FOCUS ON THE GLOBAL SOUTH

RESEARCH FOR A SUSTAINABLE WORLD

IRD Éditions

FOCUS ON THE GLOBAL SOUTH

RESEARCH
FOR A SUSTAINABLE WORLD

FOCUS ON THE GLOBAL SOUTH

RESEARCH FOR A SUSTAINABLE WORLD

Preface by Valérie Verdier and Achille Mbembe

IRD Éditions

Editorial management
IRD/Marie-Lise Sabrié

Production coordination
IRD/Jasmine Portal-Cabanel, Catherine Guedj

Iconographic research
IRD/Daina Rechner

Graphic design and layout
Format Tygre/Alan Guilvard

Copywriting
Alice Bomboy, Françoise Dupuy Maury
IRD/Jasmine Portal-Cabanel, Marie-Lise Sabrié

Traduction
Hancock Hutton

Proof-reading
Anne Causse

Distribution coordination
IRD/Christel Bec

Cover photo: Brown pelican, Puerto Lopez, Ecuador. © IRD/O. Dangles
Portraits: rights reserved (unless otherwise stated)

Print version ISBN: 978-2-7099-3060-4
PDF version ISBN: 978-2-7099-3063-5
Epub version ISBN: 978-2-7099-3064-2

This work has been published to celebrate the IRD's 80th anniversary.
It was coordinated by the Scientific and Technological Culture Mission,
in collaboration with the Communication and Information Sharing Department.

Scientific Committee

Editorial Committee

Acknowledgements

Nejma André, Catherine Aubertin, Ouidir Benabderrahmane, Anne-Gaël Bilhaut, Paul-André Calatayud, Rafael E. Cárdenas, Claudine Chamoreau, Sylvain Cloupet, Vincent Corbel, Fabrice Courtin, Pascale de Robert, Marc Descloître, Laure Emperaire, Jacques Gardon, Claude-Anne Gauthier, Pierre Journeaux, Isabelle Lefrançois, Oumarou Malam Issa, Sylvie Manguin, Jean-Michel Martinez, Nicaise Ndam, Léti Obavamian, Franck Poitrasson, Nicolas Puig, Stéphane Raud, Frédéric Simard, Cheikh Sokhna, Bruno Turcq, and the IRD scientists whose photos feature in this book.

Madagascar © IRD/V. Porcher

CONTENTS

PREFACE 12

Valérie Verdier and Achille Mbembe

FERTILE LANDS 14

TESTIMONIALS 32

Claire Nicklin, Bepunu Kayapó, Nabil Mohamed Ahmed

LIVING WORLDS 38

TESTIMONIALS 54

Silvia Restrepo, Adolé Isabelle Glitho-Akueson, Emilia Velazquez, Jan Leach

SOCIETIES ON THE MOVE 62

TESTIMONIALS 80

Sari Hanafi, Nicaise Moulombi, Mary Teuw Niane, Slim Khalbous, Taivini Teai, Tea Frogier

CLIMATE 88

TESTIMONIALS 104

Marie Christina Kolo, Eddy Ngonkeu, Hana Gannoun

ONE HEALTH 110

TESTIMONIALS 130

Joseph Kamgno, Mame Sidy Ndour, Mamadou Sarr, Coumba Touré Kane, Theeraphap Chareonviriyaphap

COASTS AND OCEANS 138

TESTIMONIALS 156

Jihad Zahir, Flávia Lucena-Frédou, Carmen García Dávila, Dorothy Wanja Nyingi

LAND AND WATER 162

TESTIMONIALS 176

Véronique Yoboué, Thi San Hà Phan, Silvana Hidalgo, Claude Borna, Adèle Rayangnéwendé Ouédraogo, Mamadou Diol, Kieu Thi Kinh

POSTFACE 186

Olivier Dangles and Rafael E. Cárdenas

PREFACE

In our Anthropocene era, science is proving more vital than ever in providing a holistic understanding of the conditions that make the Earth habitable and how they are changing. Scientists act as sentinels, detecting and anticipating the emergence of the profound changes at play, analysing the complex mechanisms behind them and warning of their possible consequences. More than ever before, scientists are being called upon to make a resolutely innovative contribution to solutions that support the transition of societies towards social, economic and ecological models that are fairer and more sustainable.

This book, published on the occasion of IRD's 80th anniversary, demonstrates our commitment to research aimed at defining paths towards a desirable future given the global challenges that lie ahead. It illustrates the unwavering determination of the Institute's scientists and partners to put science at the service of developing countries, which are the most exposed to the impacts of global change and the inequalities resulting from globalisation, but which are also committed to research of excellence and are driving innovations for a sustainable future adapted to their local context. These decades of research, training and expertise, carried out and shared together, represent fruitful collaborations. They have enabled IRD to propose a model of equitable scientific partnership and a form of science that is committed to constructing solutions together with all stakeholders in the field to best meet the needs of people living in the Global South. Our aim today is to conduct research founded on long-

term partnerships and to share the results for the benefit of as many people as possible, to transform the future.

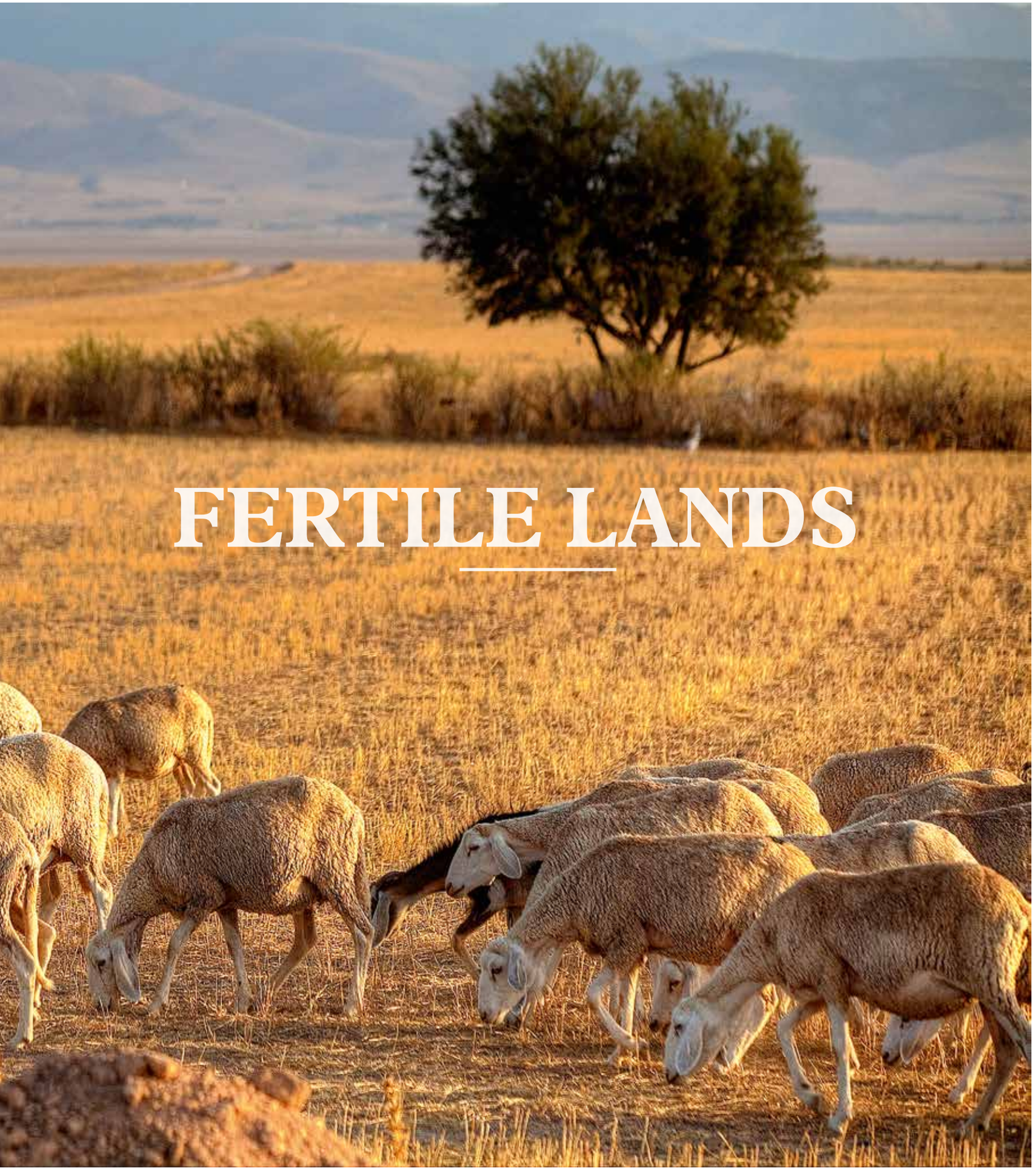
Throughout these pages, illustrated with magnificent photographs from every continent, readers will discover 80 major scientific advances. This book is a plea for open and shared science; it contains fascinating testimonials from the Institute's long-standing partners, including researchers, development stakeholders, entrepreneurs, public policymakers and artists. It highlights the fundamental role played by men and women in working together to conduct multi- and transdisciplinary research that places dialogue at the heart of its approach. This approach enables us to grasp the complexity of the issues at stake and to work together to create more inclusive and resilient societies. Today, all forms of knowledge, regardless of their cultural origins, need to work together to invent new relationships with the living world and different ways of inhabiting the Earth. The aim is to turn the planet into a true *terrestrial community*, one that is welcoming to all, humans and non-humans alike.

As this book demonstrates, the Institute's past and recent history has been shaped by major projects and scientific breakthroughs, but we are acutely aware of the immensity of the task that remains to be accomplished are given the profound upheavals that are affecting the planet today: environmental, health, economic and social, and which are all challenges that research must continue to address now and in the years to come.

Valérie Verdier
IRD Chairwoman
and Chief Executive Officer

Achille Mbembe
Professor of History and Political Science
at the Wits Institute for Social and Economic Research,
South Africa

Nile Delta, Egypt © Reza/Webistan


FERTILE LANDS

Agriculture is currently facing difficulties on an unprecedented scale, particularly in countries of the Global South, due to the combined effects of rising demand for food, the overexploitation of ecosystems, biodiversity loss and climate change (increasing scarcity of water resources, desertification, etc.). Can we envisage production systems that guarantee food security while protecting the sustainability of resources and the resilience of socio-ecosystems? Research has been successfully exploring a number of avenues to meet this challenge, including the fight against erosion, the revival of traditional agricultural practices and knowledge, sustainable aquaculture, the recycling of waste from agro-industry, and many others.

