing their own tools and knowledge to bear, enriching discussions about the future of the territory.

Tanzania: a participatory observatory, an unwelcome dam

In order to promote dialogue between resource managers and residents of Tanzania's Rufiji delta (Warufiji) on flooding-related matters, a Franco-Tanzanian interdisciplinary research team (comprising anthropologists, geographers, biologists hydrologists) established a participatory observatory which has been affiliated with various research programmes since 2000. Its goal is to monitor the effects of flooding on agricultural and fishing strategies, faced with the threat of a mooted dam at Stiegler's Gorge, upstream of the delta; the project was first proposed in the 1970s, and has been abandoned several times because of the likelihood that it would have a severe environmental impact. The participatory observation project has incorporated measurements of water levels and rainfall, calculations of the intensity of fishing activities, and work to monitor agricultural and dietary practices. The resulting observations have been shared in regular workshops bringing together Warufiji, local officials, government technical agencies, NGOs and national and international scientists. These sessions have made use of various tools to facilitate dialogue (conferences, field visits, theatre, games, videos etc.). The result of this

consultation process is an agreement that below 2,500 m^3/s (depending on the definition used, 4.40 m at Mloka, or a "good" flood year, made possible by rituals) the economy of the delta would be greatly perturbed with irreversible environmental consequences. Nonetheless, the success of this collective effort of observation and dialogue in the field has not sufficed to stave off summary decisions imposed from the top down. This should serve as a reminder that water management is an eminently political affair: the decision to build the dam was taken without even conducting an impact study, and announced by presidential decree in 2020. However, the present government and the energy company responsible for running the dam are prepared to take into consideration the environmental impact and climate risks of the project, opening the door to a discussion on how best to define the associated socio-environmental flows.

Renegotiating the unequal sharing of water resources in Mozambique

Unequal sharing of water resources is also a reality of life in the Incomati drainage basin in Mozambique. This situation stems from the Piggs Peak agreement of 1991, whereby South Africa is required only to guarantee a mean average flow of 2 m^3/s to Mozambique, located downstream and at the time just emerging, weakened, from a long civil war. By way of a comparison, in the 1950s the mean annual flow was recorded as 200 m^3/s. Much of that water is now consumed upstream by sugar plantations and other forestry activities (including eucalyptus cultivation) in South Africa. The drastic reduction in the flow of water has led to the salination of land in the delta, inducing transformations in the practices of subsistence farmer/fishermen. Nevertheless, they still manage to grow rice thanks to groundwater

Multi-actor simulation focusing on the Incomati River, Mozambique.

and irrigation channels, now abandoned and used as small reservoirs. However, salination is a major constraint, particularly when no water is discharged upstream to offset the equinox tides. In this case, contrary to the Tanzanian example, there is a genuine political will to gauge the impact of river infrastructure. Mozambique's government, at the behest of the Nairobi convention, entrusted the recently-formed Itango team at Maputo's Engineering faculty[1] with the task of calculating the optimal environmental flows for the delta. Building upon the experience gained in Tanzania, as well as the desire to better involve all actors from the delta, particularly its residents, a new participatory observatory project has taken shape. This new project is focused on observing salination levels and avoidance practices, making use of photographic "field journals," shared via social media with voluntary local observers. The different potential scenarios are then discussed in workshops (see illustration), where simulations are constructed for different models of freshwater discharge (whether the water comes from the dam or the spirits of the river).

KEY POINTS

Deltas are disputed territories characterised by different types of knowledge and cosmogonies pertaining to water, divergent interests and significant power imbalances. Adopting a transdisciplinary approach encompassing academic and non-academic actors, in order to collectively study potential scenarios for the future, takes time in order to build up relationships of trust. This approach will only work if the different participants have something to gain from it, even something as simple as the opportunity to learn about and discuss different practices and forecasts for the future. Researchers must be modest in their ambitions: participatory research structures are imperfect by nature, constructed through trial and error and evolving in response to the circumstances. But they nonetheless provide a vital opportunity to move beyond technical and scientific expertise, taking on the role of "*honest broker*" (as per Pielke R. A., 2007 – *The honest broker: making sense of science in policy and politics*. Cambridge University Press) and playing a central role in sustainability debates. This is a real commitment, striking up a dialogue between divergent visions of African rivers, getting to the heart of matters and studying the relations between water governance stakeholders. When the political context allows it, this approach may also provide an opportunity to enrich decision-making processes with informed, plural analyses, defending the water rights of the most vulnerable citizens.

1 · Recently-formed team affiliated with IRD: Innovative tools and approaches for the governance of natural resources in Mozambique, led by Dinis Juizo.

Moving beyond transdisciplinarity

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Background

As we face up to the sustainability challenges of the 21st century, transdisciplinarity represents a strident call to reinvigorate our research practices. But what exactly is transdisciplinarity? Several definitions co-exist in the academic literature, but tend to prioritize the importance of taking account of knowledge held by actors from outside the academic sphere, as well as a "problem-centric" approach aimed at designing practical solutions (in the spirit of the Zurich School), although not without embracing the philosophical, or even metaphysical and mystical, dimension of research (drawing inspiration from physicist Basarab Nicolescu; Bernstein, 2015). The concept is far from stable. The fact that it is difficult to define serves as a useful reminder that transdisciplinarity cannot be imposed by decree, and that it can never be taken for granted. We suggest that it is forged in the field, and it is therefore to the field that we must look for a definition.

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Observing transdisciplinarity "in action"

Taking a step back and observing discreet, spontaneous forms of transdisciplinarity "in action" requires the ability to spot the patterns formed by the discreet, spontaneous interactions which occur at the interface between science and society. By way of an illustration, we propose to consider the discreet transdisciplinarity at work in the practice of phytostabilisation (the use of plants to restrict the mobility and dissemination of pollutants within soils) in Saint-Laurent-le-Minier, in the Cévennes region of France, a former mining territory which is one of the world's most zinc-contaminated areas. The story begins with a farmer working in this contaminated zone, whose suspicions were aroused by unusual deaths in his herd. He invited researchers, to analyse his soils, and they duly declared the land to be unfit for agricultural use. They then turned their attentions to identifying plant varieties capable of withstanding this pollution, attracting interest from fellow researchers in the process. A research project devoted to phytostabilisation thus began to take shape at Saint-Laurent-le-Minier (see illustration). As scientific work progressed on this site, which at the time was still owned by the farmer, the latter gradually built up a relationship with the researchers, progressing from opening the gates to offering help moving equipment, or sowing and watering test crops while the researchers were away. A relationship of trust was formed, facilitated by the farmer's curiosity and his interest in the research work. The farmer himself became a source of fruitful ideas, offering a fresh and situated perspective, one rooted in the realities of this terrain. According to one researcher, his contributions enriched the research project and allowed it to produce more pertinent responses to the challenges posed by pollution. Ultimately, a new species of bacterium belonging to the *Mesorhizobium* genus, discovered on the farmer's land, was named in his honour, a way for the researchers to express their recognition of his contributions to their scientific work. We can observe a certain form of transdisciplinarity at work here: this was not the initial objective of the project, nor did it serve any declared purpose. These interactions were not formalised, nor were they highlighted in the resulting academic publications. But a relationship was established and evolved as the researchers and the farmer interacted. Moreover, this transdisciplinarity engendered multiple transformations: in the research, in so far as it influenced the team's methodological choices, and thus their results; and in the field too, since the results of the phytostabilisation research initiated on the farmer's land enabled the French Agency for the Ecological Transition (ADEME) to proceed with the rehabilitation of the site.

Rethinking the diversity of knowledge

In its most widely-accepted definition, transdisciplinarity invites us to take the diversity of knowledge into proper consideration. Different forms of knowledge are generally defined with reference to the actors with whom they are associated: scientific (or academic, or expert) knowledge, on the one hand, and local (or traditional, lay etc.) forms of knowledge on

Replanting of the former settlement tanks at Saint-Laurent-le-Minier, 3 years after the test was launched.

the other. However, our example of transdisciplinarity in action in Saint-Laurent-le-Minier demonstrates that this dichotomy is essentially meaningless. Knowledge is a hybrid thing, (Agrawal A., 2009 – Why "Indigenous" Knowledge? *J. R. Soc. New Zealand*, 39: 157-158), since each individual – whether they are defined by others as a scientist, an expert, a citizen, a local resident etc. – carries with them multiple forms of knowledge (Raffles, 2002). Experiential, practical, theoretical, sensory and other forms of knowledge are above all relational in nature, made possible by a "sense of otherness." (Poirot-Delpech S., 2013 – La traversée des apparences. *Socio-anthropologie*, 27 : 103-111).

The importance of approaching transdisciplinarity as a research topic in its own right

Conducting research into such discreet instances of transdisciplinarity "in action" is important in several respects. Firstly, in order to better understand the territory: the circulation of different forms of knowledge, particularly by means of interactions between researchers and local actors, can contribute to the emergence of new research subjects, of new perspectives and positions on pollution, and of concrete solutions to mitigate its effects. In other words, transdisciplinarity has the power to shape a territory. Some steps towards better implementing transdiscipli-narity in the future: investigating the diversity of spontaneous transdisciplinary practices, which often fly under the radar, could cast light on the mechanisms underpinning the transmission and co-construction of knowledge and their effects at territorial level, creating a snowball effect. Analysis of the results could prove useful to subsequent research projects, helping to make the jump from experimental initiative to established research practice. Finally, in order to make an active contribution to the transitions needed to make the planet liveable for the long term: by making transdisciplinarity standard practice in sustainability science, part of our "research routine," we can facilitate the subsequent circulation of knowledge and ideas between academics and citizens. This could be a means of boosting our social inclination for thinking reflexively and changing our behaviour, or even our vision of the world. Observing discreet transdisciplinarity in action has the potential to help us better identify windows of opportunity at the territorial level, and also to trigger more profound transformations in the relations between society and the environment.

KEY POINTS

Transdisciplinarity is not a static concept: it is a team which belies a diverse array of often informal and undervalued practices, which are nonetheless deserving of further study. In order to grasp the diversity of transdisciplinary practices, we must acknowledge the diversity of knowledge and rethink traditional systems of classification. Adopting a more practical approach to transdisciplinarity may help us to more effectively deploy transdisciplinary methods in the future and, in the long term, to facilitate socio-environmental relations.

Sustainable food systems in the Global South(s)

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Background

Transforming food systems to make them more sustainable and more resilient is a stated priority for many institutions, in accordance with the Sustainable Development Goals. Providing healthy food for all while limiting the negative impact of agriculture on the environment requires us to rethink our food systems, i.e. the dense web of social, economic, technological and political changes and dynamics which influence food-related activities and actors at the territorial level. The Knowledge Community for Sustainable Food Systems (Cosav SFS) recently studied the specific challenges attendant upon the research in this pluridisciplinary field conducted by IRD and its partners in the Global South in 2022. This article presents the principal results of this analysis.

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Further reading
https://www.ird.fr/la-communaute-de-savoirs-systemes-alimentaires-durables-syad

Food systems as trans- and interdisciplinary objects

From the fields to our plates, food production is intended to help meet our essential physiological needs. But food production activities also have a defining impact on the relations between human societies and their lived environments, as well as their social and cultural structures. The present challenges to the sustainability of our political, ecological and nutritional systems necessitate a renewed focus on inter- and transdisciplinary knowledge in order to maintain harmony in these systems of relations. In order to analyse the manner in which trans- and interdisciplinarity are handled within IRD, a questionnaire was sent out to IRD partners in the South affiliated with recently-formed research teams (JEAI), international joint laboratories (LMI), or International Research Networks (IRN), all of whom are involved with research into the sustainability of food systems. Thereafter, we conducted a round of interviews with some of these researchers, conversations which we continued at the annual Cosav SFS seminar held on 22-24 November 2022*.

Research into food systems in the Global South(s)

We identified a total of 20 research structures (LMI, JEAI, IRN) working on food systems, primarily in Africa (65%), Asia (30%) and Latin America (5%), with the most prominent research topics being:

- the development of agroecological practices (7 structures): e.g. LMI Lapse in Senegal, working to collate knowledge on plant varieties resistant to environmental stresses, in order to secure agricultural yields;
- the development of sustainable aquaculture (3 structures): e.g. LMI Limaqua in South Africa, working to improve aquacultural output in the interests of people's health, while also bolstering their income;
- innovations in agricultural technology (2 structures): e.g. JEAI Jatro-agro in Burkina Faso, working on an innovative procedure for producing bio-fertilizer using jatropha cakes.

Other topics of research include food safety, the impact of pesticides on human health, pastoralism, pressure on land resources and inter-actor conflict, and the adaptation capacities and resilience of indigenous communities. The majority of these research fields are rich in interdisciplinary approaches – bringing together biologists, ecologists, modelling experts, geneticists and agronomists, along with anthropologists, sociologists and economists – in order to take cultural practices into account when seeking to comprehend the catalysts and obstacles associated with the development of new agricultural practices and/or measure the socio-economic impact on those directly affected. These partnered research structures are also keenly aware of the importance of adopting multi-actor approaches in

* We would like to thank all of the partners who took the time to respond to our email questionnaire, and those with whom we spoke by telephone, particularly Konan Dibi, Ndeye-Helene Diagne Diallo, Éric-Joël Fofiri Nzossié, Hassanebil-Assanou Issou- fou, Ndjido A. Kane, Ousmane Koita, Sitou Lawali, Brett Macey,Ynoussa Maiga, James B. Neya, Kimchhin Sok and Tahina Raharison.

Results of the Word café activity at the annual Cosav SFS seminar (November 2022).

order to rethink technological innovations with and for food system actors, while also facilitating uptake by users or consumers.