The beneficial effects of soils. Soils play a central role in the balance of the living world, providing fertility and acting as carbon sinks. While pedological studies have shown the capacity of humus to fertilise the soil through the decomposition of plant, animal and microbial matter, scientists are now proving that better farming practices, such as agroforestry or the African zaï method, improve soil fertility and its capacity to sequester carbon.
Pilchecocha, Ecuador © IRD/O. Dangles and F. Nowicki

Traditional knowledge supporting sustainable agriculture. Throughout the world, the overexploitation of agricultural and forestry resources is leading to a decline in soil fertility, biodiversity and carbon sequestration. Traditional farming practices have long been ignored and undervalued. Ancestral techniques, such as slash-and-burn or zaï, are proving to be a source of sustainable solutions, thanks to the diverse range of resources they help to produce and their ability to adapt to climate change. These techniques deserve more than the archaic reputation they are given, and are even essential to the ecological transition.
Andes, Peru © IRD/O. Dangles

Wind erosion in the Sahel. Arid environments are subject to erosion caused by both water and wind, threatening soil fertility and conservation. Thanks to research stations in several African countries, scientists have measured sand grains and their movement, and have defined the composition of terrigenous particles and the preferred trajectories for their transport over long distances. Dust from the Sahel can travel as far as the Amazon rainforest. This research has led to the modelling of wind erosion and the identification of aggravating factors, such as mass cropping or the systematic collection of agricultural residues.
Bay of Arguin, Mauritania © IRD/O. Barrière

Trees, allies for agriculture. Long regarded as a commodity or an obstacle to intensive agriculture, trees are now viewed in a new light. This change stems from the observation of traditional farming practices that closely combine food crops and trees, in Africa and later in South America and Indonesia. These long-neglected ancient practices are now providing a model for the future. Agroforestry promotes better environmental management and, for example, regulates crop diseases through plant and animal biodiversity.
Yrga Chefe, Ethiopia © IRD/G. Michon

Land rights for farmers in the Global South. For over a century, two concepts of rural land rights have been at odds in many countries in the Global South. In contrast to the law governed by title deeds, which are mainly held by elites, a different approach to land management exists, based on "informal" customary law, governed by long-established local norms. The stakes are high for farmers, who risk being dispossessed and losing access to natural resources that are vital to their survival. Multidisciplinary research has contributed significantly to discussions on land policies and reforms at national and international level.
Bali, Indonesia © IRD/M. Bouvet

Useful waste. Most agricultural processing (oil, wine, coffee, sugar, etc.) leaves over 90% of "green" waste unused, ending up as a source of pollution. Based on this observation, scientists have explored solid-state fermentation techniques and other ways of recovering this agro-industrial waste. Experiments have been carried out to grow mushrooms to decompose plant biomass, and to innoculate green waste with mushroom spores, opening up new agricultural, industrial and medical outlets. The future looks bright for bioconversions!
Praia, Cabo Verde © IRD/J.-F. Molez

Controlled reproduction of farmed fish. More than half of the fish consumed worldwide is farmed. This sector is continuing to grow rapidly, mainly in tropical areas, creating environmental imbalances and sometimes causing tensions between neighbouring countries, as is the case in Vietnam and Cambodia. These tensions stem from the harvesting of young fish from the wild. In response to this, scientists have succeeded in controlling captive reproduction of certain species for food or ornamental purposes, using hormonal protocols or methods to distinguish between the sexes of the spawners.
Arapaima gigas © IRD/M. Jégu

Towards virtuous aquaculture. In Africa and Asia, the association of farmed fish with various species of aquatic plants or algae is being closely analysed, as these plants can consume the waste produced by the fish. This "integrated and multi-trophic" form of aquaculture has, among other things, helped to limit environmental pollution by using plants to purify the water in the ponds. In other farms, fish are fed insect meal as an alternative to marine fish meal. Finally, to reduce the use of antibiotics, researchers are studying the use of certain plants to treat fish.
Next page, top left: **Indonesia** © IRD/J. Slembrouck
Next page, bottom left: **Dakar, Senegal** © IRD/P. Brehmer

The mysteries of the senilia. In Senegal's Saloum Delta, the vast majority of women earn their living from fishing. Gathered on foot for thousands of years, the senilia, their main resource, has been in decline for over twenty years. Is this due to the pressure of what has become a commercial fishery, or to climate change? Using data collected on site, researchers are endeavouring to understand the variability of the resource and to develop models for its progression. Another aim of this research is to involve these women in proposing sustainable management methods that are tailored to their needs.
Next page, right: **Saloum, Senegal** © IRD/O. Sadio

Small-scale family farming, a sustainable solution. Small family farms account for 80% of agricultural businesses in countries in the Global South. They are a model of interdependence between the family and its agricultural, forestry, pastoral, fishing or aquaculture environment. The shift operated by some farms towards more intensive crops has made them economically fragile. Scientists and farmers' organisations highlight the importance of family farming in preserving the environment and ensuring safe, healthy food. International organisations now recognise and value this model.
Left: **Limu, Ethiopia** © IRD/F. Verdeaux
Right: **High Atlas, Morocco** © IRD/O. Barrière

High altitude pastures. On the high plateaux of Bolivia lie the *bofedales*, an ecosystem supplied with water by glaciers and which contrasts with the arid surroundings. They play an essential role in grazing livestock. The melting of the glaciers as a result of climate change could put an end to this vital balance. Thanks to satellite images and field data, scientists are working on the recent evolution of the *bofedales* and on several long-term scenarios, in order to support local populations with strategies for protecting these ecosystems or for the sustainable management of water reservoirs.
Cordillera Real, Bolivia © IRD/O. Dangles

Claire **Nicklin**

Representative for the Andean region in the "Global Collaboration for Resilient Food Systems" programme of the McKnight Foundation (Ecuador)

We work in the Andean region with a wide range of stakeholders, including researchers, farmers and NGOs, to advance upstream strategies that pave the way for change. IRD has been one of the beneficiaries of this programme for fifteen years, and we have seen the impact of its research both locally and globally.

For example, IRD conducted a study on the potato moth. Scientific articles presenting the results of this research have been published, a crucial step in bringing about change. But the impact of this research goes beyond the academic knowledge it has produced. Many local students took part in the project alongside IRD researchers. This collaboration accelerated the development of skills in agro-ecology at regional universities. IRD has also produced videos for farmers, participatory games for stakeholders to better understand the issues, and brochures on how to control

> **“WESTERN COUNTRIES TEND TO OVERLOOK SOLUTIONS FROM THE GLOBAL SOUTH”**

the potato moth. This myriad of innovative ideas and creative efforts has helped to integrate IRD’s recommendations into local farming practices.

We know that Western countries tend to overlook agroecological solutions that come from the Global South. I recently spoke to a French farmer who practices agroecology in Montpellier. His knowledge of agroecological practices and the agroecological movement comes from Brazil. He learned from scientists who shared the knowledge they acquired from Brazilian farmers: a powerful transfer of knowledge despite the distance.

I would like to see IRD participate in this circulation of knowledge, not only from the Global North to Global South, but also from one region of the Global South to another. It represents a major shift in expectations, and invites us to think differently about what sustainable development means. Breaking down the imaginary boundaries between innovative approaches to agroecology for “developed” countries and those for “developing” or “underdeveloped” countries will help us to safeguard our health, our ecosystems and our climate on this planet we all share.

Bepunu **Kayapó**

Bêngôkre filmmaker, Cacique of the village of Môikàràkô (Kayapo indigenous territory, Brazil)

Interviewed and translated from Brazilian by Pascale de Robert, researcher at IRD

Brazil, a country of the South of America! Although we are speaking from the perspective of France, the term "South" can lead to confusion. Take my village, it's in the south (of the State of Pará), in other words in the north (of the country) and is therefore far from the South (of Brazil). Research is very important to me, and we have already taken part in several projects. "Sustainable development" should be a very meaningful term, but it's not always easy to understand. "Development" is a clear term, but in my region, for many people, it means cutting down forests, sealing roads, buying new cars, etc. If the idea is really to improve the future, then we should be talking about "improvement" and not "development". To improve the future, we need to do research. And above all, do research together.

I have learnt a lot through research, knowledge that is very different from traditional knowledge, and I continue to learn as a photographer and teacher. To strengthen the role of research, I think we need to encourage collaborative work, the circulation of ideas and dialogue. One way of

> **IMPROVING MEANS TAKING CARE OF NATURE AND INDIGENOUS LANDS**

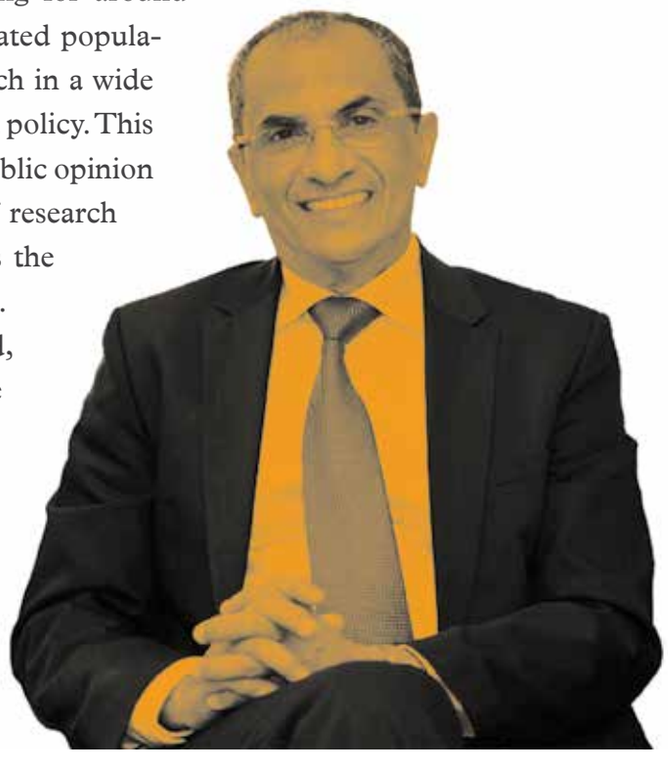
achieving this is to increase the number of research centres and meetings.
In towns and villages, we need to host indigenous researchers, in museums, at workshops, exhibitions or collections. After all, our thoughts are embedded in the things our ancestors made and in the things we are still making.
Especially in villages, there is a lack of scientific culture, and there are often documents and photographs that we don't even know exist. We want to create a "Môikàràkô art house" so that women, men, old people and young people can learn together. This place could, for example, show the different forms of visual arts: we could film women painting, study old photos, or present a research project on cultivated plants that was carried out several years ago. We need to conserve, exchange and develop these things in order to improve the future. This project for my village is under construction.
"Improving" means taking care of nature and, in the Amazon, that means taking care of indigenous lands. There are many problems, such as the illegal exploitation of our lands, which has to stop. We Amerindians are here, and always have been. Looking after nature is something that concerns everyone, even those who live far away. Another interesting word is "well-being", as it encompasses people's health. The health of the forest goes hand in hand with the health of the people. To achieve this, we also need to work with other countries, because we all need it. Nature and well-being concern us all, whether we live in the Global South or Global North.

Nabil **Mohamed Ahmed**

Minister for Higher Education and Research (Djibouti)

African countries are facing various crises that are undermining their development and exacerbating the poverty of the most vulnerable communities. Nevertheless, with their young populations and the emergence of dynamic economic growth, there is hope for a better and fairer future. Meeting the challenges of turning hope into reality requires a better mastery of technologies and scientific research aimed at sustainable development.

Yet the African continent already has major assets that are not to be underestimated. It is the world's largest free trade area, with a market estimated at nearly 1.2 billion people and with young people accounting for around 77% of its population. This increasingly highly educated population makes it possible to conduct high-quality research in a wide variety of fields that are also priorities for government policy. This impetus is encouraged by the growing awareness of public opinion and political decision-makers who see the results of research and innovation, in partnership with local players, as the means to an intelligent way out of underdevelopment. Nevertheless, in an increasingly interconnected world, international collaboration is essential to consolidate these assets. Training, dialogue and the transfer of scientific and technical knowledge and expertise will be the driving force behind this collaboration.



“AFRICA MUST INVEST MORE IN HIGH-LEVEL RESEARCH”

On the occasion of IRD’s 80th anniversary, we must pay tribute to the work carried out by this institution to support its partners in consolidating their training, research and development policies. For example, in Djibouti, IRD has contributed to an oasis farming project and to a climate change project.

Historically, research has been an important activity in Djibouti for over 50 years, strengthened by a political will that is convinced of its value for promoting sustainable development and preventing conflict in the region. Two flagship projects were recently successfully completed. The ORREC *Observatoire Régional de Recherche pour l’Environnement et le Climat* (Regional Research Observatory for the Environment and Climate), inaugurated on 23 October 2022, provides a research space open to all national and international researchers working on the collection and processing of climate data to develop reliable models for risk management.

The space programme, meanwhile, has built two nanosatellites in partnership with the Montpellier University Space Centre (CSUM). These satellites, designed by young engineers and technicians from Djibouti, will be used both to collect hydrometric data in the region and to improve climate models.

We are therefore faced with a real desire for a paradigm shift in a world that is in a perpetual state of “rupture”, in which Africa must find its place and do so in an uninhibited way by investing more in very high-level scientific and technical research made possible by collaboration with countries around the world, in accordance with the words of Pasteur: “Science knows no country, because knowledge belongs to humanity”.

Andaman Sea © D. Mukherjee

LIVING WORLDS

Protecting biodiversity is one of the most urgent challenges facing humanity. The future of the planet depends on it, because species are disappearing at a rate not seen since the last great extinction. It is also one of the most complex issues for science, because biodiversity cannot be considered in isolation from its interactions with human societies, which sometimes destroy it but also try to preserve it. This complexity is exacerbated by the need to combine global trends - such as climate change - with specific local cultural, social and environmental contexts. The research illustrated in this chapter, conducted from the molecular to the landscape level, paves the way for more sustainable relationships between humans and the living world to which they belong.

A virtuous application. The Pl@ntNet application has become a worldwide success, both in terms of downloads and daily connections, and in terms of the number and diversity of countries using it. This free application provides accurate plant recognition (over 90% accuracy) thanks to its impressive database and validation by botanists. The application is constantly being updated, with users providing geolocated photos. It demonstrates the positive impact of collaborative work in which scientists and the public both benefit and play an active role.
Right: *Aerangis gracillima* © IRD/V. Droissart
Next page, left: *Anigozanthos manglesii* © IRD/A. Rival

Right:
Cassava putting up a fight. Cassava is the fourth-largest source of calories in tropical countries, and is drought-resistant, making it a plant of the future in the face of climate change. But it can also be decimated by epidemics caused by a bacterium. By identifying and deactivating one of the bacterium's genes, scientists can prevent it from multiplying. The mapping of the genetic diversity of this bacterium, which is currently underway, will also help to understand its evolution and future in Africa and South America. Finally, the development of a tool for diagnosing infected cuttings will limit their spread.
Manihot esculenta © IRD/V. Verdier

Making an inventory of the forest to protect it more effectively. The forest of French Guiana, which accounts for almost a third of France's total forest area, is made up of a mosaic of around twenty habitats. These habitats have been mapped using satellite data to identify the species they contain according to soil type and topography. This methodology has produced a catalogue that has become indispensable to Guiana's forest managers. It is expected to be adopted in neighbouring countries and Central Africa in the near future.

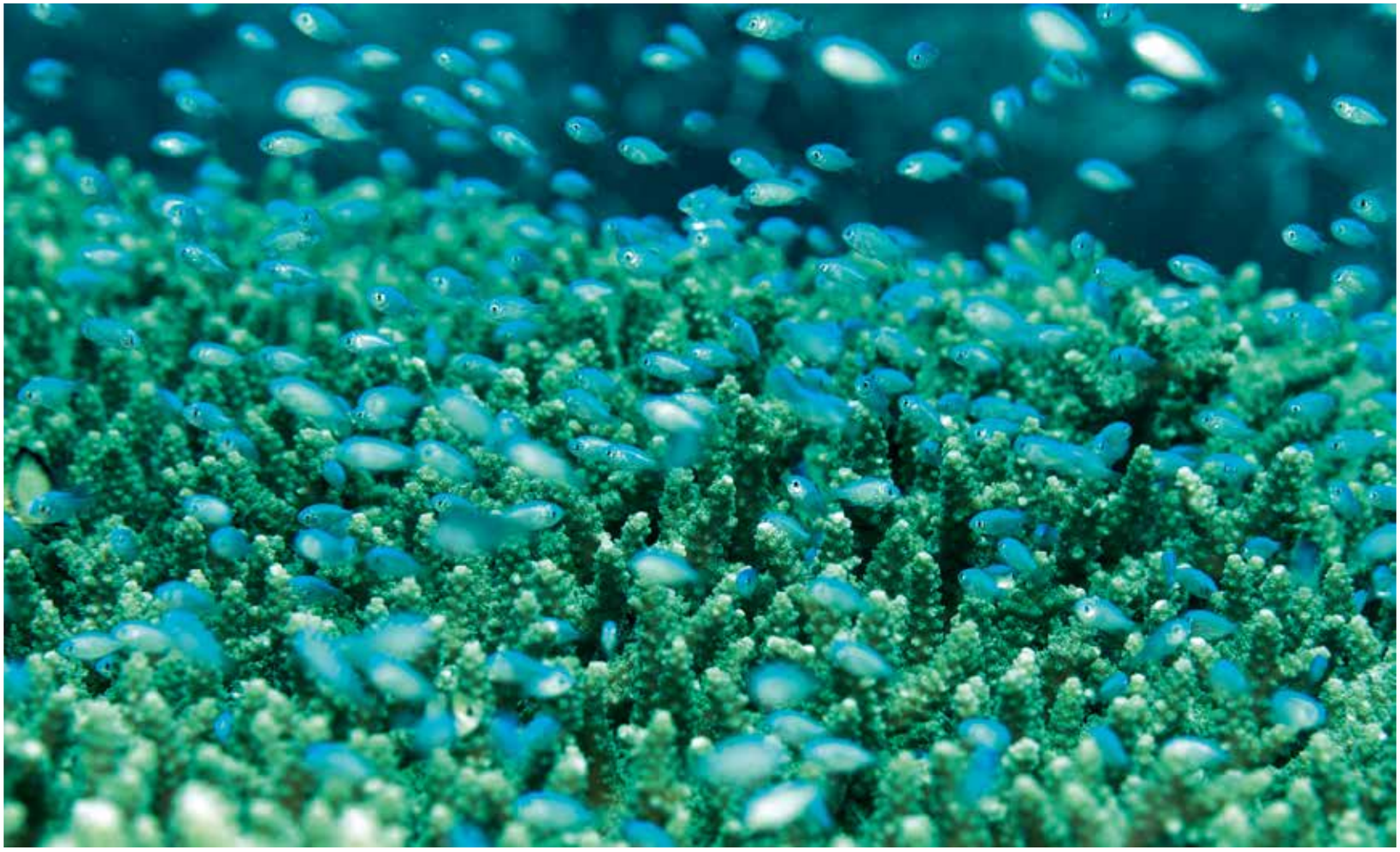
Nouragues Nature Reserve, French Guiana

Left:
The ravages of the fall armyworm. The maize fields of sub-Saharan Africa have recently been suffering the ravages of the fall armyworm. In Kenya, researchers have shown that it has not replaced the preexisting pests, but coexists with them, rendering the control methods used up to now ineffective. However, there have been some promising trials in Senegal: two biological insecticides appear to be effective against the caterpillar and could provide a sustainable strategy for preserving the yields of a crop that is vital to the local communities.
Fatick region, Senegal © IRD/S. Brabant

Right:
Genetics to the rescue of rice growers. Specific to Africa, rice yellow mottle virus causes severe yield losses that threaten the continent's food security. Research has explored two ways of tackling the disease. The first involves selecting resistant plants. The second is by studying the genetic diversity of the virus that causes the disease. Researchers have been able to draw up a map defining the distribution area and virulence of the different strains of the virus in Africa. These results will help to judiciously deploy the varieties with the greatest resistance to the virus.
Komati River estuary, Mozambique © IRD/D. Rion

Precious symbioses. Legumes (soya, groundnuts, beans, etc.) are rich in nutrients and fertilise the soil through symbiosis with nitrogen-fixing bacteria. This technique has long been used by farmers in Asia and South America, and can now be applied to African agriculture through the selection and inoculation of bacteria adapted to the legumes grown in Africa. Studies on the molecular mechanisms at play pave the way for this type of bacterial collaboration for non-leguminous plants such as rice, wheat and maize. This innovation will improve yields while using less chemical fertiliser.
In vitro cultivation of rice, Vietnam © IRD/F. Carlet Soulages

Destructive deforestation. What is the impact of the destruction of the tropical rainforest, which regulates the climate and is a haven of biodiversity? Research into the Amazon rainforest, which has lost almost 20% of its surface area in fifty years, has shown that deforestation contributes to delaying the start of the rainy season in the southern Amazon. This creates a vicious circle: longer periods of drought increase the risk of fires, which in turn damage the forest.
Amazon, Ecuador © IRD/T. Couvreur



What environmental DNA has to reveal. Remnants of skin, urine, blood... All living things leave traces of their DNA in the environment. By analysing this environmental DNA, scientists have been able to shed light on "dark biodiversity", i.e. species that are barely or not at all visible, but present in a given environment. For example, this technique has made it possible to identify 13 species of shark simply using water samples taken from the Pacific: an innovative way of revealing little-known biodiversity and protecting it!
Left: **Lengguru, West Papua** © IRD/É. Bahuet
Right: **Tuamotu, French Polynesia** © IRD/S. Andréfouët

Top:

Living archives. Sometimes created several hundred years ago, naturalist collections help us to know and understand species, but also provide information about changes in the climate and the environment. Some of these collections, which are still very much "alive", have become references. There is a laboratory in Montpellier that houses more than 400,000 arthropod specimens collected since the 1950s. New species are identified every year and preserved in this archive, making it possible to track the genetic evolution of these disease vectors or to study them for medical purposes.

Left: **Cayenne Herbarium, French Guiana** © IRD/T. Vergoz

Right: **Montpellier Vectopôle, France** © IRD/P. Landmann

Bottom left:

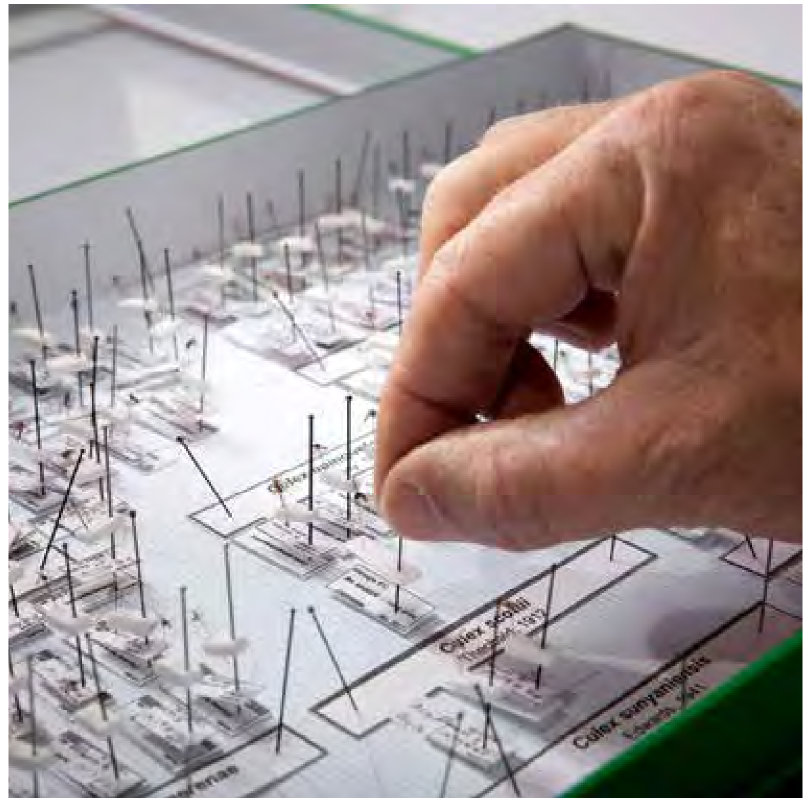
Under the surveillance of drones. In the Ecuadorian Andes, the Guatemalan potato moth can ravage up to 100% of potato crops. Having observed that plants damaged by this invasive insect undergo a change in temperature, researchers have developed an innovative method for monitoring the condition of crops. How does this work? By using drones equipped with cameras capable of displaying thermal variations in crops at centimetre scale. This is an effective way of detecting the presence of the pest and programming targeted action.

Carchi, Ecuador © IRD/O. Dangles

Bottom right:

The wonders of earthworms. Earthworms are essential to soil fertility and healthy crops. Scientists have shown that they help plants to protect themselves against diseases, such as a critical fungal disease which affects rice, by increasing the availability of silica which is beneficial to plants. They therefore recommend encouraging the development of earthworms, in addition to more soil-friendly farming practices, rather than making extensive use of chemical inputs.

Worm cast, Vietnam © IRD/J.-M. Boré



Silvia **Restrepo**

Professor at the University of the Andes (Bogotá, Colombia) and President of the Boyce Thompson Institute (USA)

I am convinced that without science there can be no sustainable development. By "science", I mean not just biology, mathematics, physics, and so on, but also the social sciences, because it is the interaction between them all that will provide us with the answers. For instance, agriculture, which is my field, needs biotechnological solutions, and their adoption by farmers requires social work with communities.

In addition, the countries of the Global South need more basic information and fundamental research. For example, it is often said that Colombia has incredible biodiversity, but we know nothing about the diversity of species in many regions, and this is true of most of the countries in the north of Latin America.

More broadly, the Ministry of Science and the universities are making significant efforts to send students to train at the best establishments around the world. We therefore have excellent scientists. Although some return, many remain in the countries of the Global North because of the violence that has affected Colombia, but above all because they lack sufficient funding

> **“WITHOUT SCIENCE, THERE CAN BE NO SUSTAINABLE DEVELOPMENT”**

to pursue their research. Only 0.2% of GDP is spent on science, which is virtually nothing, especially for fundamental research. This is because the people who govern us do not understand the benefits of science. Above all, they want to see application, so there is money only for applied research.