Challenges in the South(s)

The dozen or so interviews we conducted with partners from the South highlighted the ways in which the sustainability of their food systems has been weakened by climate change, fluctuating food prices against a backdrop of demographic growth, and a pressure on land resources which has exacerbated the vulnerability of peasant farmers, in particular. The solutions developed heretofore are often regarded as being short-term (and thus unsustainable), since they regard satisfying demand for food as their sole guiding objective (making them "quantitative" rather than "qualitative"). As one researcher put it to us: "sustainability is about making sure, in a low-resource context, that we are capable of producing

enough." Examples of this principle in action may include the abandonment of permanent crops in favour or plants grown to order, or less costly varieties with shorter production cycles. Collective discussion of the question "What is preventing food systems from being more sustainable?" revealed a shared vision of the factors holding food systems back from sustainably and efficiently meeting food needs in their entirety: inadequate political visions, conflicts of interest between actors within the food system, social inequality restricting access to information and resources, models of consumption, and finally a lack of transformative actions at the local, micro-social level.

Towards a more sustainable approach to food systems

We found two, opposing, visions of sustainability: "It is not a new concept, because it is implicit to agricultural and food knowledge" *versus* "It is an essential concept for shifting the paradigm of food production." One thing that researchers do agree upon is the work needed to improve the sustainability of food systems. Seven priority themes emerged from our discussions (see illustration): 1) strengthening the capacity for political action by those essential food system actors who are currently underrepresented in the debate; 2) strengthening participatory governance at all levels; 3) promoting measures which encourage people to consume local produce (cutting transport requirements while strengthening the local economy and increasing food sovereignty); 4) promoting environmentally-sound production practices; 5) fostering culturally and socially appropriate technological innovation; 6) improving communication on matters of sustainability; 7) promoting a sustainability-based economy (circular economy, economic incentives to change etc.).

KEY POINTS

The sustainable food systems knowledge community aims to engage with the major challenges facing food systems and their sustainability. With this goal in mind, the annual Cosav workshop in 2022 provided a timely reminder that research into sustainable food systems is also a matter of:

- **ramping up knowledge sharing between academics, development specialists and the people directly affected by such research, in a spirit of participation;**
- **making research equal and equitable for all research partners;**
- **reconciling the local and global dimensions of food systems.**

International joint laboratories: experiments with a sustainable, equitable partnership model

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Background

Establishing fair and sustainable institutions, and partnerships conducive to co-construction and the sharing of knowledge between North and South, is an essential priority for the implementation of Agenda 2030 and its Sustainable Development Goals (SDG 17.6). International joint laboratories (LMI, for French *Laboratoires Mixtes Internationaux*) represent one of IRD's principal forms of partnered research. They are structured as research and training-through-research platforms, co-constructed with partners in the South and hosted by them. Since its launch in 2008, this programme has evolved to incorporate more co-construction, thematic calls for projects focused on the SDGs and major societal and environmental challenges, and greater appropriation of the structures by the partners. In 2022, a review of the entire programme in Africa was conducted, highlighting some of the key concepts of sustainability science with which the LMIs have experimented.

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Further reading
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Co-construction, shared governance and appropriation by partners from the South

LMIs provide a vital space for experimentation with modes of partnership which diverge from the models traditionally encountered in French and international research and higher education. Based on the feedback from project leaders, the insistence on joint North-South governance for LMIs, as set out in the reference framework for this programme, encourages co-construction and forward planning from the draft project stage onwards. The collegiate manner in which these laboratories are managed encourages a constant focus on consensus. The mobilisation of partners in the South, who are proactive in the running of LMIs and the definition of their strategic and scientific direction, guarantees that the project will always hew closely to the needs and realities identified on the ground. Partners are encouraged to appropriate the project every step of the way. Co-construction is thus conducive to the long-term stability of these structures within the research and higher education ecosystems, promoting the reputation of the LMI scheme as a mark of quality among partners and financial backers.

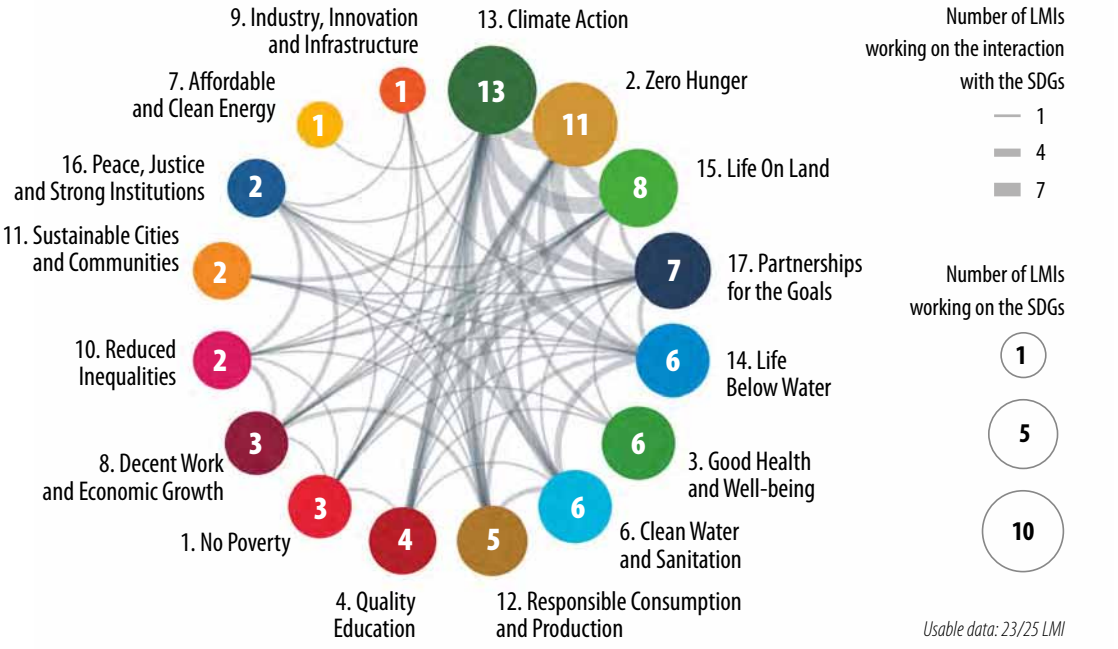
Problem-centric science spanning the local and global dimensions

LMIs are territorial tools hosted by partners in the South, strongly rooted in their territories. They exist at an intermediary level between field projects and institutions, helping to bridge the gap between local needs and research and development strategies defined at the national and international levels: 1) they seek to respond to concrete, local problems (e.g. neglected tropical diseases, agricultural crops of particular importance in national contexts, seismic risks) while also furthering the strategic priorities (food security, access to water, pollution, health, migrations, etc.) of the LMI partner institutions and the countries in which they operate; 2) the trajectory of their work is necessarily determined by constraints on the ground, which may be financial or geopolitical in nature, or else linked to research culture and infrastructure, or indeed to the vagaries of institutions. The flexibility of the LMI structure is an indispensable asset when it comes to adapting projects to their contexts, fostering creativity and dealing with diverse situations.

Pluri- and interdisciplinarity

The activity review also revealed that the LMI programme in Africa has brought together researchers with a vast spectrum of expertise, encouraging them to collaborate on research questions germane to multiple disciplines, adopting a resolutely interdisciplinary perspective (see illustration). The connections forged between seemingly unrelated disciplines within certain LMIs illustrate this defining commitment to interdisciplinarity based upon interactions between the disciplines represented within each LMI. For many LMIs concerned with physical and biological environments, the challenge has been to combine human and social sciences and study the interactions between different research fields,

The circles represent the SDGs and the arcs the interactions between the SDGs within the LMIs. Each LMI could declare up to six SDGs. SDG 5 "Gender Equality" was not declared by any LMI.



Interactions between SDGs within LMIs in Africa.

societies and peoples. All LMIs champion the advantages of combining perspectives and breaking down disciplinary boundaries in this manner. As such, sharing facilities and field missions, as well as coming together for academic discussions and teaching (seminars, colloquia, summer schools etc.) dynamizes the exchanges between teams and disciplines and encourages interdisciplinarity in research.

The potential to go further: participatory sciences and transdisciplinarity

While the principal benefits of the LMI programme may be academic in nature (training students and doctoral candidates, updating facilities, training researchers and technicians in techniques and disciplines not well-established in their countries), some LMIs also work

with at least one non-academic partner with the capacity to have a real societal impact: agencies responsible for managing natural resources, NGOs, government agencies, farmers, incubators and start-ups etc. Nevertheless, the review of LMIs in Africa reveals that only 14% of LMI partners in the continent are from outside the academic sphere. More early involvement – including in discussions ahead of drafting and submitting the LMI project application – of partners specialising in knowledge transfer, scientific mediation, innovation, the management of natural resources etc., along with other civil society stakeholders (producers, users), would probably help to amplify the societal impact of these projects.

KEY POINTS

Although not specifically created with sustainability science in mind, LMIs have shown themselves to be ideal arenas for experimenting with concepts and practices of partnered research: co-construction and shared governance help to promote equity between teams based in the Global North and South; engaging with "problem-centric" research topics requires teams from different disciplinary backgrounds to work together in pursuit of solutions; the institutional ties and scale of the programme help to bridge the gap between the local and global scales. Some LMIs are experimenting with participatory science and transdisciplinarity, involving partners who are also direct beneficiaries of the research. The flexibility of the LMI format makes it possible to experiment with alternative partnership formats, which are fairer and more compatible with the fundamental concepts of sustainability science.

TRANSFORM

The ambition of sustainability science is to find answers to some of the great challenges facing our planet, contributing to the acceleration of the transformations our societies must undergo in order to face up to global changes and the intersecting crises they entail. In this complex context, all those engaged in research and higher education focusing on matters of sustainable development have a duty to reflect upon their own contribution to the global effort.

Sustainability sciences and education

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Background

Sustainability science requires new approaches to education. Designated by UNESCO (in 2017) as a top priority for higher education and research, it should prompt us to rethink the connections between education and territories, between sciences and society, between education and citizenship. Our goal must be a new configuration of our *curricula*, transcending disciplines in pursuit of real change and political action (political in the sense that it must be rooted in the *polis*). Sustainability science is about reformulating the way we teach environmental issues and sustainable development, subjects which belong to the political sphere and are informing the emergence of new ways of relating to the world, to knowledge and to others.

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Further reading

Barthes A., 2022 – Quels *curricula* d'éducation au politique dans les questions environnementales et de développement ? *Éducation & Socialisation*, 63.

Current events and educational approaches to the environment and sustainable development

Educational trends evolve in response to overarching societal issues and international political transformations. Different approaches to environmental education, founded upon the realisation that the environment is finite, have emerged from a diverse array of activist milieus, integrating mainstream education systems (formal and informal) over the decades since the United Nations Conference on the Human Environment (1972). From the 1980s onwards, the growing political realisation of the environmental impact of human activities led to landmark moments such as the Bruntland Report (1987) and the sustainable development summits held in Rio (1992) and Johannesburg (2002). Since then, education on matters of sustainable development has witnessed two broad phases. The first was predominantly behaviouralist and normative in character, connected with UNESCO's decade of sustainable development initiatives 2004-2014, focusing primarily on green lifestyle changes and eco-efficiency (recycling more, for example). The second phase was shaped by the "challenges and objectives" of the 2015-2030 road map for global education, with a greater focus on translating local challenges into global principles. More recently still, sustainability science has been supporting popular mobilisation

Epistemological turning points and the language of modern "educations in".

in response to the climate emergency, and the integration of the Anthropocene concept into educational curricula. This global trend has allowed for a general migration towards forms of education that are more holistic, more complex and more avowedly political than past approaches focusing on the environment and sustainable development. In this respect, it represents a counterweight to other recent trends which are very managerial in nature, such as the ecological transition and the green economy.

Epistemological turning points in educational approaches to sustainability science

Sustainability science, the environmental humanities and the Anthropocene are all facets of a paradigm shift away from officially-sanctioned environmental crises and institutional policies focused on "sustainable development," "transition" and the "green economy." Transposed into the field of education, these concepts challenge previous models of education, based on the vertical compilation of knowledge: 1) thinking about changes; 2) engaging in political action, (in the sense that it must be rooted in the *polis*). Extended to the field of "educations in" (health, citizenship, the media, heritage, territories, the environment, sustainable development etc.), this new paradigm is accompanied by a new vocabulary (see illustration). New educational paradigms draw upon broader societal approaches to problem-framing – sometimes regarded as being vague and unhelpful, or at the very least complex and systemic – beset with uncertainties, risks and stakes of their own, encompassing a spectrum of ends, norms, value and outlooks and bringing protean political messages to a broad audience.

Sustainability science: towards a salutary political education

French historian and sociologist Pierre Rosanvallon has argued that "today the problem is not passivity, but rather the rise of the unpolitical, which is to say a failure to achieve a global understanding of the organisational issues facing our shared world." (Rosavallon P., 2006 – *La contre-démocratie*. Paris, Seuil). Education is a force for improving our comprehension of what is at stake, and our political understanding of situations, thus providing a tonic against the "unpolitical urge." However, the 7 didactic positions most frequently-encountered in formal education situations are *a priori* antipolitical, to the extent that they do not allow for a better understanding of the underlying forces. They are: 1) superficial neutrality (for example via ideological attractors or "soft" concepts such as "capacity for action," " citizen participation," "engagement," "the learning society" etc.); 2) affirmation of a shared set of *a priori,* over-arching values which are not up for discussion (consensus, respect, etc.); 3) relativist positions ("all views are equally valid"); 4) non-contextualised technocracy (e.g. the technical dimension of waste recycling); 5) trivialisation; 6) failure to differentiate; 7) moralising behaviouralism (fear or guilt). *A contrario*, with sustainability science and political education, the

goal is to make clear the reality of the social relations which underpin the "accepted curriculum," transcending normative political and/or technical injunctions and allowing learners to define their own positions, and even helping them to defend themselves in situations of injustice.