Yet all the applications we see today are the result of fundamental research. For example, the development of genome editing, a biotechnological tool with incredible applications, particularly in agriculture and medicine, began with fundamental studies on the bacterial genome! If one country is dependent on the fundamental research of another, it will not progress. And if it can’t develop the biotechnological tools that will help it achieve sustainable development, it will have to buy and import them.

Finally, in terms of North-South collaboration, I think that the International Joint Laboratories (LMI) are a fantastic idea. The LMI BIO_INCA (for “biodiversity of natural and cultivated Andean phytosystems”), which I co-directed with IRD ecologist Olivier Dangles, was all the more fantastic as it involved three countries: France, Colombia and Ecuador. It was the best of all possible worlds, with the South-South cooperation that is so lacking in developing countries. We tend to look to the countries where we did our doctorates, and rarely to the countries around us that are dealing with the same issues.

Adolé Isabelle **Glitho-Akueson**

Honorary Dean of the Faculty of Science at the University of Lomé, Honorary President of the Unesco Chair "Women, Science and Reasoned Water Management in West Africa" and member of the African Academy of Sciences (Togo)

The role of research in sustainable development only came to the fore after a long process that began in the 1970s: it is no longer a question of researchers carrying out research alone for their own scientific production and promotion, but of working as part of a multidisciplinary team in which each specialist contributes their own skills to address societal challenges. Researchers in Africa have embraced this dynamic, albeit with a greater disadvantage than their counterparts on other continents: Africa produces less than 2% of the world's research output, and the figure is even lower when it comes to innovations for development. In sub-Saharan Africa, there have been a number of success stories in agriculture, ecology and public health, against a backdrop of social science research. Among other examples, the "West and Central African Virus Epidemiology" (WAVE) project, which has been strongly supported by the authorities of its member states and involves small-scale farmers in research, is a good illustration of the idea of a research programme for sustainable development. Its main objective is the sustainable management of viral diseases of root and tuber crops. In the first phase, between 2015 and 2019, plans to combat viral diseases in cassava were drawn up in each partner country (Benin, Burkina Faso, Côte d'Ivoire, Democratic Republic

> **AFRICAN RESEARCH MUST ACCELERATE PROJECTS THAT BRING RESEARCHERS TOGETHER**

of Congo, Ghana, Nigeria and Togo). In the second phase, Plantvillage Nuru, an artificial intelligence assistant, was adopted for monitoring plant pathogens. The programme has now been established as a regional centre of excellence (WAVE CRe), enabling it to "work with others to build a genuine strategy for food security in Africa".

Despite the success of such projects, the genuine development of research in Africa remains hampered, not by the quality of African researchers - who are trained in good conditions and often have access to the latest technical facilities thanks to international university partnerships - but by the lack of dedicated staff in research centres and universities. Even more problematic is the drastic lack of funding: almost twenty years after the African Union member states pledged to devote 1% of their GDP to research, the reality remains far from the rhetoric and promises. In order to work, African researchers are obliged to respond to calls for proposals/projects whose priorities are often far removed from the continent's innovation and economic development strategies. Some calls for tender even exclude African researchers. As long as research continues to rely essentially on external funding, the infrastructure will never meet the scientific ambitions of African research. For now, the only way to save research on our continent is to accelerate projects that bring researchers together to work on cross-border issues, with the aim of pooling skills, infrastructure and scarce national and international funding.

Emilia **Velazquez**

Professor at the Centro de Investigaciones y Estudios Superiores en Antropologia Social and co-director of the MESO International Joint Laboratory (Mexico)

In Mexico, the issue of sustainable development has been addressed since the 1990s by both non-governmental organisations and universities. Non-governmental organisations have been more interested in promoting environmentally-friendly community development initiatives as a means of conserving natural resources. Academics have tended to conduct research into the deterioration of the environment (accelerated reduction in forest cover, biotic resources threatened by overexploitation or inadequate management), but also to propose solutions to the loss of biological and agricultural diversity. One of the common foundations of these initiatives is that they promote the active participation of those directly concerned, in particular farmers. In this context, one of the ongoing challenges is to establish a fruitful dialogue between these different stakeholders: NGOs and civil society organisations on the one hand, and scientists and academics on the other. These two groups have very different agendas, obligations and needs. For example, the first group has to submit financial and technical reports by specific deadlines set by the sponsors, while the second group has to carry out academic assessments based mainly on the publication of results in "high-impact" journals on the basis of priority issues determined by the national scientific councils of the countries involved. Strengthening the role of science in sustainable development remains highly dependent on

“ESTABLISHING A FRUITFUL DIALOGUE BETWEEN DIFFERENT STAKEHOLDERS”

better communication between scientists and decision-makers. There is an abundance of academic output, but it remains little known and rarely taken into account by governments to improve their actions. It is also up to us, as academics, to work harder to find appropriate ways of communicating our findings to decision-makers. The asymmetry in academic relations between the Global North and Global South is also problematic: the scientific agenda is still set by the Global North, the scientific knowledge produced is recognised there, while the Global South is used to gather the information required to produce this knowledge, with little attention paid to socio-political and cultural contexts. It is not that research is not carried out in the Global South, but it is generally ignored by the Global North, unless it is published in journals considered by the Global North to be of high quality and with a high impact factor - journals that are accessible in dollars or euros and remain inaccessible to students, independent researchers and social organisations in the Global South. Finally, there is also a lack of consideration of how the Global North contributes to the socioenvironmental problems of the Global South. In this respect, sustainable development should refer not only to proper management of resources, but also to equitable and genuinely equal scientific interaction between academics in the Global North and those in the Global South. Finally, another major challenge is to develop less vertical mechanisms for interaction between the academic world, public authorities and farmers, placing the farmers’ needs truly central to the design of research projects and public policies.

Jan **Leach**

Emeritus Professor at the College of Agricultural Sciences at Colorado State University and a member of the American National Academy of Sciences (USA)

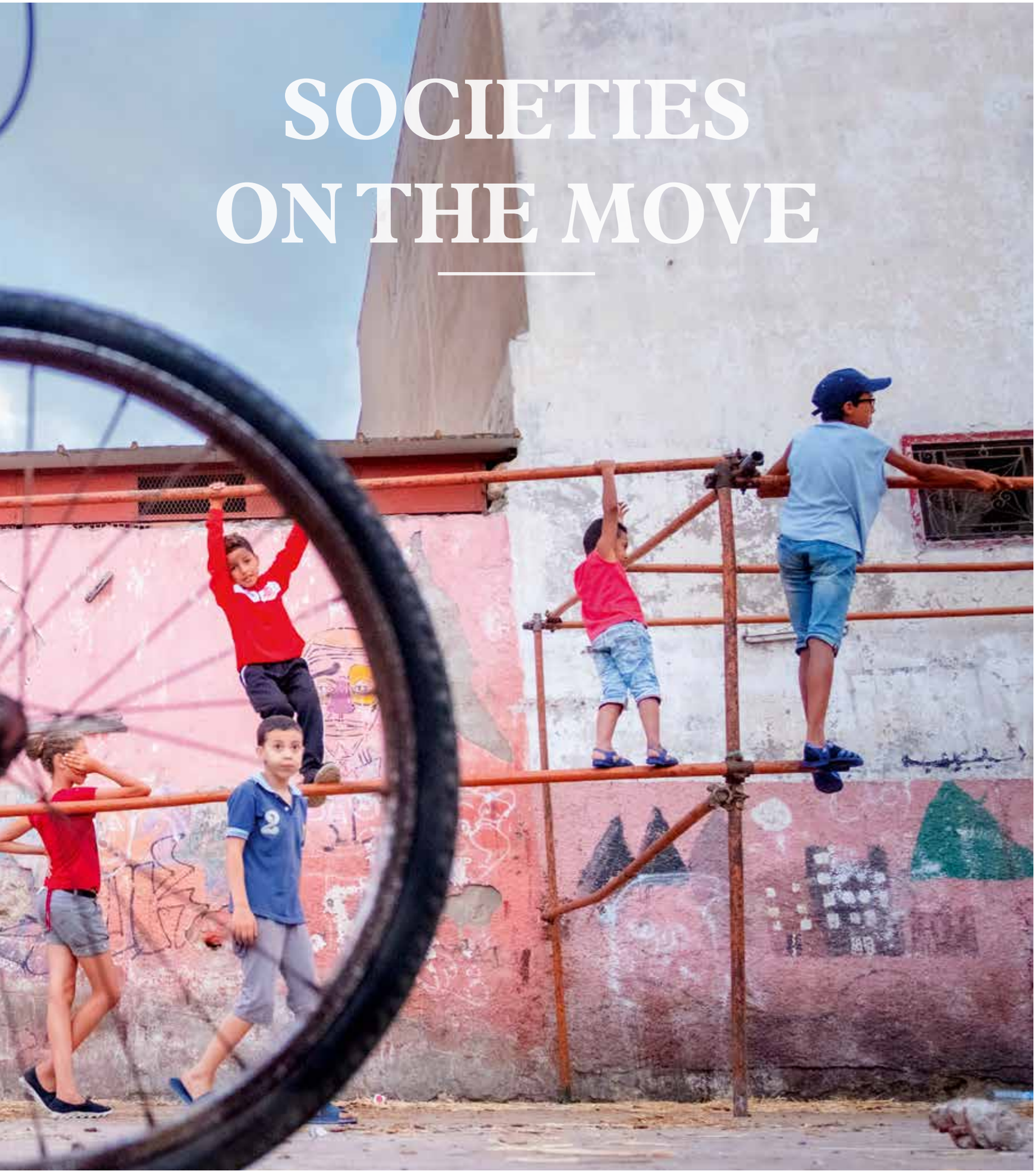
Over the past thirty years, my research team has focused on improving the productivity and quality of rice by studying how pathogens cause diseases in rice and how rice defends itself against these attacks while undergoing other stresses such as high temperatures and drought. I worked for many years with Valérie Verdier's team in Montpellier, before she was appointed Chairwoman and CEO of IRD. I myself spent a long time working in Asia, where rice diseases are well documented. At the time, it was not known whether these same rice diseases existed in Africa. Valérie and her colleagues discovered that a particularly devastating bacterial disease was present in several West African countries. They showed that the strains

“RESEARCH CHANGED THE GAME”

of pathogens in West Africa were slightly different from those in Asia. Several years later, an IRD team led by Boris Szurek showed that new strains of the pathogen identified in East Africa (Tanzania) were similar to those in Asia. These results changed the game: we realised that the sources of resistance in Asian rice could work in rice grown in certain regions of Africa, but not in all countries. Virulence is a key issue in our research: pathogens differ from one another in terms of virulence factors, which may or may not be present, and which define the way in which the pathogen interacts with plants. It is said that “you can’t find your enemy if you don’t know who it is”. The IRD team has carried out extensive research in Africa to identify and quantify rice pathogens, and also to develop pathogen-resistant varieties. This is a perfect example of where research teams play a very important role in bringing international knowledge to a local level to control and manage diseases in a country.

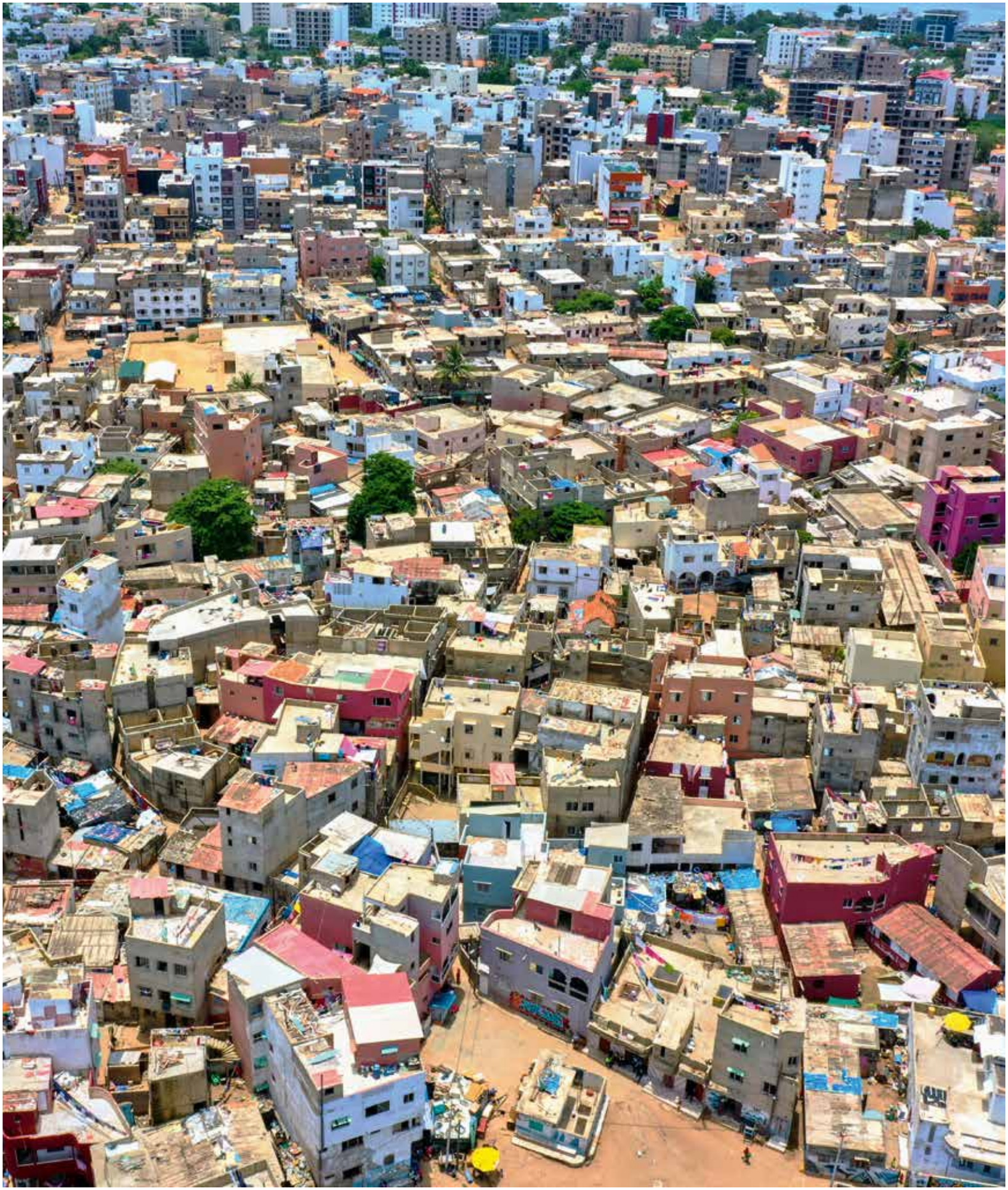
Casablanca, Morocco ©Y. Alaoui

SOCIETIES ON THE MOVE



Contemporary societies in the Global South are profoundly affected by globalisation and global change, which are leading to far-reaching transformations both in socio-economic terms and in the relationships between people and their environment. Understanding these changes requires multidisciplinary research at different scales into the many dynamics at work, such as the increased mobility of people, goods and ideas, accelerated urbanisation, social, cultural and religious restructuring, growing inequalities and vulnerabilities, and new forms of exclusion and social success. Understanding these processes provides insight for public policies and action programmes aimed at creating fairer, more resilient societies.

Connected urban air. More than 9 out of 10 people live in areas where exposure to air pollution exceeds limits. The fast-growing cities of the Global South are particularly affected. How can we monitor air quality in these areas? Cotonou, Dakar and Abidjan are now equipped with low-cost, connected, stand-alone stations that assess concentrations of fine and ultrafine particles in the air. As well as collecting scientific data, these stations inform local residents about air quality using indicators that can be accessed in the street using QR codes.
Dakar, Senegal © IRD/S. O. Boye



The invisible but essential informal sector. Often confused with the underground or illegal economy, the informal sector accounts for up to 80% of jobs in Asia and up to 90% in sub-Saharan Africa. To gain a better understanding of the workings of this informal economy - consisting of exchanges, home-based jobs and itinerant work - and the contribution it makes to family incomes, an innovative approach (known as "1-2-3" surveys) is gradually being adopted internationally. A better understanding of these insecure jobs will help developing countries plan public policies for the most vulnerable populations.
Left and right: Hanoi, Vietnam © F. Carlet Soulages

Protecting forest peoples. The forests of the Congo Basin are increasingly under the influence of the divergent interests of a wide range of parties, including new powers such as China, which may threaten the sustainability of these ecosystems. The way of life of indigenous populations is being severely disrupted by extractive activity, the creation or expansion of protected areas, the construction of infrastructure and agro-industrial plantation projects. Researchers argue that rigorous application of the laws protecting these forest peoples would be a first step towards finding a solution.
Left: **South of Libreville, Gabon** © IRD/R. Oslisly
Right: **Nki National Park, Cameroon** © IRD/E. Dounias

Migration money. If we are to understand the factors behind migration and the economic ties between migrants and their relatives back home, we need to study these two groups in parallel. This study has revealed a contrast between the perceptions of migrants and those of their families and friends with regard to the living conditions and monetary situations specific to each. The research has also made it possible to better quantify the sums sent home, to understand the social control over their frequency and to participate in the creation of tools (commercial platforms or applications) that give migrants control over the use of the funds sent home.
Beguedo, Burkina Faso © CNRS/O. Pliez

High-risk migration. Migration increases the health risks faced by migrant populations at every stage of their lives. Scientists have shown, for example, that a third to half of cases of HIV infection among African people living in France occurred after migration. The fragility of these populations makes them more vulnerable to sexual violence and prostitution. These findings suggest the need for targeted prevention and screening campaigns. The methodology used for the study has been transposed to other national contexts and types of population.

Marseille, France © IRD/S. Bredeloup

Valuable traditional knowledge. Local knowledge of plants is vital for protecting ecosystems in the face of widespread biodiversity loss. However, this knowledge is threatened by the fragility of its transmission, the dwindling number of communities that possess it and pressure from agro-industry. In particular, researchers recommend combining the conservation of seeds with the conservation of indigenous knowledge, for example by promoting community access to in situ collections or official recognition of such knowledge to prevent it being lost.

Ouro-Gueygueybé, Senegal

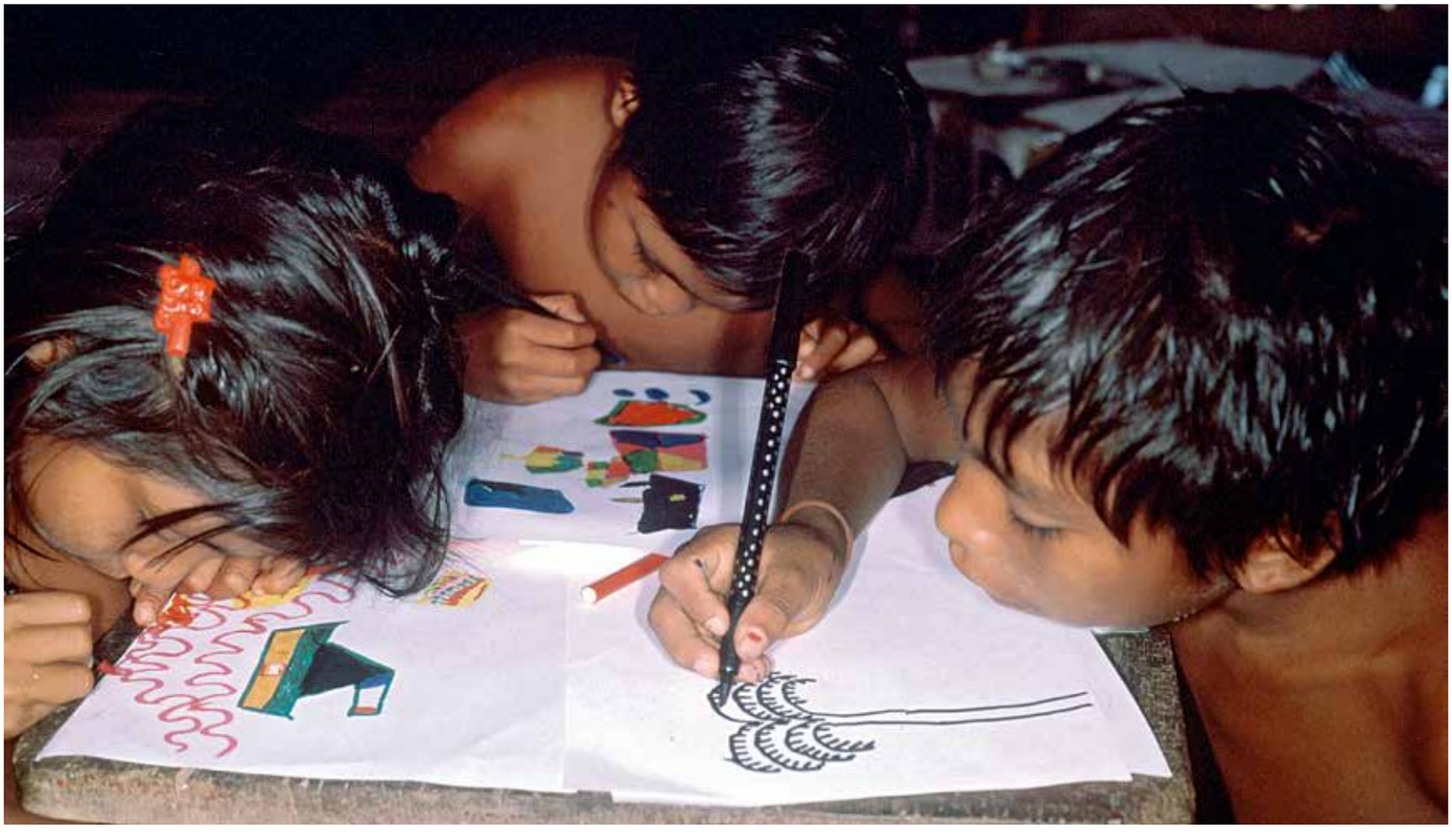
Schools and gender inequality. While the number of girls attending primary school is on the rise, they are still in the minority at secondary school level. The main reasons for this are the lack of schools and their cost, girls being assigned household chores and a lack of safety. Education is also failing to change gender role stereotypes. This is all the more true given that school itself reproduces the gender inequalities that make women more vulnerable. However, studies show that the longer teenage girls study, the more aware of inequalities they become.

Java, Indonesia © IRD/C. Z. Guilmoto

Protecting multilingualism. Encouraging the use of the thirty or so languages spoken in French Guiana is essential to promoting educational and social inclusion. One of the obstacles to integrating these languages into the education system is the lack of dictionaries and grammar books to enable teachers to teach them. A participatory project aims to fill this gap by publishing dictionaries for several Guianese languages and making them available online. *Teko*, an Amerindian language, and *Nengee*, a Creole language, now have their own dictionaries available on the Internet.