By way of an example, asking a pupil to summarise something is a form of technical learning, whereas asking the same pupil to identify the actors involved, their importance, their contradictory or complementary values and their positioning in relation to values such as social justice belongs to the realm of political learning. Sustainability science thus involves a robust education in the interests of societal transformation, which must be fair and collective, and not a weak education focused on attenuating the harmful effects of unequal development, from a purely economic perspective. It is a matter of facilitating comprehension of the political challenges facing society, an education in politics which is at once empowering, critical, creative and mobilising.

KEY POINTS

Sustainability science and its didactic offshoots challenge previous models of education, based on the vertical compilation of knowledge, with a new focus on: 1) thinking about changes; 2) engaging in political action. At stake is the way we frame complex and systemic societal problems, reaching the widest possible audience with an "education in politics" with its own specific vocabulary, methods and "curriculum."

From urban tips to extractive territories: reformulating the waste issue

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Background

As the mass of by-products generated by human activity reaches the point of outstripping the planet's biomass in its entirety, exceeding a 5th planetary limit in the process (largely as a result of the proliferation of microplastics in the oceans, which are rapidly becoming clogged up with junk), now more than ever we need to rethink our society's relationship with materiality. The issue of waste – long neglected, now unavoidable – is in need of reformulation. The materiality of our lives is generally "coded" in terms of waste by the producers themselves, and it is left to each individual to "decode" this information. In this article we propose to "recode" it, i.e. to reformulate it in an original manner which makes clear the connections between urban tips and the mines at the origin of the consumption cycle. This reconfiguration opens up new questions which get to the heart of sustainability science (tackling the causes of problems, developing a holistic approach), and allows us to make some suggestions for concrete action.

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Further reading

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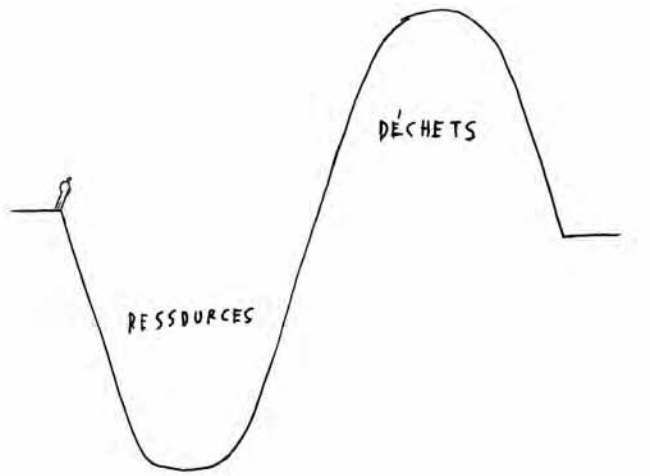
Haberl H et al., 2019 – Contributions of sociometabolic research to sustainability science. *Nat Sustain*, 2 : 173-184.

From rudology to socio-metabolism

From the Latin *rudus* (debris), "rudology," the science of waste, was founded in 1985 by French geographer Jean Gouhier. It concerns itself with the study of refuse, those things we shun and discard, and with the conditions and assumptions behind this rejection. It is a pluri-disciplinary approach spanning the human and social sciences (geography, sociology, economics etc.) in order to explore the polarities revealed by the circulation of different forms of waste, primarily of household origin. Formerly regarded as a pioneering approach, rudology is no longer fit for purpose in light of the unsustainable proliferation of waste in all of the planet's milieus: terrestrial, fluvial, marine, oceanic, atmospheric and even orbital. All of which leads us to the following hypothesis: studying that which is left behind when the economic system reaches the "end of the line," focusing exclusively on downstream technical solutions, leads us into an analytical and operational impasse. We thus propose a shift of perspective. We need to turn our attentions further upstream, reconsidering the socio-metabolism in its entirety. Borrowed from biology, this term is applied to the quantitative study of physical flows within a socio-economic system (Haberl et al., 2019). Socio-metabolism allows us to resituate the issue of waste within a more systemic understanding of how our societies function in sheer material terms. To do so, we must be clear about the connections between downstream processes of surplus disposal and upstream processes of resource extraction. It is essential to bear in mind that the mountains of waste which continue to grow all over the world are inseparable from the mines dug to extract more resources. These two phenomena are two sides of the same coin, leaving lasting scars on our territories.

Complication no. 1: The hidden footprint of things

Attempting to understand waste solely in terms of municipal refuse is grossly misleading as it overlooks the biggest source: industrial waste, which is 18 times greater than household waste. The average resident of the Greater Paris region consumes 6.5 tonnes of products each year (visible consumption). In reality, however, the average material footprint is three times greater (20 tonnes/year) when we include all of the materials used upstream in the process of manufacturing those goods. The "material footprint" encompasses all of the natural resources used in the production of a specific good. The quantity of material displaced or utilised in this process far outweighs the mass of the finished product. We thus need to shift our focus away from household waste, and instead consider the total material footprint of the things we use and consume. This shift requires us to look more closely at the issue of mining waste, an industry where reject rates of 99% – perhaps even 99.9% – are common. Digging up the earth's crust is first and foremost a gigantic exercise in waste creation. And yet the handling of mining waste, which can be highly toxic in some cases, is anything but ideal. Striking examples can be found in the deadly, polluting mudslides seen in Brazil (Minas Gerais) in 2015 and 2018.



© B. Bonnemaison-Fitte, in collaboration with Encore Heureux
(taken from *Matière grise*, 2014, Éditions du Pavillon de l'Arsenal).

Complication no. 2: Dismantling urban mines

The term "urban mine" is generally used to describe the potentially useful resources found in our waste, particularly household waste. For example, discarded mobile telephones constitute a vast reservoir of precious metals. In theory, retrieving and recycling these metals would reduce the demand for virgin materials while also reducing our waste problem. "Socio-metabolism" is enlightening in this respect, since it serves to remind us that a large proportion of the materials extracted upstream in the process do not immediately become waste. Each year, 31 billion tonnes of materials extracted from the critical zone (the Earth's outer layer, defined by the chemical interactions between air, water and rock) are initially used in relatively permanent buildings and infrastructure (immobilising these resources for several decades). The volumes involved are such that the total mass of anthropogenic artefacts which make up our urban environments is close to outstripping total planetary biomass (Elhacham et al., 2020). This is an unprecedented tipping point in human history, and the greatest concentration of mined resources is found in urbanised areas. This stock of extracted, transformed materials (in the form of buildings, infrastructure, networks, industrial facilities, vehicles, electrical appliances etc.) constitutes an urban mine of "secondary" materials to be utilised. The challenge we face is to rethink the infrastructure of the fossil economy, viewing these artefacts as objects to be "unpicked," an old world to be broken up. How do we go about organising this great dismantling?

KEY POINTS

The perspective offered by socio-metabolism is enlightening in several respects. To begin with, it highlights the major problem posed by the declining liveability of the critical zone: upstream, the extraction of materials from the earth's crust has reached unprecedented proportions with severe consequences for biodiversity; downstream, the massive scale of waste gives the lie to the circular economy discourse, since fewer than 10% of the materials we use are currently recycled. This perspective also highlights the exaggerated emphasis placed upon household waste, particularly in the human and social sciences, when in reality it accounts for less than 10% of total man-made refuse. Finally, our urban environments constitute an enormous reservoir of potential resources, which continues to grow by 31 billion tonnes each year. Indeed we have reached the point where anthropogenic artefacts are close to exceeding, in terms of sheer mass, the entirety of the planet's biomass.

How do we define "sustainable meat consumption"?

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Background

Defining what constitutes "sustainable" consumption of meat is a complex undertaking which depends, among other factors, on how we define "sustainability." Previous scientific studies have been predominantly informed by environmental and nutritional objectives. They thus adhere to a definition of "sustainability" which is too narrow, failing to take the ethical (environmental and climate justice, animal ethics) and socio-economic (means of subsistence for farmers) dimensions of consumption into consideration. Furthermore, these studies fail to draw upon the knowledge embodied by non-academic stakeholders, eschewing public participation. We now urgently need to build a holistic, participatory model, establishing a conceptual framework which will inform more ambitious future public policies on meat consumption.

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Further reading

Cué Rio M. et al., forthcoming – The elephant in the room is really a cow: using consumption corridors to define sustainable meat consumption in the European Union. *Sustainability Science.*

Fuchs R. et al., 2020 – *Europe's Green Deal offshores environmental damage to other nations.* Nature, 586 : 671-673.

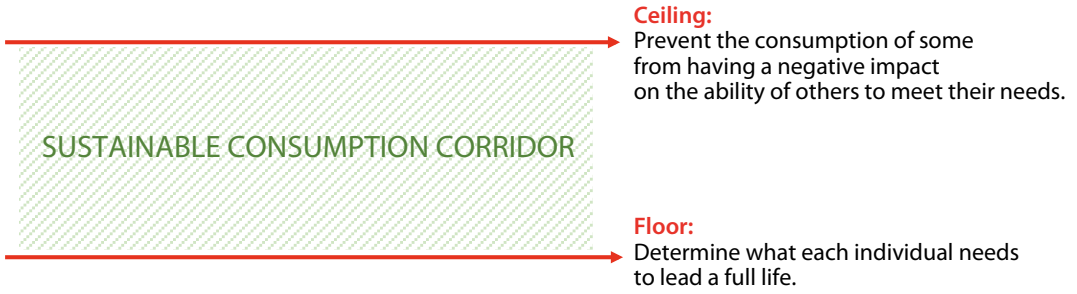
Sustainable consumption corridors: an original model for sustainability governance

The concept of "sustainable consumption corridors" is rapidly gaining acceptance in the literature on sustainability governance. Much like the "planetary limits" or "Doughnut model," these corridors seek to preserve human well-being in a world of finite resources. What makes this approach original is its focus on consumption as a major cause of the socio-environmental crisis. The corridors model is also innovative in its ambition to simultaneously tackle both over-consumption and under-consumption, combining the problems of the global North and South in a single model.

A consumption corridor is the viable space between a maximum level of consumption which must not be exceeded (the ceiling) and the minimum required level (foundation), allowing everybody to meet their nutritional needs without compromising the ability of others to meet theirs. The ceiling is defined from an ecological perspective, in terms of planetary sustainability: to remain within the planetary limits, we need to ensure that the consumption of certain individuals does not negatively impact upon the capacity of present and future generations to meet their needs. The foundation is defined in terms of well-being: ensuring that everybody has access to sufficient resources, determining what individuals need to maintain a satisfactory standard of living. The space between the foundation and the ceiling constitutes a "sustainable" corridor, within which we are free to make our own consumption choices. The space will evolve with time, shaped by technological, cultural and other changes.

Consumption corridors and meat consumption in Europe

Europeans are among the world's biggest consumers of meat, with the continent coming in third place behind the USA and Australia. However, the consequences of this over-consumption are not felt solely in Europe: this is



Sustainable consumption corridor (adapted from Cué Rio et al., forthcoming).

a global issue with serious repercussions for the climate and the environment in the Global South. In spite of this, Europe's politicians have thus far failed to take sufficient action to reduce the continent's meat consumption, which is "governed" by vague, and sometimes contradictory, dietary recommendations. The restrictions introduced by the European Green Pact are largely aimed at rebalancing Europe's agricultural output, with most impact studies suggesting that they will lead to a reduction in meat production in the continent. However, numerous studies (including Fuchs et al., 2020) have pointed out that focusing exclusively on output will not suffice to combat climate change. At the same time, we also need to take action to drive down demand for meat in Europe – or else run the risk that the gap will be filled by meat from elsewhere, thus shifting the associated environmental damage elsewhere in the world. This raises crucial questions about environmental justice, which cannot be resolved by approaches focused solely on the production side. In this context, the advantage of the corridors approach is its capacity to illustrate the impact of European over-consumption on the rest of the world. The ceiling of the corridor represents a maximum threshold for meat consumption in Europe, which would be compatible with the planetary limits regardless of where the meat is produced. A second advantage of the corridors model is its potential for defusing the sometimes-feisty debates that meat consumption inspires. Often excessively simplistic in nature (eat meat/eat no meat), these debates elicit some extremely polarised opinions (animal rights campaigners v. farmers, meat-eaters v. vegetarians etc.). By legitimising a "sustainable" degree of meat consumption, the corridors model has the potential to satisfy the demands of those who wish to continue producing and consuming meat. Nonetheless, this consumption would be capped at a certain level which, for Europe, will necessarily be below current levels of consumption. This cap could be an at least partly satisfactory solution for those who are opposed to meat consumption outright.

Towards a holistic definition of sustainable meat consumption

Led by IRD, an interdisciplinary network of European researchers is now working on formulating quantified objectives (ceiling and foundation) for sustainable meat consumption, based on the corridors model. The network promotes the co-construction of quantitative objectives at EU level, in collaboration with the principal stakeholders (consumers, the meat industry, farmers, animal rights campaigners, politicians etc.). For the ceiling values, discussions must take full account of the environmental impacts of meat consumption in Europe, whether that meat is produced in Europe or elsewhere in the world. The foundation values, meanwhile, must integrate nutritional criteria as well as socio-economic considerations (e.g. the livelihood of farmers). Questions of animal well-being and ethics, meanwhile, are relevant to both the ceiling and foundation values. The definition of consumption corridors is a process of multi-actor collaboration in which researchers interact with the various stakeholders in order to arrive at target values (ceiling and foundation) between which meat consumption could be regarded as "sustainable."

KEY POINTS

The current recommendations issued by public health agencies (eat less meat, or meat of greater quality) are clearly not enough to inspire the change in dietary habits required to preserve the planet's resources. Founded upon a number of key principles (recognising universal needs, environmental justice, public participation), the consumption corridor model provides a solid basis from which to work towards a holistic, equitable vision of sustainable meat consumption.