Gawapa, French Guiana © IRD/P. Grenand


EXAMINATION
CARD

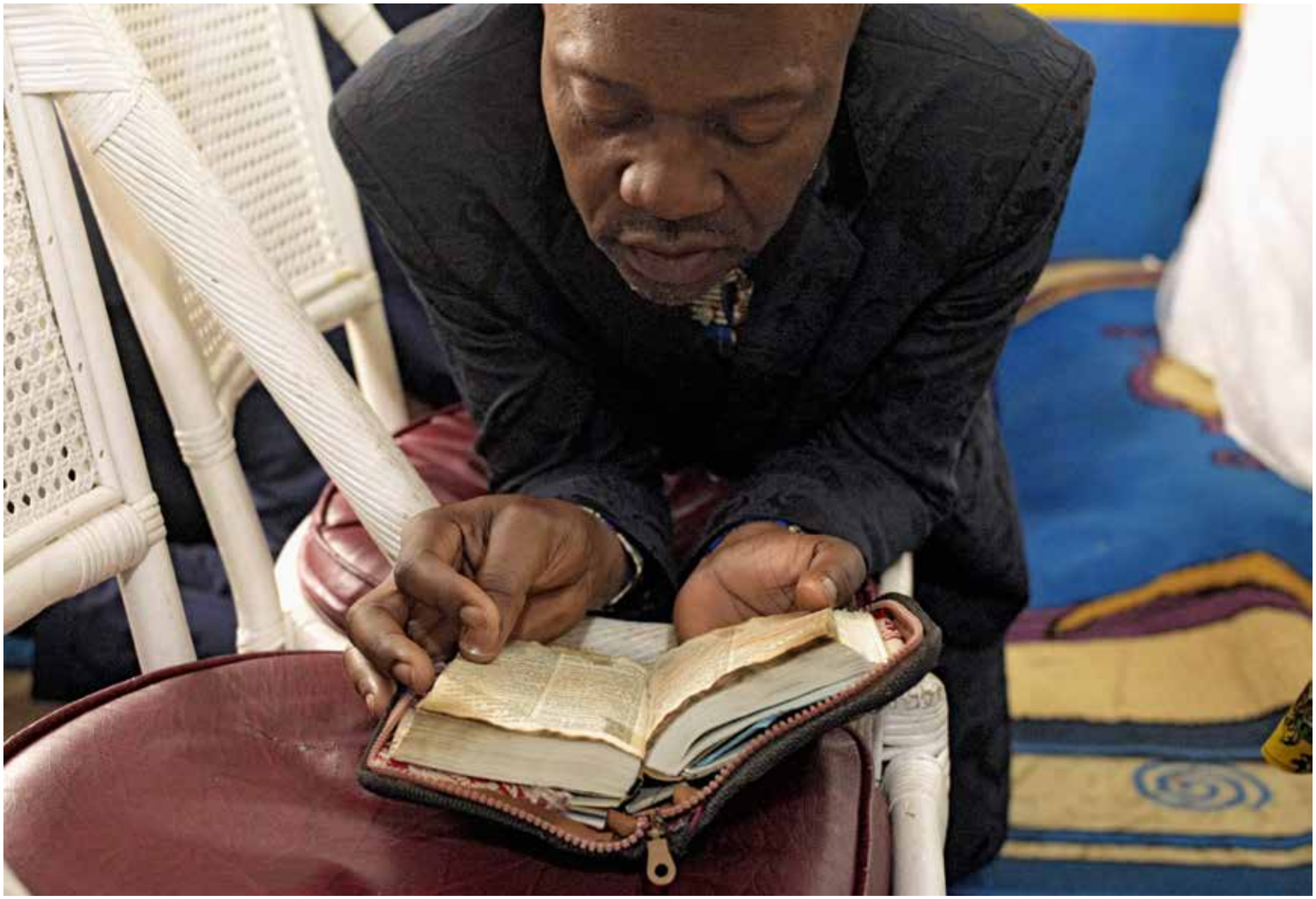


Caesarean sections in the city and in the countryside. In Vietnam, caesarean sections account for almost 30% of births, whereas the "ideal" rate is 10-15%. This high figure can be explained by rising living standards, changes in medical practices and improvements in hospital facilities. Caesarean sections are twice as common in urban areas as in rural areas in Vietnam. Research has revealed certain factors: wealth doubles the number of caesareans in urban areas, but is not a determining factor in rural areas; conversely, ethnicity has no impact in urban areas, unlike in rural areas.

Binh Duong province, Vietnam © IRD/M. Loenzien

Gender discrimination. In some countries, such as India and China, the number of girls is falling dramatically. This lack of women results in long-term demographic effects. Prenatal selection has surfaced as a result of a social preference for boys and the use of sex identification techniques during pregnancy. Young girls also suffer higher mortality due to a lack of care in childhood. These studies have fuelled public debate and encouraged governments to tackle these issues.
Pondicherry, India © IRD/J.-L. Duprey

Women, at the heart of debt. In India, women play a crucial role in the management of family debt. This phenomenon speaks volumes about the inequalities between men and women, and the economic practices of families who compensate for their low incomes and lack of social protection by taking on debt. In fact, around 30% of household income is used to pay off interest rates. However, despite the rise in debt in recent years, poor women are still very good at paying back their debts, albeit at great sacrifice.
Tangail, Bangladesh © IRD/I. Guérin



Religious revival. Religion is a spiritual as well as a material resource for migrants, who often spend many years on the move. Religious practices change as people move, and this can lead to the revitalisation of places of worship, new vocations or conversions in the host country. In Morocco, for example, researchers have shown how the legal recognition of Christian sub-Saharan migrants has led to a revival and reshaping of Christianity in the country.
Rabat, Morocco © M. Nejmi

Sari **Hanafi**

Director of the Centre for Arab and Middle Eastern Studies and former President of the International Sociological Association (Lebanon)

> **“WE NEED TO ASK OURSELVES HOW SCIENCE CAN BE PASSED ON”**

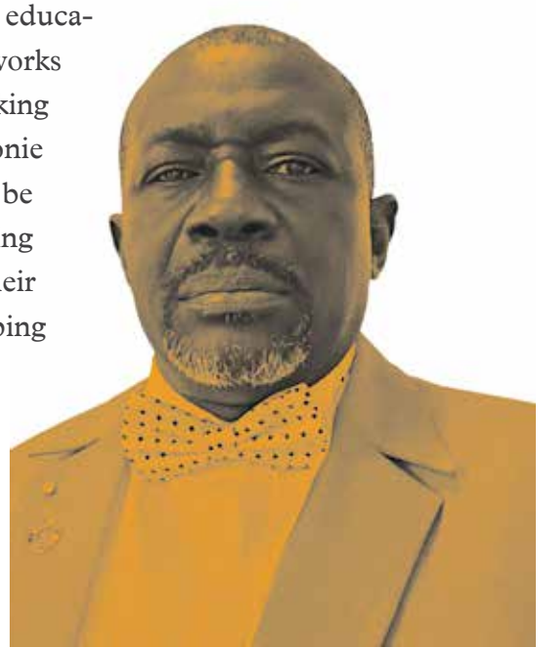
Since the 1990s, the production of knowledge in the Arab world has accelerated considerably in fields such as biomedicine and chemistry, as evidenced by the increase in the percentage of publications. And this is good news. The bad news is that although this high-quality academic research is produced, it is not used. This is because there are obstacles preventing the transmission of science to raise public awareness and the influence of civil society and politicians. Indeed, policies implemented by today’s authoritarian regimes are not based on scientific findings. We therefore need to ask ourselves how science can be passed on. In the same spirit, universities in the countries of the Global South, particularly those in the Gulf States, need to become more independent if they are to produce a wider range of truly interdisciplinary knowledge.

Nicaise **Moulombi**

Member of the Steering Committee of the Institut de la Francophonie pour le Développement Durable, Chairman of the Network of Civil Society Organisations for the Green Economy in Central Africa (Gabon)

“SCIENCE ACTS AS A CATALYST FOR THE SUSTAINABLE DEVELOPMENT OF EMERGING COUNTRIES”

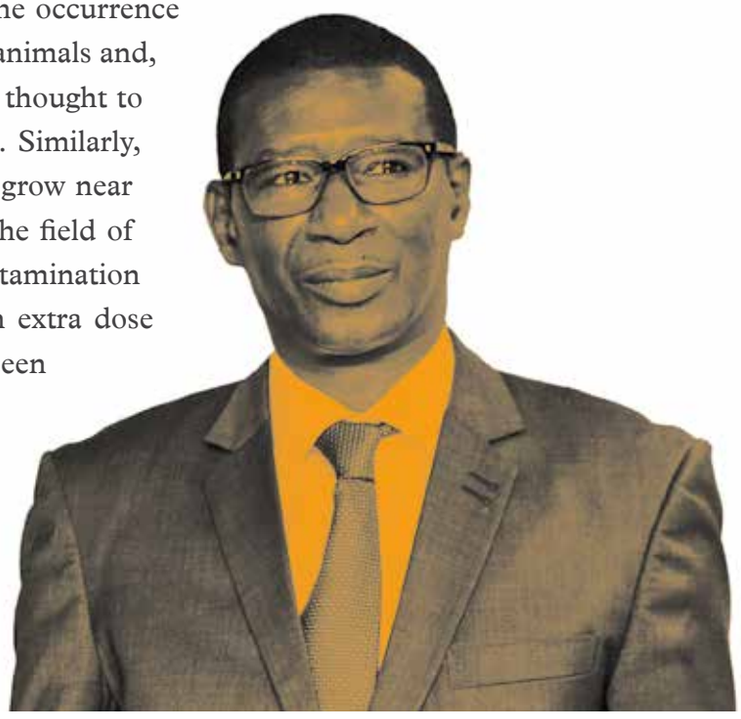
Science acts as a catalyst for the sustainable development of emerging, intermediate and fragile countries, in socioeconomic, health and environmental terms. For example, research has helped farmers to increase their productivity and resilience against the impacts of climate change. It has also made it possible to identify parasites and vectors of diseases such as Ebola and COVID-19, and to find treatments. On the environmental front, it has established the link between global warming, biodiversity loss and the deterioration of forest habitats. Thanks to this research, we have also been able to connect the significant increase in cancer to environmental pollution. This is why we need to invest in education and research, as well as improving legal frameworks and environmental regulations. The French-speaking world in general, and the Institut de la Francophonie pour le Développement Durable in particular, are to be commended for their driving role in providing training on emerging issues, equipping countries to update their legislative and institutional frameworks, developing scientific expertise, skills, etc., providing scientific support for African negotiators during the Conferences of the Parties (COP), and highlighting the importance of biodiversity and the exceptional ecosystem of the Congo Basin.



Mary **Teuw Niane**

Minister, Chief of Staff to the President of the Republic of Senegal and Senegalese mathematician

In my experience as a mathematician, Rector and Minister, scientific research is a driving force for sustainable development in the countries of the Global South in general, and Senegal in particular, on three levels. Firstly, there is the impact of the results of research work, as illustrated by four examples of projects carried out with IRD. The study of mosquito population dynamics in relation to Rift Valley fever has provided a better understanding of the occurrence of this viral haemorrhagic fever, which mainly affects animals and, to a lesser extent, humans, and which was previously thought to be a random occurrence in Senegal and Mauritania. Similarly, we have studied the dynamics of invasive plants that grow near dams as a result of the softening of river waters. In the field of health, an analysis of the differences in hepatitis B contamination between Asia and Africa has shown that we need an extra dose of vaccine. In Africa, the vaccination protocol has been adapted accordingly. Finally, the modelling of irrigation canals for water management and conservation has demonstrated the need to take into account the presence of swelling clays in the subsoil of the new town of Diamniadio. These studies have had



“RESEARCH NEEDS SUBSTANTIAL, LONG-TERM FUNDING”

a real influence on town planning: buildings are built on stilts or after major excavations that isolate them from the clay.

Secondly, as Rector of Gaston Berger University in Dakar, I saw that training in research helps to strengthen the teaching staff at universities. For example, when the Agricultural Sciences, Aquaculture and Food Technology Department was set up, a significant proportion of the teaching staff recruited had been trained in research, in particular by IRD.

Finally, when I was Minister for Higher Education, Research and Innovation, and the Sine Saloum Elhadj Ibrahima Niass University was set up in 2013 in a region known as the “granary of Senegal”, the curricula were not developed along traditional academic lines. They were designed using a skills-based approach, combining knowledge, expertise and interpersonal skills. This innovative approach was made possible thanks to the collaboration of our teachers and IRD researchers, who have first-hand experience in the field.

But there are still challenges to overcome. The first is the availability of heavy equipment to enable our researchers to carry out all their work on site. Research also needs competitive, but above all substantial, long-term funding. The final challenge is the ongoing recruitment of teacher-researchers in our universities.

Slim **Khalbous**

Rector of the Agence Universitaire de la Francophonie and University Professor of Management Sciences (Tunisia)

The countries of the Global South are facing many challenges - sustainable development, water, migratory flows, new societal dynamics, health, education, etc. - with which we are all familiar, but first and foremost is the issue of good governance. In our sector, this applies to educational, university and research structures. This essential prerequisite is in line with the vision shared by the Agence Universitaire de la Francophonie (AUF) and IRD. The development of knowledge and science in the countries of the Global South requires collaborative South/North construction within a formal framework, rather than a "transfer" from the Global North to Global South, without any real ownership, as was all too often the case a few years ago. This is why the AUF's strategy includes the notion of support for this restructuring, which is the basis for the success and effectiveness of future co-constructed projects, particularly in research and development. Today, there no longer needs to be a "giver" and a "receiver". There are partners who are both givers and receivers and who will co-construct research in a "win-win" joint development approach. This approach takes us out of the loop of development aid with no follow-up and no tangible impact on the ground. Working in partnership with the beneficiary

“THE DEVELOPMENT OF KNOWLEDGE REQUIRES COLLABORATIVE SOUTH/NORTH CONSTRUCTION”

country and its stakeholders enables politicians to take greater ownership of the projects. The more convinced and involved they are, the more administrative and political support they will give to the scientists whose work will inform their final decisions, which of course remain their responsibility. In other words, collaborative work brings policymakers and scientists closer together. As the COVID-19 pandemic illustrated, this approach is absolutely essential. The pandemic made politicians realise that they were really at a loss, and that they had no choice but to turn to scientists. The crisis sparked an awareness, which until then had been in its infancy, of the need for policymakers and scientists to work together on the best way to govern our education and university structures and to organise themselves to make the most of partnerships in an institutionalised way.