Isopolis, a project of societal transformation for La Réunion

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Background

Our globalised societies are faced with increasingly complex economic, social, political and environmental challenges. A systemic response is required, based on a broader understanding of issues which are too often approached in silo mode by institutions. Isopolis is a societal experimentation project in La Réunion which aims to support the co-construction of public policies for boosting resilience, inspired by the example of Bhutan and their Gross National Happiness model, in order to improve the well-being of all Réunionnais.

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Further reading

https://www.isopolis.re/fr/1/home.htm
Petrovič F., Murgaš F., 2020 – Linking sustainability and happiness. What kind of happiness? *GeoScape*, 14 (1) : 70-79.

La Réunion: a laboratory for the ecological and social transition

The unique nature of La Réunion makes it a living laboratory for societal innovation of international importance, not least on account of the island's renowned sense of community and geographical particularities. Since the arrival of the first human settlers on La Réunion, four centuries of shared history have forged a fruitful cohabitation between cultures and religions originating in all five continents, woven together in a populace that has shown itself to be resilient in the face of major sustainability challenges (external dependency, unemployment, poverty, inequality, demographic pressures, ageing population, conservation of resources, natural risks etc.). Socio-economic and environmental imbalances have left the island exposed to a series of crises which residents must now learn to overcome, all while continuing to develop in a manner which is both sustainable and desirable. The Isopolis project has its roots in civil society, specifically the citizen-led Risom initiative (network for open and shared societal innovation) and local association Isolife, the "society and science interface." IRD is the project's key backer, conducting interventional research and evaluating the scientific dimensions of the programme. Réunion's National Centre for Territorial Government (CNFPT), with the support of the laboratory for public innovation, has come on board to facilitate collaboration with the island's civil servants (who number 40,000). This cooperation between different stakeholders from civil society, the economic sector, the sciences and territorial government is an important element of the framework for territorial governance. The experiments conducted here (including measures to improve living standards for people in difficulty, physical and mental health initiatives for seniors, education and ecological outreach etc.) all seek to build bridges between available knowledge (developing evaluation and decision-making tools) and the concrete needs of the local economy, government and citizens. This collaborative interweaving of research and action will allow for more effective responses to the challenges facing the island, acting as a vector for societal transformation.

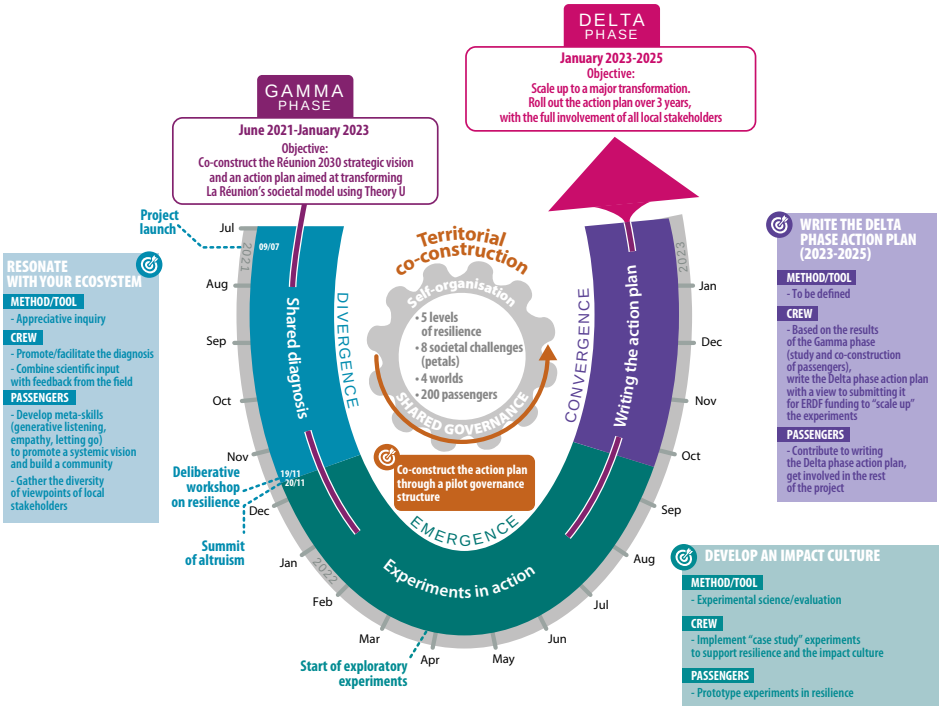
Co-construction, resilience and societal happiness

Isopolis works to support the co-construction of public policies in La Réunion, fostering a collaborative dynamic among the various stakeholders involved in territorial governance. Resilience can be understood as a dynamic process whereby systems withstand crises, bounce back, develop strategies and create and mobilise resources in order to overcome present and future adversities. In order to steer this societal transformation, the project emphasises the importance of facilitating collective, territorial decisions regarding the outcomes to be pursued: should we prioritise financial gain or well-being? Discussions regarding the definition of objectives, with the potential to bring about a profound transformation in La Réunion, have included debates as to the pertinence of growth-oriented economic models, driven by unprecedented levels of production and consumption. Promoted in the latter half of the twentieth century as a source of well-being – creating jobs and wealth – the shortcomings of this model are by now well known, not least

its harmful impact on the environment and tendency to exacerbate societal tensions through the over-exploitation of natural resources (with negative consequences for human health, natural and climate-related risks etc.). These discussions have laid the groundwork for a new, sustainability-led model, raising the possibility of replacing or combining gross domestic product (GDP – a common yardstick for measuring development) with indicators designed to measure well-being. Happiness, an important component of the subjective dimension of quality of life, is considered to be one of the pillars of sustainability (Petrovič & Murgaš, 2020). Happiness on a societal scale, gauged in La Réunion by adapting the gross national happiness (GNH) indicator to the local context, has been mooted as a key measurement of territorial sustainable development. Since there are any number of ways of defining happiness, Isopolis has adopted an interdisciplinary and transdisciplinary approach mobilising various scientific capabilities (sociology, psychology, economics, anthropology, ecology, political science) as well as a diverse array of territorial actors, in order to better define this multidimensional phenomenon and take on board the perspectives of all actors.

Divergence, emergence, convergence: the three key stages of societal transformation

The project's chosen model of co-construction is broken down into three stages, based on the Theory U concept (Scharmer, 2009). The first stage is divergence, corresponding to the downward curve of the U. This is a diagnostic phase, during which a process of co-construction is used (in this case, with 215 participants) in order to collectively identify obstacles to the emergence of a more resilient society in La Réunion. At the same time, the diagnosis was fleshed out with three "*scoping reviews*" focusing on individual, cultural and territorial resilience, along with qualitative surveys focusing on five interdependent measures of resilience (individual, cultural, organisational, nutritional and ecological/ territorial). During the second phase – emergence – experimental initiatives were launched with a view to improving living standards, physical and mental health, education, the environment etc. A number of collaborative projects took shape during this phase, aimed at prototyping public policies conducive to sustainable happiness and well-being, and tackling some of the problems identified in phase one. The third phase – convergence – is devoted to evaluation and capitalisation on the results of the experiments conducted in the preceding phase. This exercise in co-construction has already succeeded in highlighting the challenges attached to changing practices which are deeply-rooted on the island. It has also illustrated the extremely promising potential of collaboration between the research community and civil society – with the latter taking the lead – particularly in terms of developing a shared culture of impact. This work is still in progress, and should soon yield a written action strategy for upscaling the programme to encompass the entire island with the support of decision-makers (pilot municipalities) and civil servants. By focusing on experimentation as a vector for transformation, the project partners have learned the value of participatory methods of evaluation when it comes to assessing the impact of projects and public policies developed on the island.



Co-construction process in the Gamma phase.

KEY POINTS

One way to transform a territory is to adopt a theory of change which incorporates and inter- and transdisciplinary approach to co-construction, using Theory U and striving to unify all four components of territorial governance (public action, civil society and the economic and scientific spheres). With this goal in mind, the Isopolis project in La Réunion is promoting experimentation and evaluation as a new methodological framework for collaboration between stakeholders, allowing for joint decisions on strategic objectives and a multi-dimensional indicator for gauging happiness. The initial results of the scheme illustrate the importance of transition engineering and the creation of a research and development ecosystem in support of more resilient public policies.

Academia and sustainability: towards a holistic approach

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Background

In the early years of this century, UNESCO launched its Decade of Education for Sustainable Development (2005-2015), which yielded, among other things, the sustainable development goals (SDGs) adopted in 2015. Throughout that period, and down to the present day, UNESCO has remained dedicated to this mission, publishing several studies devoted to the integration of the 17 SDGs in educational strategies. In 2022, the publication of a report by a panel of independent experts, along with the World Higher Education Conference (WHEC) in Barcelona, embodied the solidification of these initiatives.

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WHEC, an arena and a platform for global cooperation on matters of higher education and research

The attendees at WHEC were a carefully-selected bunch, chosen for their institutional affiliations and with a cap on the number of participants per country. 2500 participants attended the conference in person, with 8300 more following online. WHEC also attracted representatives of various governments (and ministries), higher education institutions and national, European and international authorities. Students were somewhat under-represented when compared with events such as the *Transforming Education Summit*, organised in July-August 2022 by the United Nations and aimed primarily at students. The over-arching theme of the WHEC event was "Reinventing Higher Education for a Sustainable Future," broken down into 10 key topics for discussion: the impact of Covid, SDGs, inclusion, the quality of teaching programmes, academic mobility, university governance, funding, data, international cooperation and the future(s) of higher education. The SDGs were identified as a particular priority, after discussion of the fall-out of the pandemic, with ample discussion of UNESCO's role in Agenda 2030. The motto "*leaving no one behind*" was a motif running throughout the conference, and discussions of inclusion served to highlight the social dimension of sustainability.

Transforming higher education for global sustainability

Co-authored by 14 independent experts, the report "*Knowledge-driven actions: transforming higher education for global sustainability* (https://unesdoc.unesco.org/ark:/48223/pf0000380519) – only available in English at time of writing – focuses on the need to transform higher education in the interests of sustainable development. The report highlights the responsibilities of universities, and the opportunity they now have to play a leading role in the transformation. The authors discuss how and why we can break down disciplinary boundaries in the pursuit of the SDGs, diversifying the forms of knowledge we produce and teach and opening up the academic sphere to engage with other sectors of society. They conclude with a series of general and specific recommendations touching upon all three components of the university triptych: teaching, research and outreach. These recommendations include putting sustainability modules on university *curricula*, establishing a global fund to support research and teaching on the SDGs, and creating an annual conference on this subject. The report also reiterates the importance of defining universal access to education as a fundamental human right. Higher education has a key role to play in this context, particularly in support of life-long learning. The report duly insists upon the individual and collective dimensions of higher learning, the notion of equity and also the importance of cultural diversity.

Radical transformations taking shape

Perhaps unsurprisingly, the report's authors place great stock by multi- inter-transdisciplinarity as a means of promoting sustainability, calling for greater integration of *Arts, Social*

Sciences and Humanities (ASSH) with physics, natural sciences and engineering/information sciences. They also call upon the humanities to develop more explicitly critical, or even "transgressive," approaches to engaging with the concepts and conclusions produced by the "hard" sciences, rather than focusing solely on their societal applicability. By opening up universities to trans-epistemic perspectives and embracing all forms of knowledge, the report seeks to push back against the creeping tide of populist obscurantism encroaching upon public opinion worldwide. Forces keen to manipulate public opinion often decry academia as a hermetic and elitist sphere, bent upon mystifying the population in order to maximise private profits. In concrete terms, the epistemic pluralism championed by the authors of this report takes the form of "organised scepticism," an approach dear to scientists, and indeed anybody concerned with the rigorous production of knowledge. The goal is thus to adopt an inclusive position which makes all forms of knowledge welcome in our universities, without every tipping over into intellectual relativism – the idea that any and all cognitive expressions are of equal value – and rendering the whole enterprise meaningless. Opening up to society in this manner will require a break with some of the traditional and more recent practices and trends of *academia*. They include the tendency towards splendid isolation, sometimes institutionalised, as well as the precarious employment circumstances of university personnel and the faith placed in international university rankings based on competitive factors that are manifestly at odds with the principles of sustainability. Indeed, sustainability must be the guiding principle behind a system which

Closing ceremony of the World Higher Education Conference (Barcelona, 20 May 2022) with Stefania Giannini, UNESCO Assistant Director General for Education.

is both rigorous and diverse in its approach. A global system of SDG *benchmarking* has been mooted as a replacement for the existing rankings.

The missing links

This report, and the discussion of its findings at WHEC, are concrete examples of the emerging sustainability-led approach to higher education and research at the global level. They do not seek to deny the political dimension of this change, acknowledging that the sector's priorities need to change and that proactive decision-making is required. Nonetheless, both the report and the conference confirmed a rather worrying suspicion: the French-speaking world was very poorly-represented, and French-speaking developing nations were virtually absent! Not one of the 14 authors of the report is based at an institution in the French-speaking developing world, whereas English, Spanish and Portuguese-speaking academics from developing nations were actively involved in this exercise. This observation is borne out by a recent bibliometric analysis which highlighted the remarkable decline of French-language contributions to major international debates (Meyer, 2021). Is there not a very real risk that our academic authorities are being left behind in discussions of universities and sustainability? In any case, there now appears to be a strategic window of opportunity in which we can take action to bridge this nascent divide between the international community and ourselves. The risk appears to have been spotted in certain quarters: the Jouzel report, published in February 2022, recommends closer relations and identifies the European scale as the first priority. The expansion of this collaborative dynamic to the developing world is no less important, and it falls to us to rise to that challenge.

KEY POINTS

The World Higher Education Conference consolidated the higher education sector's new focus on sustainability. A report published to coincide with the conference identifies a number of working perspectives for the development of inclusive, trans-epistemic universities. There is an opportunity to be seized here, particularly for the French-speaking academic community, which has thus far been underrepresented in international debates.

The contribution of gender studies to transdisciplinary sustainabilty science

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Background

The rise of transdisciplinary research (i.e. the integration of knowledge from a variety of disciplines, including non-academic knowledge) has been fuelled by the realisation that complex problems require analytical approaches that transcend disciplinary boundaries. Transdisciplinarity is thus regularly cited as a response to the challenges of studying complex problems pertaining to "sustainability." "Transdisciplinarity in sustainability science" is an increasingly widespread concept in research publications, particularly in English, with an emphasis on its "transformative" potential. All of which raises questions as to the nature of the epistemological transformation associated with transdisciplinarity in sustainability science.

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Transformative epistemology or epistemological transformation?

Transdisciplinary sustainability science must be defined not only with reference to the epistemology of transdisciplinary research, but also to the normative objective sustainability (i.e. the production of knowledge which will enable us to face the challenges of sustainable development, focusing on the interactions between humans and the environment, the essential subject matter of sustainability science). Sustainability science is defined more by the problems it studies than by the disciplines upon which it draws. The recent surge in interest in transdisciplinarity in sustainability science is closely connected to its transformative potential. What we have here is a transformative epistemology, potentially conducive to the resolution of complex problems. This in turn raises further questions for the scientific community: should fundamental research remain aloof from the political objectives of development? In reality, science focused on contemporary problems is capable of producing knowledge conducive to change, while research processes involving non-academic actors and utilising methodologies with an emphasis on processes of critical consciousness (informed by the work of Brazilian philosopher Paulo Freire) can foster the development of knowledge built upon co-construction, combining scientific knowledge with experiential and local knowledge. Approaches of this kind nurture critical consciousness, with the potential to catalyse societal transformation.

Participatory approaches of this kind require reflexive thinking, as well as the capacity to question the power dynamics in play between the different actors involved in processes of co-construction. We may also wonder whether transdisciplinarity should be regarded simply as a transformative epistemology, i.e. valued for its potential to transform socio-ecosystems, or if it does not also represent a form of epistemological transformation. While transdisciplinarity necessarily implies contributions from varied forms of knowledge, it differs from other forms of disciplinary interactions in terms of the manner in which these forms of knowledge are produced. Max-Neef (2005) proposes a review of the various definitions applied to different modes of disciplinary interaction, gauging levels of cooperation or coordination using a gradient which stretches from multidisciplinarity to pluridisciplinarity, to interdisciplinarity and as far as transdisciplinarity. Cross-pollination of knowledge – the essence of transdisciplinarity – represents a challenge to the binary, linear logic of the Aristotelian tradition, cleaving instead towards the "complementarity of opposites" proposed by Danish physicist Niels Bohr. Transdisciplinary epistemology thus recognises iterative, systemic and holistic modes of reasoning, reconciling the rational with the relational. It thus constitutes an "open structure" endowed with "extraordinary epistemological consequences," because closed theories are not capable of delivering the necessary "permanent potentiality for the evolution of knowledge."

The contribution of gender studies

In this context of knowledge co-construction, gender studies offer a number of analytical frameworks which can help us to deconstruct

the power dynamics in play. Standpoint feminism posits that knowledge is dependent upon the point of view of those who produce it, and thus argues for the development of a feminist epistemology based on women's experiences. 'Decolonial' feminism (which emerges from this process) incites us not only to challenge the patriarchy, but also to decolonialise knowledge. Ecofeminism, meanwhile, allows us to re-examine gender-based systems of exploitation simultaneously with the systems of exploitation pertaining to nature. Feminist critical theories can thus help us to challenge the social relations of gender dominance and rethink our positioning as researchers, i.e. the ways in which the power dynamics within which researchers operate can influence the production of knowledge. Building upon these theories, Staffa et al. (2022) propose approaching sustainability science via the feminist ethical framework of *care*. This allows us to reframe the practices of transdisciplinarity within the relations of care which bind participants together. This shift of perspective allows us to more effectively engage with the conflicts and divergent interests which are inherent to the multiple systems of knowledge in play, adopting an approach to relationship management – including their conflictual aspects – which defies institutional expectations of research programmes, namely the demand to turn out win-win solutions while refraining from engaging with underlying power relations (between genders, social classes etc.). Whereas in fact, the transformative potential of transdisciplinarity – according to the authors – resides in its capacity to develop research "communities" defined by their relations of care, i.e. pushing back against the individualisation and marginalisation of such collaborative relationships within the neoliberal academic milieu. They thus call for a more inclusive, participatory vision of research, founded upon collaborative processes with a long-term scope. Much as materialist feminists have laid bare the connections between neoliberal globalisation and gender inequalities, the time has

Popular education programme teaching women about solar engineering technologies; Barefoot College, Tilonia, Rajasthan, India, August 2018.

now come to challenge the neoliberal model of academic research, characterised by "fast science," competition and evaluation on the basis of impact factors. Gender-informed sustainability science offers an alternative vision of academic research which could form the basis of a relational approach to the construction of knowledge, a form of "slow science" which is resolutely collaborative rather than competitive.

KEY POINTS

Transdisciplinary sustainability science is a "transformative" prospect. It encompasses both a transformative epistemology, i.e. the capacity to transform socio-ecosystems, and an epistemological transformation based upon modes of reasoning which are holistic and iterative, reconciling the rational and the relational. Gender studies can cast new light on the very essence of this transformative potential: the capacity to challenge power dynamics. An approach informed by the ethics of *care* enables us to better comprehend the relations of care – as well as the conflicts – which are inherent to processes of knowledge production drawing upon multiple forms of knowledge. This shift in perspective paves the way for transdisciplinary and transformative sustainability science founded upon a relational and collaborative approach to knowledge production.


VISÃO
GRANDE CONTRASTE
SUSTENTABILIDADE NO SEMI-ARIDO ?
RELATOS
SISTEMAS DE CONVIVÊNCIA
TRAJETÓRIAS
ESCALA ESPACIAL
SEMANA
AGUA
SOLO
ESCALA
INTERDISCIPLINARIDADE
RIQUEZA
DESAFIO
SEMIARIDO
HISTORIA DO NORDESTE
REALIDADE LOCAL
HOMEN
NATUREZA
ANALISAR
TIPO SECA
ESSA VAI FICAR!
JOVEM
NOVO
CONSERVAÇÃO DOS SOLOS
COOPE
SAUDE
NOVA
CLIMA
JA VAMOS INTEGRAR
NOSSOS MODELOS
ESCALA
AGUA


ABORAÇÃO
MUDAR PENSAMENTO
BIO
RURAL
RURAL
RURAL
RURAL
VIDA NO MODO URBANO
MODELO DESENVOLVIMENTO DAS COSTAS
RESOLVER PARADOXOS
CONSIDERAR
COMUNICAR TODOS ANÁLISES AOS AGRICULTORES
INTEGRAR CONHECIMENTO SOBRE O SAHEL
INTEGRAÇÃO DAS CULTURAS DIFERENTES
RAÇÃO
AÇÕES NO FUTURO
OBJETIVAR
CONTINUAR
COMO INTEGRAR AGRO ECOLOGIA ?
STRATEGIAS DE QUEIMADAS
MEDIR
AVALIAR
PARCEIRIAS
TENDENCIAS DAS CHUVAS
ALIANÇA
IRD
CIRAD
FUNDEMA
GOVERNO
ONG
TICO
FALTA TRABALHO DE CONSERVAÇÃO
SOLOS
COMO & QUAL ?
VALORIZAR!
PESQUISA CIENTÍFICA
DEFINIR OBJETIVOS & STRATÉGIA
POLÍTICAS PÚBLICAS

Sustainability science in Mexico: taking the plunge

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Background

A country with a population of 129 million, bordered by arid deserts in the north which account for 40% of national territory, along with flooded zones and flood plains in the south-east, a swathe of Caribbean coast under threat from Sargassum seaweed, acute urban/rural inequalities and serious migration and security issues, Mexico faces many challenges in its efforts to achieve social justice and a decent standard of living. In order to face up to these challenges, the country must balance the need to protect its natural resources with the necessity of tackling its profound inequalities. Government efforts in this direction have afforded particular prominence to approaches based on sustainability science. This represents an opportunity for IRD teams to co-develop research and training projects that are ambitious, interdisciplinary and transcend sectoral boundaries.

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Further reading
https://sostenibilidad.posgrado.unam.mx

Mexico and the sustainable development goals

Currently ranked 74th out of 163 in terms of progress towards achieving the sustainable development goals (SDGs), Mexico is faced with many environmental, social and economic challenges, particularly with regard to SDGs 2, 3, 6, 8, 9, 10, 14, 15 and 16 and, to a lesser extent, SDGs 1, 7, 11, 12, 13 and 17 (see graphic). The situation is improving (albeit modestly) for SDG 11, but the conservation of biodiversity and achieving peace and justice remain the country's most pressing challenges. Against this backdrop, over the past five years Mexico has developed a programme focusing on well-being, the fight to end corruption and poverty, access to education and health and food security. With these goals in mind, the National Council of Science and Technology (CONACYT) has launched 10 strategic programmes at the national level (PRONACES) designed to organise and steer scientific research into these matters of national importance.

Dashboard showing progress and trends in SDG measures in Mexico (https://dashboards.sdgindex.org/profiles/mexico).

Within the purview of sustainability science, the goal is to foster collaborations between researchers and social partners from the public and private sectors, in order to establish short (1 year), medium (3 years) and long-term (5-6 years) projects capable of delivering concrete, integrated solutions to Mexico's economic, social and environmental problems. Many Mexican research institutions have adopted this scientific strategy as a pillar of their research and training programmes.

The National Autonomous University of Mexico: a sustainability science pioneer

Among these institutions, the National Autonomous University of Mexico (UNAM), a strategic IRD partner since 1991, has established a National Laboratory for Sustainability Science (an offshoot of the Ecological Institute), an academic intermediary championing a process of knowledge production which brings together academics, public-sector decision-makers and a variety of civil society organisations. UNAM has also established a sustainability science doctoral school, a grouping of 11 research institutes and doctoral schools. Its primary objective is to champion innovative academic perspectives, tackling the need to train the future professionals who will shape Mexico's sustainable development. This is the first UNAM programme to formally combine natural and social sciences, engineering and town planning. The aim of this doctoral school is to train experts with a solid understanding of the conceptual and methodological dimensions of sustainability science, capable of developing new solutions, with a transdisciplinary angle, to problems which currently represent major obstacles to sustainable development. The school has its own ethics committee, an autonomous collegiate body which is independent of the university authorities and is charged with: 1) monitoring and maintaining equality, honesty and academic and scientific integrity; 2) guaranteeing safety, respect and protection for all persons involved in research; 3) ensuring that best practices are followed; and 4) resolving ethical problems arising from relations between members of the post-doctoral community. In this spirit, IRD's involvement with the Eldorado international joint laboratory (devoted to the links between biodiversity and new diseases; IRD-UNAM) is aimed at establishing an interdisciplinary doctoral school devoted to sustainable livestock farming, adopting the One Health approach. This future doctoral school, currently focused on master's level programmes, is also backed by the Universities of Montpellier and Lyon, the National Autonomous University of Yucatán and the University of Nottingham.

IRD representatives as facilitators

IRD representatives - by virtue of their detailed knowledge of their host countries (not least their regular contacts with partner research institutions and universities, development agencies and civil society), as well as their capacity to think beyond disciplinary boundaries and their contacts with funding agencies – are uniquely well-placed to create connections between "discipline-determined" projects in order to achieve a more regionalised approach to sustainability science, whose challenges, more often than not,

transcend national borders. IRD representatives in Mexico, in partnership with UNAM, have been involved with numerous projects spanning the Latin America-Caribbean region: co-construction of a One Health master's programme in Cuba with the help of a Solidarity Grant for Innovative Projects (FSPI) from the French Ministry for Europe and Foreign Affairs; collaboration with the One Health university forum and the climate change team based at the University of Quisqueya (Haiti); support for the programmes launched by the VP for Sustainability Science at the University of Costa Rica, in collaboration with UMR Urmis and Université Côte d'Azur; another project to found a sustainability science doctoral school by means of a twinning arrangement between UNAM and the Papal University of Ecuador, with support from LMI BIO-INCA (Biodiversity and sustainable agriculture in the Northern Andes). Through actions such as these, IRD representatives are helping to plot the future of sustainability, in a thematically and geographically-targeted manner which takes full account of the requirements of decision-makers as well as broader societal accountability (by means of research impact evaluations).

In Mexico, the community of actors united under the banner of the Eldorado project act as an anchor in the South for the global One Health knowledge community, committed to developing more collaborative and more inclusive working methods hand-in-hand with Mexican partners. Here again, IRD representatives have a key role to play in interdisciplinary scientific coordination, the organisation of site visits with researchers from multiple disciplines as well as non-academic actors (for example in the Yucatán region, in the case of LMI Eldorado), and indeed the coordination of One Health scientific and strategic steering committees including representatives of high-level partners (the Mexican Agency for International Cooperation, the Secretariat for the environment and natural resources, CONACYT, the state authorities in Yucatán, Campeche and Quintana Roo).

KEY POINTS

In order to build and implement sustainable solutions to the country's economic, social and environmental problems, for several years Mexico has been promoting the development of sustainability science. Mexico now has a national research institute devoted to sustainability, as well as a doctoral school issuing master's degrees and doctorates in sustainability science. There is high-level political support for One Health research projects, and efforts to establish a multi-actor platform on a territorial scale. Working to support this win-win dynamic, IRD teams are contributing their own scientific expertise in the field of One Health, while also learning from their partners on how to put sustainability science into practice.