This is what the AUF calls “Francophone scientific diplomacy”, which has given rise to a manifesto - a methodological and thematic roadmap for partnerships - signed in 2022 by 42 governments in the French-speaking world. It should be emphasised that this manifesto is more than just a simple declaration. It has practical applications on the ground. Today, an increasing number of projects start with an expression of the country’s needs and a feasibility study of what already exists. This is followed by the networking of national and international partners and experts who are best placed to bring the projects to fruition.

Taivini **Teai**

Minister for Agriculture and Marine Resources, in charge of Food and Research (French Polynesia)

Tea **Frogier**

Research Delegate (French Polynesia)

Taivini Teai: "In my opinion, societal development should be based on three main pillars: health, education and research. Research - in the "hard" sciences, but also in the humanities and social sciences - provides an insight into the special characteristics of French Polynesia, which is characterised by a very high level of endemism, and allows us to look at its development beyond the "classic" European circuit."

Tea Frogier: "Since fundamental continental concepts do not apply to our tropical island ecosystem, it was first necessary to carry out extensive fundamental studies from the 1970s onwards by research operators such as IRD. Once this knowledge had been acquired, major applied research programmes were gradually launched. Now, a new era is beginning. Our constituents - with whom we are very close, since Polynesia has only 300,000 inhabitants - want to see the scientific results reflected in their day-to-day lives. This is why, while research is mainly public, we now need to encourage public/private partnerships to ensure that the results of this work contribute to the development of Polynesian society."

Taivini Teai: "I am convinced that collaboration between scientists and industry is a source of innovation. For example, during

“COLLABORATION BETWEEN SCIENCE AND INDUSTRY IS A SOURCE OF INNOVATION”

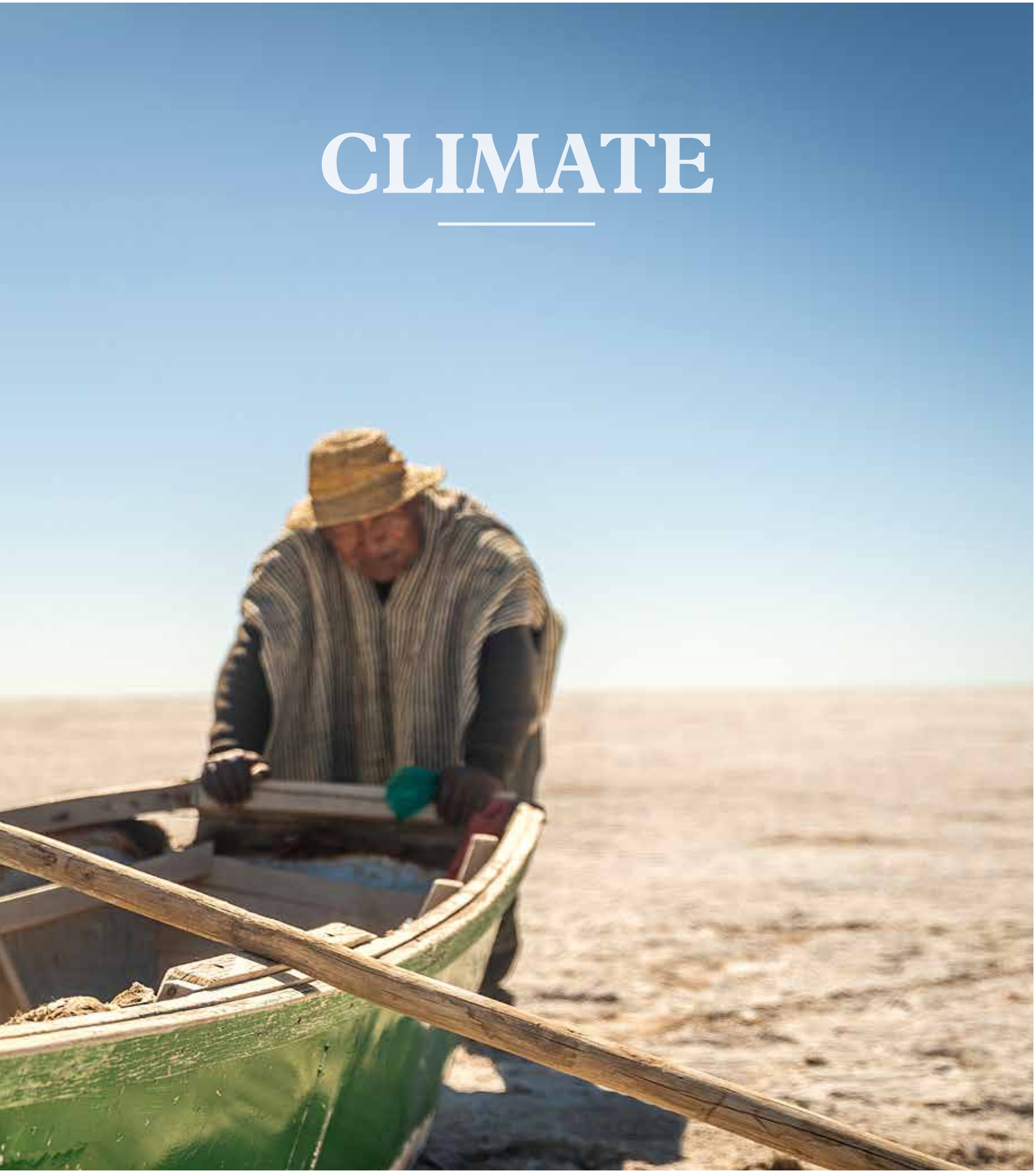
COVID-19, the synergies between all the world’s laboratories accelerated the development of tests and remedies. The pandemic confirmed that we can’t all work in isolation! What’s more, in the island territories, the interruption of travel prompted us to think even harder about the future and our autonomy through the optimisation of our resources.”

Tea Frogier: “In this respect, studies based on inventories and descriptions of our natural resources have shown that they have valuable biological properties, even though these assessments still need to be continued.”

Taivini Teai: “To achieve this, we need to bring together a critical mass of human and financial resources from a variety of backgrounds. Diversity contributes to competitiveness and emulation. The challenge for the government of French Polynesia today is to bring together business angels and research teams to recruit “brains” and set up projects, including those from other countries, but always in collaboration with us. The Pacific islands are small laboratories, not laboratory rats, with natural resources, as well as human, legal and commercial resources, that enable us to develop sustainable development strategies and solutions that can be transposed to the mainland in the future.”

Lake Poopó, Bolivia © G. Zilberman

CLIMATE



The vulnerability of environments and populations in the Global South is exacerbated by climate change. In fact, in tropical and Mediterranean regions, the many effects of climate change, amplified by certain human activities, are already being felt: disappearance of numerous tropical glaciers, devastating floods, prolonged droughts, reduced agricultural yields, deforestation, outbreaks of epidemics, etc. The scientific advances featured in this chapter highlight how research, using a multidisciplinary approach, is providing a better understanding of the complex processes at work and helping to develop strategies that reconcile climate change mitigation and adaptation, preserving the environment and protecting the most vulnerable populations.

From the sky to the earth. Protecting the environment against global change requires collaboration between disciplines to understand the complex changes in biodiversity, deforestation and the dynamics of agricultural landscapes. Data processing and interpretation are crucial to understanding this complexity. Observation by satellite is combined with data from sensors (laser beams, radar, etc.) to provide information on the ground and produce regional and continental maps. This means we can detect a palm tree in a forest, or the changes in the world's major forest areas!
Betsiboka River, Madagascar © Copernicus Sentinel Data 2019

Lake Chad under the microscope. Lake Chad is a precious freshwater oasis in the heart of the Sahel, supporting more than 45 million people. For nearly fifty years, multidisciplinary research has provided long-term monitoring of the variations in its environment. These monitoring efforts indicate that while the lake lost 90% of its surface area in the 1970s and 1980s, it has not dried up for the last twenty years. These are important results for the future of this ecosystem, which is essential to the sustainable development of a region that has been severely weakened by climate change and armed conflict.
Lake Chad, Chad © Cnes/J.-F. Crétaux

Sustainable hydropower. Hydropower is a major part of renewable energies and is affected by climate change, particularly in West Africa, where it provides more than 50% of energy. Transdisciplinary research has made it possible to better assess the reduction in energy production by West African dams as a result of global warming combined with other anthropogenic factors, including land use, increased demand for water and expansion of developed areas. This knowledge will help to improve the management of this low greenhouse gas-emitting energy source.
Pouytenga, Burkina Faso © IRD/P. Cecchi

What will the climate of the future be like? Some lakes preserve the memory of past environments. The analysis of pollen, crustaceans and microorganisms trapped over time in lake sediments in Brazil, Peru and Bolivia, as well as the concentration of oxygen 18 in the water (a very useful indicator in palaeoclimatology), has made it possible to reconstruct variations in the South American climate over the last 40,000 years. Using this valuable data, researchers can test and calibrate simulations of future climate variations.
Fossilised pollen © IRD/A.-M. Sémah

Climate-related epidemics. Epidemics can be caused by a number of factors, including the density of pathogens and vectors, living conditions and population flows. Research has shown that in many of the Pacific islands, rainy spells favour leptospirosis epidemics, while in New Caledonia variations in temperature and rainfall are responsible for dengue outbreaks. These discoveries are improving the prevention and management of these diseases.
Nouméa, New Caledonia

Uneven melting. A unique survey, based on 50,000 satellite images, coupled with field measurements, has revealed the changes in the thickness and mass of glaciers in Asia since the year 2000. These glaciers, which are shrinking at half the rate of the global average, are not all responding in the same way to global warming: some are increasing in mass, which is not observed anywhere else in the world, while others are melting at a rate equivalent to that of the Alpine glaciers. These results will help to improve models for measuring the impact of melting glaciers on sea levels.
Mera Glacier, Himalayas, Nepal © IRD/CNRS/T. Vergoz, Preshine 2017

Observatories. For nearly thirty years, environmental observation systems have been set up in South America, sub-Saharan Africa, the Maghreb and the tropical Atlantic in response to global changes, which are particularly acute in intertropical and Mediterranean areas. Following the example of the Hybam observatory, which has been monitoring the Amazon basin since 2003, these systems provide detailed documentation of hydroclimatic changes in these regions, offering essential data to decision-makers faced with the challenges of environmental disruption.
Amazon River, Brazil © IRD/J.-M. Martinez

Vulnerable waters. In El Alto, Bolivia's second most populous city, the availability of water is threatened by climate change, conflicts of use and the pollution generated by this use. Taking a multidisciplinary approach and comparing a wide range of data (on human activities, the geolocation of pollution sources and the mobility of contaminants in the water table, and water governance methods), researchers are assessing the vulnerability of the water supply and proposing strategies for the sustainable management of water in urban areas.
Milluni Lagoon, Bolivia © IRD/J. Gardon

Successful small dams. For several decades now, small dams have been springing up across the Mediterranean. Scientists have demonstrated their benefits: they provide a range of valuable services to rural populations; they extend the service life of larger structures downstream (by trapping sediments); and they protect aquatic and terrestrial biodiversity by creating wetlands. In Tunisia, a major regional development plan has included research into these structures, highlighting their fundamental role in the sustainable development of arid areas.
Yagour Plateau, Morocco

A new era. Global warming combined with profound changes in land use are having a major impact on the water cycle in the Sahel. The region was affected by drought at the end of the 20th century, and over the last ten years has been faced with extreme rainfall and devastating floods. Adaptation measures are being guided by research into this new hydroclimatic era, including small dams in rural areas to facilitate water infiltration, revised urban drainage schemes, and new hydrological standards to improve the sizing of infrastructure.
Mélé Basin, Niger © IRD/M. M. Abdou

Water warning! Rain dampens the signals from mobile phone base stations. In Burkina Faso, this problem has been turned into an opportunity. By combining the analysis of these signals with hydrological models, researchers have created an application capable of detecting more than 90% of rainfall events, thereby mapping the risk of flooding. This innovation, which has been tested in several countries on the African continent, gives a more complete coverage of the country at a lower cost than that provided by weather radar stations.
Burkina Faso © IRD/R. Fauck

Marie Christina **Kolo**

Initiator of the Indian Ocean Climate Network, founder of Green N Kool and the digital platform Ecofeminism (Madagascar)