The hatchet and the seed: never mind about old positions, let's work together!

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Background

Sustainability science invites us to rethink our approach to research, as well as the role of science in resolving the social and environmental crises now rocking the world. The challenge is twofold: to work effectively within collective structures embracing multiple disciplines and existing at the interface between science and society, all in a crisis context which breeds chronic uncertainty and regular emergencies. In this article I reflect upon the opportunities that sustainability science offers for collaboration between scientists and civil society, while acknowledging the tensions which may arise between different scientific perspectives on what sustainability science actually represents.

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Working together in a time of crisis
(Lison Bernet).

Sustainability science: working together in a time of crisis

The pillars of sustainability science are not all that different to the founding principles of conservation science, a concept floated almost forty years ago (Soulé, 1985): a meta-field created in response to a crisis situation, with an emphasis on action. While conservation science was established as a multidisciplinary response to the decline in biodiversity, sustainability science concerns itself with changes linked to socio-ecological challenges. These changes manifest themselves in one of two ways: slow and gradual (rising sea levels, increasingly acute environmental pressures, globalisation), or sudden and violent (increased frequency and/or amplitude of extreme weather events, tipping points). In order to face up to these challenges, sustainability science places its faith in inter- and transdisciplinarity. It prioritises those research subjects considered to be most pertinent to furthering our understanding of the current socio-ecological crises, focusing on the relations between the environment and human societies. This approach requires greater interdisciplinarity between natural sciences and human and social sciences. Moreover, sustainability science straddles knowledge creation and action, inciting us to re-examine the science/society axiom and our understanding of transdisciplinarity. It considers the consequences of our own research practices, while also taking an interest in the practices of others, which can be tested, evaluated and adjusted as required. It creates new narratives and explores alternative systems of reference (transitions, transformation, sustainability, liveability etc.). There are any number of ways of engaging with this meta-field, depending upon one's scientific background and the resources at your disposal.

The key pillars of sustainability science invite us to rethink science as a whole, in light of the twofold challenge we face: on the one hand, the context of crisis, uncertainty and change in which we live demands urgent measures in short timeframes; on the other hand, we need to learn to take decisions and take action together within collective structures which will vary in terms of both their membership and their size (embracing different disciplines, academics and non-academics, civil society etc.). These things take time…

A familiar path… and lingering doubts

This is not a new story. There have been any number of attempts, from the 1970s onward, to "do science differently" in response to environmental crises, particularly by expanding collective scientific structures. And yet, the crisis continues to get worse, causing researchers to doubt their own capacity to conduct interdisciplinary, action-oriented research. The human and social sciences are still only marginally involved, and interdisciplinary exchanges can sometimes be difficult. Although transdisciplinarity is increasingly being invoked early on in the research process, with critical reflection on its political dimension, it seems regrettable that science/society approaches largely remain linear and "top-down," almost impermeable to non-scientific forms of knowledge. For some proponents, sustainability science offers an opportunity to "put the magic back into science." For others, it is nothing more than a series of failures and disappointed best intentions. For more radical dissenters, it is an offshoot of capitalist and neoliberal thought, incapable of bringing about a genuine change of perspective.

Coalitions, positions, transformative potential

Any researcher wishing to engage in transdisciplinary science at a time of crisis must face certain key questions. Firstly, what is the right position to adopt: knowledge, co-production, transformation? Secondly, with which actors and coalitions should one seek to ally oneself? When, and in what context? Some believe that the real capacity for change resides with those in positions of power, who need to be accompanied as they change their ways. Such is the crux of the recommendations formulated by Virdin et al. (2021) regarding the ocean economy, dominated by a small group of powerful companies known as the *Ocean 100*. Others criticise the decisional inertia and immobilism inherent to dominant frames of reference, preferring to work directly with those proposing alternative solutions, often at a more local level and with closer societal engagement. This is the approach championed by geographer Cyria Emelianoff in a recent sustainability science debate: direct collaboration with local people to imagine the sustainable cities of the future. Others, particularly in the human and social sciences, prefer to adopt a critical perspective on the structural obstacles and power games which arise when multiple actors work together. How, then, can we navigate a path through these different approaches – external observation, support for grass-roots collectives, radical critique – and form effective

coalitions to support the transition to a more sustainable, ecological and socially just world? If we adopt a position too close to dominant systems of reference, can we ever hope to achieve transformative change? On the other hand, are excessively radical or locally-specific positions doomed to remain marginal? These divergences create tensions between researchers who, each in their own way, are all striving to find solutions to the social and ecological crises we face.

Between the hatchet and the seed: let's work together!

Based on their own personal background, their means and the context in which they work, researchers must make their own choice: to form coalitions with those in positions of power, or else champion alternatives, decrying the inertia of politicians or choosing the path of radicality. Faced with this diverse array of positions, the challenge is to maintain a spirit of dialogue within the scientific community, in order to collectively defeat immobilism and change the *status quo*. To return to the old analogy, we need both the *hatchet* – i.e. a critical approach – and the *seed* – i.e. alternative strategies (Robbins, 2004) – in order to bring about the transformations we want to see. An alliance of different positions would allow for a more reflexive perspective on the different coalitions within which we operate, and the transformations that these coalitions are capable of achieving. The success of this self-reflexive turn in sustainability science will depend largely on the role taken on by the human and social sciences. Whether the current enthusiasm for sustainability science in France endures or dissipates, we can only hope that it will serve to strengthen the bonds between actors united by a desire for societal, structural and institutional transformation. A transformation which will change science as much as it changes society.

KEY POINTS

Sustainability science seeks to do things differently in order to rise to the challenge of the environmental crisis, particularly by expanding collective scientific structures. This ambition requires researchers to rethink their own positioning, the coalitions to which they belong and the strategies they deploy in support of the sustainable transition. Differences of positioning may give rise to certain tensions within the scientific community. It therefore seems essential to remind ourselves of what we have in common – a desire to break out of the rut of immobilism – in the interests of a more fruitful dialogue, promoting reflexivity and collective endeavour for a successful transformation to a more sustainable, ecological and socially just world.

Managing marine ecosystems: the crucial contribution of research

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Background

Over the past thirty years or so, the ecosystem approach to fishing has sought to reconcile marine resource exploitation with the need to protect biodiversity, supporting sustainable fishing grounds. Nevertheless, the industry continues to intensively fish certain species of pelagic fish (sardines, anchovies, mackerel etc.), which now account for more than a third of global catches. New approaches and indicators are now being developed to further advance the ecosystem approach to fisheries management, taking into consideration the interactions with other marine species (e.g. predators) as well as different societal stakeholders. However, more needs to be done to recognise the increasingly global dimension of this issue.

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Further reading

Grorud-Colvert K. et al., 2021 – The MPA Guide : A framework to achieve global goals for the ocean. *Science*. Review 10 September 2021: 373. https://www.science.org/doi/10.1126/science.abf0861

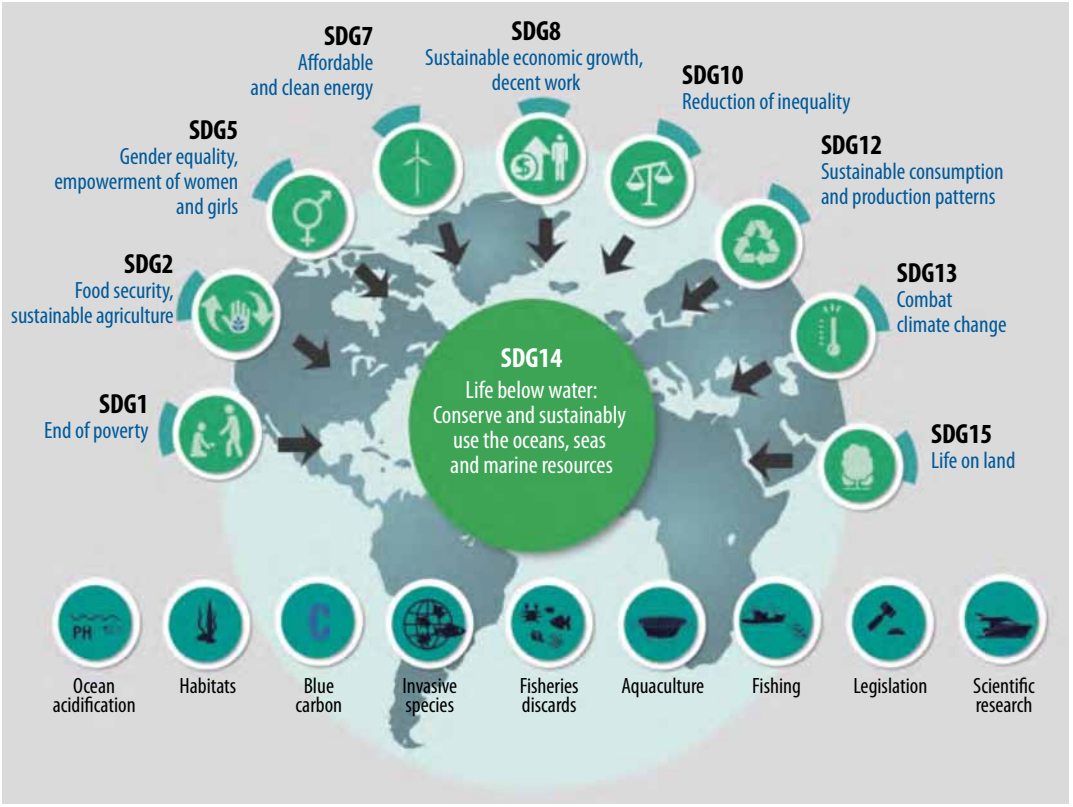
Moatti J.-P., Cury P., 2017 – « L'océan et les objectifs de développement durable ». *In* : Euzen A. (dir.) et al., *L'océan à découvert*, Paris, CNRS : 46-47.

The exploitation of marine resources must be sensitive to ecosystem dynamics

A global response to this problem has recently emerged in the form of the Ecosystem Approach to Fisheries Management (EAFM), a model of sustainable resource usage which is respectful of marine ecosystems. The EAFM approach proposes to reconcile exploitation and conservation at the ecosystem level, now acknowledged as the appropriate scale at which to manage fisheries and integrate scientific knowledge. EAFM first appeared in the Rio Declaration of 1992 (Agenda 21) and the Food and Agriculture Organization (FAO) fisheries code of conduct published in 1995. The role and importance of EAFM were recognised by 47 countries at the conference on sustainable fishing and marine ecosystems held in Reykjavík in October 2001. EAFM now has a direct impact on fisheries management in many countries, including South Africa, Australia and the USA. In Europe, it is written into the Common Fisheries Policy (CFP), but its actual implementation has proven to be slow and halting, with researchers still struggling to develop the tools and methods required to manage it effectively. One major priority is to better understand the impact of fishing not only on the species it targets, but on the marine ecosystem as a whole. Currently, more than 37% of the world's fishing catches are made up of small fish destined to be transformed into flour and oil for animal consumption in aquaculture systems. And yet, these fish are the fuel that powers marine ecosystems, providing sustenance for all marine predators (sharks, marlin, swordfish, marine mammals, turtles etc.), whose numbers are now dwindling (by as much as 80% or more).

The Namibian example

In Namibia, home to one of the world's most fertile oceanic ecosystems, the sardine population was around 10 million tonnes in the 1960s, but by the 1980s it had collapsed as a result of over-fishing. Previously abundant stocks dwindled to next to nothing, and marine predators including various bird species (penguins and gannets) died of starvation. Bird populations thus plummeted by more than 90%, and some species are now on the brink of extinction. The ecosystem reached a tipping point and began to behave in an entirely new manner (what we call an ecological shift). Jellyfish began to proliferate, to such an extent (their collective mass is now estimated to be somewhere between 12 and 20 million tonnes) that jellyfish now outweigh fish by 2.5 to 1. Namibian fishermen with no interest in jellyfish must now wait for brighter days to come, when fish will once again outnumber jellyfish. The problem is that nobody knows how long it will take for this ocean ecosystem to begin producing fish in such quantities again. There are example of similar ecosystem shifts all over the world: the Black Sea, the Mediterranean, the Bohai Sea and others have witnessed a proliferation of short-lived species such as jellyfish and octopuses. Scientific studies have recommended cutting catches in half in many ecosystems, while doubling the minimum biomass of prey fish which must be left in the water (in relation



Research on SDG 14 (Oceans) must focus on interactions, synergies and compromises with other SDGs featuring in Agenda 2030, in order to grasp the complexity of the global challenges transforming our oceans, and their exploitation
(source: Moatti & Cury, 2017).

to the current conventional targets). These new indicators have already been incorporated into national fishery management plans in some countries, including South Africa.

More research is needed on the relationships between SDG 14 and the other SDGs

For scientists responsible for drafting fishing policy recommendations, EAFM has ushered in some profound transformations. They can no longer be content with analysing and

modelling fish stocks, but must instead strive to comprehend the multiple interactions which define the workings of marine ecosystems and their systems of exploitation. Major scientific breakthroughs have been made in this field in recent years, including the contributions made by protected marine areas and certain plants, particularly Posidonia, to the fight against climate change, as well as the importance of small-scale fishing in the fight to end poverty and inequality, particularly that suffered by women. Recent scientific results have provided powerful, albeit still underused, tools for improving the operational management of marine resources. Now, in application of Agenda 2030 and its 17 SDGs, we need to take an even broader view of the problems created by fisheries exploitation. Building scenarios to plot the evolution of socio-ecosystems in the context of climate change and declining biodiversity will be indispensable in order to better understand the constraints associated with the Sustainable Development Goals (SDGs) pertaining to food security (SDG 2), poverty (SDG 1), employment (SDG 8), climate change (SDG 13), the fight to end inequality (SDG 10) etc. (see illustration).

KEY POINTS

EAFM is, or should be, a process of continuous improvement reshaping our relationship with nature and the governance of the oceans. Research has an essential role to play in the implementation of EAFM, helping us to understand the workings of marine ecosystems and calculate new ecosystem indicators for fisheries management. Scientific research should allow us to implement the ecosystem approach within an increasingly integrative framework, facilitating the sustainable management of marine ecosystems in the face of increasingly urgent and complex, global problems. Only a proactive approach which is open to all scientific disciplines will be capable of identifying cogent solutions to these planetary challenges.

Scientific diplomacy: a concept still waiting to be invented?

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Background

Scientific diplomacy is a relatively new concept.[1] Although science and political power have always been connected, the theorisation (or at least the formal expression) of the role of science in foreign policy or within international organisations is a recent development. Worldwide, a relatively small number of public and private-sector organisations – think tanks, international organisations, ministries, universities, research agencies – have taken an interest in this concept. And yet, it could have a significant bearing upon the sustainable development goals (SDGs), many of whose targets (particularly SDG 17, Strengthening the means of implementation and revitalizing the Global Partnership for Sustainable Development) can only be achieved by collaboration between nations.

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Further reading
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Low uptake of scientific diplomacy

There are several factors which might explain the relatively weak uptake of scientific diplomacy (SD) thus far. First of all, there are multiple definitions of the concept. For some, SD should primarily serve the interests, principles and values of the country practising it. It thus becomes a means of promoting the quality of one's research on the international stage, championing one's institutes, networks, researchers, publications and successful international project applications, foregrounding one's scientific priorities and staking out one's place within international scientific organisations and networks, or even creating new ones. In complementary fashion, SD is often used as a tool of diplomatic influence ("attractiveness," "soft power," "rearming"), steering scientific and academic cooperations in the direction of preferred partners in the interests of forging and/or maintaining links and alliances, facing up to the competition and attracting researchers, teachers and students. Last but not least, SD contributes to scientific interactions at the global level, but also plays a role in international negotiations, trade regulations (data protection and sharing, for example) and international standards in various domains of economic, social, climate-oriented and environmental development. It thus serves to promote universal values and peaceful international scientific cooperation in pursuit of humanity's shared goals.

Another factor in the poor uptake of SD may be the fact that it involves a diverse array of actors. SD can be conceptualised as a form of interaction between science and diplomacy. But these are very different worlds, in terms of the educational backgrounds of the people involved, their status, their standards, their practices and the ways in which they operate. Mutual understanding for joint action, within a shared framework, cannot be taken for granted. Moreover, this first circle of interaction needs to be expanded to embrace other circles of international relations. Different definitions of SD imply different objectives, and the question of how to order these priorities is one which arises frequently. A new instance of scientific cooperation at the international level may be regarded as an essential breakthrough in scientific circles, while receiving an indifferent reception in diplomatic salons. By the same token, diplomats are sometimes disappointed when they look to scientific institutions for the tools and allies they need to pursue their own objectives. Nonetheless, successive crises mean that such objectives are converging more and more, as witnessed by the Covid-19 pandemic. By rallying scientists, negotiators and decision-makers around shared projects, scientific diplomacy may work to facilitate dialogue between governments at the international level, while also encouraging exchanges between different sections of society within individual countries (promoting knowledge sharing, and public understanding and acceptance of health policies, for example). Nevertheless, this coming together of science and diplomacy could benefit from being more structured and more regular, in order to become more productive.

1 • Vacher J.-J., Piteau A.-F., 2022 – « La diplomatie scientifique : état des lieux et perspectives ». *In* : *Science de la durabilité*, Marseille, IRD : 132-135.

Doing more to integrate science into international relations

In light of the deteriorating health of our planet and the urgent need to accelerate the ecological transition in the Global South and North alike, more work is needed to unite the world's researchers, political leaders, economic decision-makers and representatives of civil society, in order to champion universal values and preserve the world's common assets. The challenges and repeated crises linked to global health, climate chaos and the decline in biodiversity have engendered a real "demand for science," but they have also somewhat distorted public opinion of that science. Moreover, international economic competition and different perceptions of power, the role of society and the place of the individual add to the prevailing instability. In response, scientific diplomacy – as a political statement by national governments and democratic organisations – must constantly strive to ensure that science informs public policy, in all countries and during international negotiations, in order to find solutions to the planetary challenges we all face. The procedures which allow this to happen already exist (e.g. participation in COP and other international forums; the publication of reports and policy briefs on the current state of knowledge, along the lines of the reports issued by the Intergovernmental Panel on Climate Change (IPCC) and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services [IPBES]). Different governments make use of research in different ways, depending on the roles they assign to research institutions, as well as the budgets available. The issue of how best to mobilise human and financial resources (working with major international donors, in particular) is of the utmost importance in order to make SD effective, particularly in the South (ensuring that scientists have the means at their disposal to produce and disseminate more knowledge and participate in international events so that their voices are heard). Great care must also be taken of research ethics and independence, academic freedoms and the safety of all researchers called upon to contribute to the international agenda, at a time when science and technology have become arenas for fierce, international and geopolitical competition. Access to and the use and sharing of data, along with their interdisciplinarity and intersectoral utility for research purposes (involving civil society organisations), are giving rise to new dynamics which are increasingly upsetting hierarchies and redrawing old networks of power and influence. In the case of France, SD is led by the Ministry for Europe and Foreign Affairs (cf. their roadmap for French influence, published in November 2021) and closely associated with cooperation between universities. Scientific diplomacy helps to boost France's standing and influence (role in drafting the SDGs, new geographical strategies, "public diplomacy" initiatives) as well as informing French and European positions in international negotiations (at conferences such as COP, G7, G20, etc.). SD is consistent with the EU's "Declaration on International Cooperation in Research and Innovation," promulgated in Marseille in March 2022. This charter devotes particular attention to sustainability science, which provides a scientific framework for dialogue between science and society.

Moving beyond scientific diplomacy to champion the "power of science"?

Science seeks to embrace the complexity of life, our planet, and the cosmos; as such, it knows no borders, nor should it. Researchers, on the other hand, are still beholden to political systems and borders; public research and its institutions are defined by public policies and systems of administrative authority. Researchers may find their work being used in service of disruptive political ambitions; in such cases, science becomes an instrument of power. But scientific progress is not confined by pre-established rules, spaces and timeframes, and is not always readily accepted in the political sphere. Hence the insistence among scientists that their autonomy should be respected, allowing them to focus on sharing knowledge, new paradigms and new, international ethical standards governing their professions and activities. Researchers hold a particular kind of power, their discoveries often reveal realities which diverge from existing visions, principles and standards. They are in the vanguard, as actors with their own part to play in the evolution of the international order. Recognising this unique status is a step towards reconciling the "transformative power" of science with the need for international standards and values to protect individuals and ecosystems, as we face up to the great planetary challenges. In this context, we need to see the emergence of new instruments, created by scientists themselves, in order to reinforce SD. From the continuous monitoring of political commitments to the amplification of the science/society dialogue, from coalitions of transformational stakeholders to new networks for sustainable development solutions on a planetary scale, what we need more than anything is a spirit of creativity.

KEY POINTS

Scientific diplomacy is a relatively new concept in international relations, and one which encompasses a very diverse array of fields, actors and objectives that may not always be compatible. The uptake of this concept by those directly involved – namely researchers and diplomats – has not been an unalloyed success. However, putting science at the heart of international relations is essential if we are to face up to the geopolitical, climate and health-related challenges of the age, which demand urgent action to forge sustainable solutions. It is time to rethink our approach to SD, acknowledging the transformative power of science and relaunching the dialogue between scientists and economic and political decision-makers. It is time to leave parochialism behind, working together to build a global vision for a sustainable future.

Participatory theory of change and the agroecological transition

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Background

In many countries, the agricultural sector stands at a crossroads: on the one hand we have intensive, industrial methods based on chemical inputs, while on the other we find innovative agroecological systems employing a vast array of more environmentally and socially virtuous practices: agroforestry, integrated agriculture and livestock farming, conservation agriculture etc. Such practices help to regenerate soils and biodiversity, and to avoid water shortages; they also facilitate adaptation to climate change and the attenuation of its impact. The ASSET project (Agroecology and Safe Food System Transitions in Southeast Asia) aims to capitalise on the potential of agroecology to transform food and agricultural systems in a manner which is compatible with the sustainability goals. The project as a whole is informed by the participatory theory of change, which involves forging a shared vision of the agroecological transition, identifying impact pathways to be explored collectively, and defining the respective contribution of each actor to these transformative processes.

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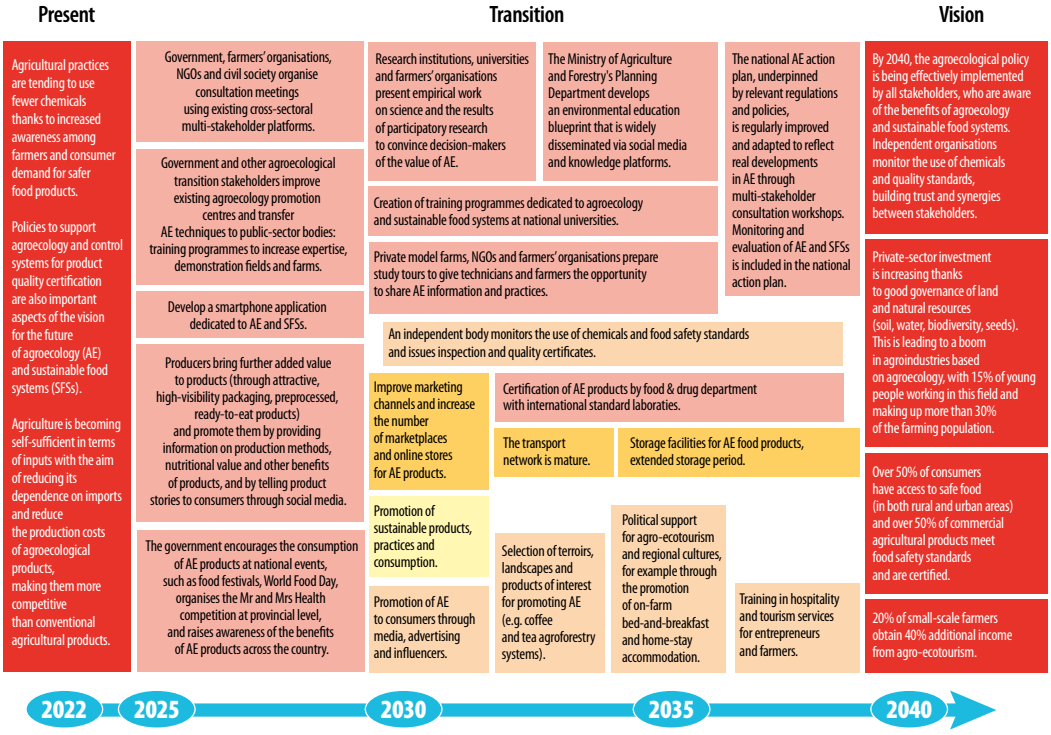
Further reading
https://www.asset-project.org

What is theory of change?

Theory of change (ToC) is an approach used to develop an explicit model for how an action (e.g. a project or policy) will contribute to a chain of results or events, laying bare the process of change we expect to see, the actions put in place to trigger that change, and the underlying hypotheses. Such models may be used at different moments: early in the project design phase (*ex ante*), as a projection of the future impact pathway which will guide the intervention; during implementation, to monitor progress and steer adaptative management and reflexive learning (*in itinere*); or once the intervention is complete, in order to assess the change it has helped bring about (*ex post*). In the case of the ASSET project, we produced specific ToC models *ex ante* for the participating countries and territories, in order to facilitate the coordination of a complex raft of actions led by a heterogeneous collective of actors comprising representatives of civil society (including farmers and producers' organisations), government agencies, development specialists and national and international research centres. The fundamental questions we asked in order to construct these *ex ante* ToC models in a participatory fashion were: what is our shared, desired vision of the future? What sort of impact do we hope to have? What changes need to occur to make this impact possible? When are these changes (results) and their consequences (impacts) likely to happen? What are the obstacles and opportunities associated with these changes? What can we do to ensure that these changes are realised with and for territorial actors?

Co-constructing impact pathways

The process of co-construction which defined the ToC dimension of the ASSET project yielded a narrative vision of the agroecological transition at the territorial and national levels (see illustration): mapping desired changes; explaining the underlying hypotheses on how these changes will come about; identifying opportunities and obstacles to change, taking different perspectives into consideration as well as the roles played by different actors. The project protocol and plan of action were then constructed with a view to supporting changes in practices, behaviours, interactions, capacities, knowledge, motivation and opportunities for the actors involved, as well as clarifying the manner in which these actors – and the context within which they operate – are liable to change. These changes are what we would call results. In this case, concerned with sustainable agroecology and food system tradition across the Mekong region (Cambodia, Laos, Vietnam), we proposed a participatory, multi-level ToC combining shared visions of the objectives to be attained with action plans to be collectively deployed at the different scales on which the project operates: from territorial interventions (within specific districts or provinces) up to the national and regional levels. Specific ToC were developed collectively by the actors involved at each level. Participatory ToC incorporates the existing knowledge and experience of partners, as well as the perspectives of the actors who will be tasked with putting the changes into practice, and who will experience their consequences.



Elements of the theory of change for the agroecological transition in Laos (national level).

Participatory workshops to catalyse collective intelligence

In order to build a participatory *ex ante* ToC, we need to begin by analysing the recent history of the territory in question and how it has defined the current state of food and agricultural systems, mapping the principal actors and activities which define the present situation. There follows a process of co-construction to establish a set of project specifications: working backwards from a shared vision of the future to the changes required to make this vision a reality, thence to the obstacles and opportunities pertaining to these changes, the risks involved, and the individual and collective actions required to make the changes happen. Last but not least, it is important to ascertain whether or not the actors involved have the motivation, capacities and opportunities needed to change their behaviour, their practices and their interactions. In other words, ToC invites a group of actors to discuss the values which underpin their vision of the future and the changes they wish to see. This process results in a shared vision, which may not necessarily correspond to the

preferred scenario of all actors: it is a reflexive, critical exercise during which power imbalances may make themselves felt, impinging upon the group's capacity to collectively construct pathways to change. Facilitation plays an essential role here, in order to address and make clear the imbalances of power liable to affect negotiations. Moreover, it is necessary to manage participants' expectations with regard to the scope of their action plans. A balanced selection of participants – along with proper training for a team of facilitators, including individuals with an understanding of the power dynamics between actors – can help to ensure that different points of view are aired and discussed at the local and national levels.

Strengths and limitations of the theory of change

By involving people from diverse backgrounds in the definition and implementation of a shared objective, ToC can play a crucial role in transformative actions. The process of collective construction is based upon the pooling of multiple sources of knowledge: academic literature, data from the field, expert and informal knowledge etc. ToC thus yields actionable knowledge of direct use to monitoring and impact assessment systems, and the learning loops they engender. Nevertheless, the recent wave of enthusiasm for ToC brings with it the risk that the approach could become largely normative, more of a superficial simulacrum than a genuine exercise in building a shared vision and pathway. ToC could thus become a commonplace of project design, meeting the same fate as the "logical framework" which it was originally intended to replace. In order to avoid such pitfalls, ToC must be used as a compass, indicating the direction of travel when planning actions, but evolving as actors engage with these actions and their understanding of how change happens is tested against reality.

KEY POINTS

Theory of change is a concrete manifestation of the principle of knowledge co-production, of particular interest when designing projects to support socio-environmental transitions. It seeks to clearly establish the different visions of change in play, along with the obstacles and opportunities they face, and thence to co-construct a shared vision conducive to a unified plan of action. ToC transforms knowledge into action, forging connections between different actors, sectors and levels of intervention. By breaking down silos, it can make solutions feel tangible. In doing so it paves the way for large-scale change, bringing political decision-makers on board via local, national and regional networks.

New ways of working

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Background

In order to achieve a genuinely integrated model of sustainability science, we need to rethink not only the methods of scientific research, but also the methods used to define public policy within our institutions. With this goal in mind, many institutions are now establishing internal project teams, often known as "innovation labs." These teams are tasked with overseeing a vast array of actions, from the implementation of structural reforms (strategy shifts, restructuring, decentralisation) to the delivery of targeted interventions (facilitation, ideation, prototyping), not to mention various forms of support and engineering (putting together training programmes, assisting with project design). In the context of a scientific research institution like IRD, we need to promote new methods and approaches allowing for better cooperation and more interdisciplinarity at all levels: between departments, between researchers and support services, and between scientific teams and society at large.

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The argument for an internal network of facilitators within our knowledge communities

Capitalising on collective intelligence is of central importance when it comes to changing the ways we work. Defined as the capacity of a group to ask questions and find answers together, collective intelligence is conducive to decision-making and the resolution of complex problems. Collective intelligence cannot be imposed from above: it needs to be organised, tested and adjusted to the context. It requires the creation and recognition of new roles within institutions. The positioning of "facilitators," along with their expertise in collaborative methods, establishes them as the guarantors of this collective framework, accompanying the co-construction of projects and fostering the emergence of shared objectives within groups characterised by divergent interests (Struelens Q., 2022 – « Les facilitateurs interdisciplinaires: polyglottes aux interfaces ». *In* : *Sustainability Science*, Marseille, IRD : 128-131). The knowledge communities (COSAV) established within IRD since 2021 act as forums in which to experiment with new forms of interdisciplinarity and transdisciplinarity. This unique positioning also makes them an ideal model for testing the dissemination of methods and tools promoting the expression of needs, stakeholder involvement, the creation of commons and the structuring of decision-making systems (Mambrini M., Mainguy G., 2022 – « Des communautés de savoirs au fondement de la multi-culturalité scientifique ». *In* : *Sustainability Science*, Marseille, IRD : 98-101). These methods (moving debates, forum theatre, De Bono's six thinking hats, co-development etc.) and positions (active listening, reformulation) may inform the working practices of researchers and support services, as COSAV members, in the interests of sustainability science (research focused on problems rather than disciplines), and inter- and transdisciplinary research projects more broadly. The aim is to recruit volunteers to test these methods during seminars and working groups. The institute's long-term goal is to establish an identifiable network of internal facilitators, including both researchers and members of support departments, capable of facilitating collective sessions for other teams. The aim is to involve, to federate, to percolate and to update practices over the long term, in a spirit of learning by doing. Having an in-house pool of personnel capable of deploying these skills for our collective benefit would be a real asset for the institution. Structuring such a network would provide opportunities for continuous learning and the exchange of best practices among peers. It would also leave the institute better equipped to face organisational challenges and broader problems that are increasingly complex and multidimensional (e.g. Covid-19).

Supporting the change: an example of reorganising workspaces

Change management methods and collective intelligence are genuine assets when it comes to delivering successful and lasting reforms, reorganisations or other structural projects.
A concrete example from recent experience is the restructuring of the IRD's South-East

Workshop, ideas and plans for a hang-out space (Latin America and Caribbean floor).

headquarters and regional delegation in the years 2019-2021. 240 members of staff were affected by this change.

The challenge was to co-construct the project with those directly affected, in order to improve their quality of life at work, to translate new ways of working into spatial reconfigurations, and to ensure that our workspaces reflect our institutional values. Projects involving workspaces are always complex, running up against deeply-rooted individual perceptions and demanding support for and participation from all members of staff. With the support of the general secretariat, this project was overseen by a project team comprising members of different departments from across the IRD's three core divisions (Science, Development and Support). The team worked with both HQ and the South-East delegation to introduce new tools and co-construction opportunities: a guide was published (*New spaces for new ways of working)*, an online consultation and call for suggestions were launched, including a poll of proposed options, 'Small step lunchtime' workshops were organised to allow staff to explore prototypes for future shared spaces (social spaces, signage, selecting photographs etc.) and regular consultation and communication sessions were held to explain the progress of the project to all staff. All of these tools made use of tangible objects to promote visualisation and discussion, essential for staff members to engage with and appropriate the project. A service designer was part of the project team, coming up with solutions to ensure that access to the new spaces was commensurate with user expectations. The project was sometimes

tricky and required a considerable investment of effort, with some readjustments along the way, but the new office facilities have already significantly improved working conditions. The communal areas have been expanded, diversified, modernised and personalised: hang-out spaces, a project mode room, a creativity space, co-working spaces, bubbles, new and more flexible meeting rooms, and a breastfeeding and relaxation room. New digital equipment has also been installed, and each floor is now colour-coded in reference to a geographical zone, reflecting IRD's global scope. Special attention was devoted to environmental considerations throughout the project, with existing materials reused wherever possible. The project was recognised by the Interministerial Fund for Improving Working Conditions (FIACT) as part of its "Public Action 2022" scheme.

KEY POINTS

The principles of sustainability science can be applied to our own research institutions, for example by creating spaces for the co-construction of knowledge, know-how and life skills, or promoting energy-saving measures for research practices. These innovations require processes and tools, as well as working methods and positions which allow a culture of interdisciplinarity to thrive within our institutions, encouraging initiative-taking, promoting collective intelligence and attracting new talent. They also create value, and intersect with major causes such as protecting the environment, gender equality at work and inclusion. Whether small steps or great strides, at every level there are first steps to be taken toward a new paradigm of business-employee-society relations. Facilitation, ideation, service design , collective intelligence, project mode… We all have a part to play in creating new ways of working.

No sustainability science without open science

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Background

The recent global health crisis, much like the climate disruption that humanity as a whole now faces, has served to further illustrate the urgent need to promote equitable access to scientific information, to facilitate the sharing of research data, to reinforce international scientific collaborations and to develop public policies informed by scientific progress, in order to tackle the planetary emergency and make our societies more resilient. These challenges are at the very core of open science, an indispensable priority not only in the context of the sustainable development goals (SDGs), but also for the implementation of sustainability science. The connections between sustainability science and open science have not received much academic attention, but in this article we propose a brief analysis.

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Further reading
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Open science will be essential to achieving the SDGs

Sustainability science is an essential pillar of the response to the societal and environmental challenges enshrined in the sustainable development goals (SDG). However, the new knowledge generated by research is often not sufficiently accessible or widely-shared to reach the international scientific community, inform public policies, foster a more inclusive model of economic development and bolster the resilience of our societies in the face of major crises. By virtue of its commitment to the values of sharing, free circulation and reproduction of knowledge, collaboration, transparency and scientific integrity, open science is an indispensable element of research for the SDGs. The Covid-19 pandemic offers a striking example of how open science, by providing universal access to research publications and data, can play a vital role in pandemic response (publishing viral genomes, accelerating the pace of scientific communication via preprint platforms, broader circulation of data to inform political decision-making etc.). Above and beyond its pertinence to health-related, environmental, economic and social challenges, open science is at the heart of SDG 9 (building resilient infrastructure, promoting sustainable industrialisation and fostering innovation), which recommends universal access to digital infrastructure such as internet services, particularly in less advanced nations, at an affordable cost and in fair conditions. It is also an essential tool for the democratisation of institutions, as championed by SDG 16 (promoting peaceful and inclusive societies, providing access to justice for all and building effective, accountable and inclusive institutions at all levels), with its commitment to the free circulation of information and the protection of fundamental freedoms in this domain. Finally, it is of direct relevance to SDG 17 (strengthening the means of implementation and revitalizing the Global Partnership for Sustainable Development), with its focus on expanding access to science, technology and innovation under the aegis of more equitable international partnerships – particularly North-South and South-South partnerships.

Open science to guarantee the sustainability of research

Open science is of vital importance to SDG-oriented research, ensuring its efficacy and productivity; in doing so, it works to make research more sustainable. Open access to data drives down the costs associated with repeat data gathering, promotes the transfer and reuse of data, and thus makes it possible to conduct more research with the same scientific raw material. Opening up the source code of software allows for community editing and collective learning (open-source debugging, transparency of changes, more effective testing of new versions). By guaranteeing access to data, tools and methods, open science promotes the quality and reproducibility of data. Open access to publications helps to reduce redundancy, plagiarism and fraud in scientific publishing, making it easier to verify scientific knowledge and submit it to critical analysis. By creating open-source documentary archives and data warehouses, it also allows for long-term, low-cost (and thus more equitable) sharing of scientific

output, something which is of particular importance for researchers in the Global South who face major obstacles in terms of both publication outlets and access to international scientific literature. Finally, as a means of boosting the visibility of academic output, it helps to make scientific progress and innovations more readily available for use by political decision-makers, economic actors and civil society.

Open science promotes interdisciplinarity

Sustainability science exhorts researchers to break down the silo walls between different disciplines and adopt an interdisciplinary approach to the complex challenges of the SDGs, which are resolutely interdependent. Synonymous with sharing and exchange, open science ensures that the data produced in one discipline can be reused in other domains, facilitating and accelerating collaborative work and the production of new knowledge. Closely associated with open science, the FAIR principles of data management (Findable, Accessible, Interoperable, Reusable; see Desconnets J.-C., Sabot F., 2022 – « Données numériques et durabilité ». *In* : *Sustainability Science*, Marseille, IRD : 150-153) reflect the central importance of interdisciplinarity in sustainability science. Above and beyond data, free access to scientific publications is conducive to interdisciplinarity in so far as it makes the scientific literature of a given discipline more visible and more accessible to others. This in turn facilitates the dissemination of research results and the reappropriation of conceptual approaches formerly confined to individual disciplines.

Open science strengthens the bonds between science and society

Sustainability science demands stronger connections between science and society. It promotes the co-construction of knowledge, which requires close collaboration between researchers and non-academic stakeholders at every stage of the research process. Here again, open science has a vital role to play. Firstly because it ensures the broadest possible access to research data, publications and software code for all communities, academic and non-academic. As such it is indispensable for the implementation of participatory research programmes, working to boost the skills and capacities of non-academic actors, allowing them to become better informed and thus to be recognised as fully-fledged actors in research processes. Open science also brings about a shift in the way that research fits into society more broadly: by ensuring that scientific information is more widely circulated, it is a valuable weapon against misinformation and the propagation of false information. Above all, by reinforcing the democratisation of knowledge and bolstering research integrity, it can help to strengthen trust in science in society at large.

KEY POINTS

In order for the benefits of open science to truly contribute to the development of sustainability science, certain conditions will need to be met, including:

- **a new approach to the evaluation of research, not founded exclusively on quantitative criteria but instead considering the intrinsic quality of scientific studies, their diversity and their societal impact, among other factors;**
- **closing the digital divide which continues to penalise many parts of the world, particularly in the Global South, with access to data warehouses and open archives, as well as the possibility of creating new ones;**
- **improved digital literacy among researchers and engineers of all disciplines, ensuring that they are capable of fully capitalising on the opportunities offered by open science;**
- **national and international policies, backed up with resources, to support the development of the culture and practice of open science within scientific communities.**

SUSTAINABILTY SCIENCE
UNDERSTAND, CO-CONSTRUCT, TRANSFORM

Volume 2

In this second tome, more than 100 authors from the IRD ecosystem – scientists, heads of department, diplomats, project leaders and representatives of civil society – continue the process of collective reflection launched in 2022. Structured around the "understand, co-construct, transform" triptych, these interweaving perspectives on knowledge, know-how and life skills combine to offer an interdisciplinary vision of sustainability science which transcends sectoral boundaries.

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