I started working around ten years ago in the Androy region, in the very south of Madagascar, as a volunteer for the United Nations. This part of my country, which regularly suffers severe droughts, is an emblematic example of what a certain approach to research can contribute to the sustainable development of a region. The Centre Universitaire Régional d'Androy (Cura) has been based here since 2013. This public university had no facilities: no electricity, no water, no computers, no Internet, and no laboratories in which to conduct scientific experiments. Despite these conditions, it admitted almost 400 students in a region desperately in need of developing local skills. No organisation was working with this public university and its teams. With the NGO I had just founded, Green N Kool, I became their spokesperson. We helped them to build a wind turbine, provided electricity, computers, etc. We also launched together the first research centre on gender and climate justice. It is important to understand that in Madagascar, even the biggest universities have few resources. The situation is even worse for regional university centres like the one in Androy. As a result, they need to forge partnerships with local NGOs,

“RESEARCH MUST TAKE AN ACTIVE APPROACH”

in line with the grassroots approach, where people from local communities become the driving force behind projects. At CURA, research must take an active approach: when it came to equipping the university with a wind turbine, local students worked with the researchers. Similarly, when we had to develop a desalination system for local communities, traditional knowledge and low tech were used. I believe that the world of research does not pay enough attention to these cross-sector collaborations, which can bring about pragmatic solutions corresponding to regional needs and contexts. For example, the exhibition produced as part of the Varuna project on biodiversity in the Androy region was a fantastic opportunity to change the narrative about this area, which is mainly known for the vulnerability of its inhabitants. The exhibition panels describe different ecosystems and were presented in a number of Madagascan towns to schoolchildren and the general public. However, French researchers were called in to talk about biodiversity in France, which is very different from Madagascar. And in the end, less than half of the panels mention Madagascar’s endemic biodiversity, even though it is so rich and varied. Malagasy children are more interested in learning about their own country than discovering ecosystems that they can’t relate to. This initiative could have drawn more on local expertise and, as with research, lacked cross-sector collaboration.

Eddy **Ngonkeu**

Researcher at the Institute of Agricultural Research for Development and technical advisor to the Ministry of Scientific Research and Innovation (Cameroon)

Sustainable development in Africa relies on scientific and technological progress. Yet research in Africa is still in its infancy, with very few applications having a major impact on the local population. In Cameroon, however, we have some outstanding researchers, thanks in particular to the cutting-edge training provided in the countries of the Global North, including France. But when they come back here, they are not always able to implement their research for the benefit of local populations. To progress from fundamental research that generates intangible goods to applications that produce tangible goods, researchers need three major elements. Technical platforms are essential. At the moment, I often have to go back to Europe to carry out certain molecular analyses on the plants I study here. Cameroonian researchers need to be more pragmatic; they need to do a better job of identifying problems through participatory diagnosis in the field, so that they can come up with practical solutions. They need to

> **“WE NEED TO STOP TRYING TO GRAFT CASSAVA ON A COMPUTER!”**

be “strategic opportunist researchers” like me, who draw on all available resources to meet the United Nations’ Sustainable Development Goals (SDGs), the African Union’s Agenda 2063 and Cameroon’s National Development Strategy 2020-2030. Last but not least, Cameroonian researchers are sorely lacking in research funding. Nevertheless, things are changing, as illustrated by the Environmental Biogeosciences Research Centre (CBE) to be built in Yaoundé, by Cameroon’s Ministry of Scientific Research and Innovation (MINRESI) and IRD, which will provide technical facilities of international standard. Similarly, since 2022, Dr Madeleine Tchuinte, Minister for MINRESI, has promoted the slogan “one researcher, one company” and set a roadmap for research. This roadmap aims to produce patents to boost the industrial fabric, thereby promoting “made in Cameroon” to ensure our sovereignty. To this end, the ministry supports public/private partnerships, for example with the support of France, enabling 100 Cameroonian start-ups to be financed. For research to have a real impact on people, the prototypes developed need to be brought out into the open. In other words, we need to stop trying to graft cassava onto a computer!

Hana **Gannoun**

Assistant Professor of Biochemical Engineering, specialising in "Environmental Bioprocesses and Bioenergies", at the Tunis El Manar University, Higher Institute of Applied Biological Sciences of Tunis (Tunisia)

Training young researchers is essential to developing high-quality, sustainable research. IRD has been able to respond to this need thanks, in particular, to the "Young Teams Associated with IRD" (JEAI) programme, which I was part of between 2017 and 2020. This scheme encourages young researchers to work in teams at the start of their careers. Personally, this involvement helped me to gradually establish productive collaborations focusing on issues of sustainable development, waste and energy - a sensitive subject in my country, where the vast majority of organic food waste is sent to landfill without being recycled, resulting in saturated landfill sites nationwide. From what started out as a small group of two Tunisian and two French researchers, we have grown into an international joint laboratory, LMI Biotech'H2, which I co-direct with Pierpol Liebgott from IRD. Today we are a team of over 40 researchers of different nationalities with varied and complementary skills, and we continue to expand as needs arise.

“TRAINING YOUNG RESEARCHERS IS ESSENTIAL”

From a technical point of view, the growth of this team has also been accompanied by the installation of a fermenter that enables us to carry out experiments on site, in particular to carry out dark fermentations at high temperature, one of the promising solutions for treating organic waste and producing biomethane and biohydrogen. Like everywhere else, our research comes up against a number of obstacles: time - because R&D requires a lot of it - and the publication of articles, which are not always compatible with the evaluation of our work; funding too, because our research will have to go through various stages of technological maturation before it can be applied in society. Although my career to date has been focused on international collaboration, I am also faced with administrative “obstacles”, as are other researchers. For missions or placements in France, the procedures for obtaining visas for permanent lecturers and young researchers on fixed-term contracts are still unclear, as are those for the reimbursement of expenses, for example. This is a real obstacle to our training: without these opportunities, we lose contact with our colleagues and our networks fall apart. This can be quite discouraging for young researchers. We are working to find sustainable solutions that are fair to all partners.

Matam, Senegal © IRD/I. Makosi

ONE HEALTH

Infectious diseases such as malaria, AIDS and Zika kill 14 million people every year, most of them in the countries of the Global South, where the "diseases of civilisation" such as diabetes and cancer are also gaining ground. There are many factors behind the emergence or spread of these diseases, including pollution, climate change, biodiversity loss, poverty, inadequate healthcare structures, lifestyles, demographics and level of education. What can be done to fight and prevent health crises? As this chapter shows, scientists favour an integrated approach that takes into account not only biomedical aspects, but also the environmental, socio-economic and cultural contexts in which health issues arise.

Maternal deaths are not inevitable. In Africa, the vast majority of deaths in childbirth are due to the high cost and poor organisation of care, compounded by difficulties of access to health centres in rural areas. In Mali and Senegal, researchers carried out "death reviews" in 46 hospitals in order to identify the source of the problems through dialogue with healthcare workers and to test solutions (access to certain medicines, reduced workload, etc.). The spectacular results (a 15% reduction in mortality on average, and 35% in rural hospitals) encouraged the WHO to extend the approach to most African countries.
Matam, Senegal © IRD/I. Makosi, MOPGA project

Tuberculosis in children: promising results. Tuberculosis is underdiagnosed in children, largely because there is no rapid, effective diagnostic test. Fortunately, research has led to the development of a molecular test using samples that are easy to obtain (stools, nasal swabs). The fight against the disease has also succeeded in making screening practices more accessible to families, detecting the disease in children affected by HIV or severely malnourished, and providing preventive treatment for children living in contact with adults with tuberculosis.
Phnom Penh, Cambodia © Alamy/M. Goldwater

Prevention and rapid diagnosis. After seven decades of wide-ranging research with very significant results (vector control, integrated mosquito nets, treatment of the disease, etc.), progress in the fight against malaria has stalled. But new strategies are emerging, combining preventive treatments and rapid diagnostic tests, which are considerable advances that enable health workers to identify cases of malaria quickly and prescribe the right treatment at an early stage. This technique has been tested in South-East Asia, and can now be used to eliminate almost all cases in certain regions of West Africa.
Comé, Benin © IRD/J. Montmarche

Growing obesity. Obesity and associated chronic diseases are on the rise in Africa. Research in North Africa has shown that more than a third of women in the region are overweight, while the proportion for men is half that. The research was conducted for prevention purposes in Tunisia, and in practice has led to the implementation of pilot measures paving the way for the launch of a national strategy to combat obesity.
Top: **Tunis, Tunisia** © IRD/P. Traissac
Bottom: **Casablanca, Morocco** © IRD/Agence H. Lucas/M. Bertrand


B-8038
Olina
تزهي الكوجينة
Affpub
Olina
15-353371


NOUVEAU
Melts
À 63 DH
OFFRE TRÈS LIMITÉE

Rapid action against zoonoses. Epidemic outbreaks resulting from cohabitation between wildlife and humans call for rapid health responses. Scientists are often on the front line in launching responses in the field. This was the case in response to the Ebola epidemic in Guinea, and more recently in the Democratic Republic of Congo to prevent the spread of an epidemic of the Marburg virus. In record time, scientists were able to identify the reservoirs of the virus, its circulation and high-risk human behaviour. The use of cutting-edge equipment and the mobilisation of health authorities and trained personnel are essential in responding to the urgency of such situations.

Nzérékoré, Guinea © AFP/C. Valade

COVID-19 under surveillance. The COVID-19 epidemic highlighted major global disparities, both in terms of epidemiology and virological surveillance. By the end of 2021, out of 4,600,000 SARS-COV-2 genomic sequencings, only 49,000 came from Africa, representing less than 1% of cases diagnosed on that continent. Since then, this figure has more than doubled. This remarkable success can be attributed to Afroscreen, a programme that has enabled an increase in the number of African countries capable of sequencing locally, with a faster turnaround time and more regular routine surveillance.
Montpellier, France © IRD/A. Tendero

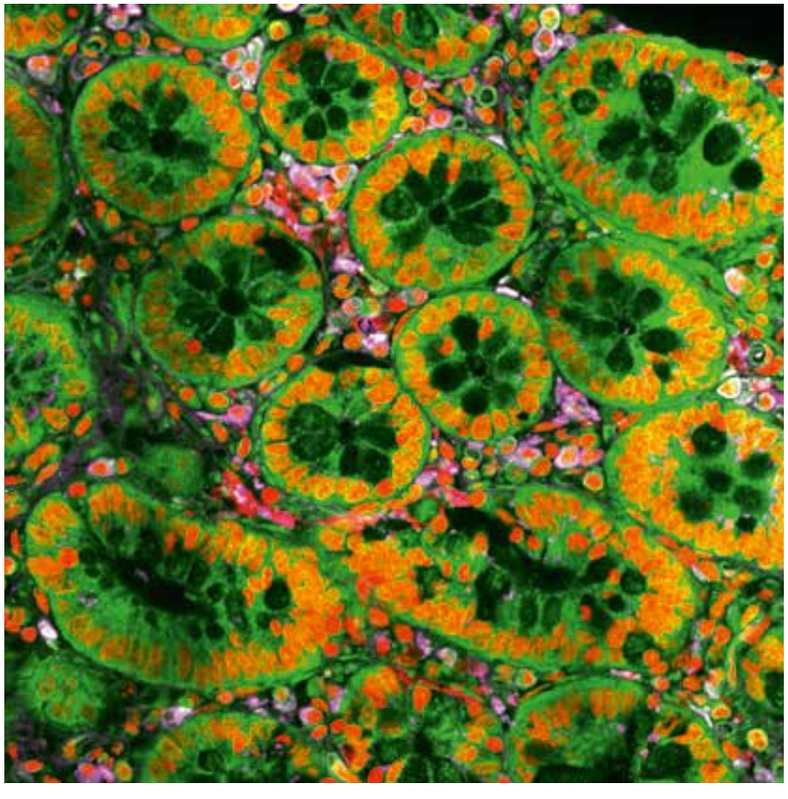
Life-saving triple therapies. Since 1996, thanks to triple therapies, AIDS has gone from being a fatal disease to a chronic pathology. In the Global North, at least. A few years later, studies in Senegal and then Cameroon demonstrated the effectiveness of this treatment in Africa, with generic triple therapies making a major contribution to the development of health policies. Since then, key studies have helped to improve these initial treatments, in particular by approving lighter treatments and the use of a new class of drugs, integrase inhibitors, which are now recommended by the WHO.

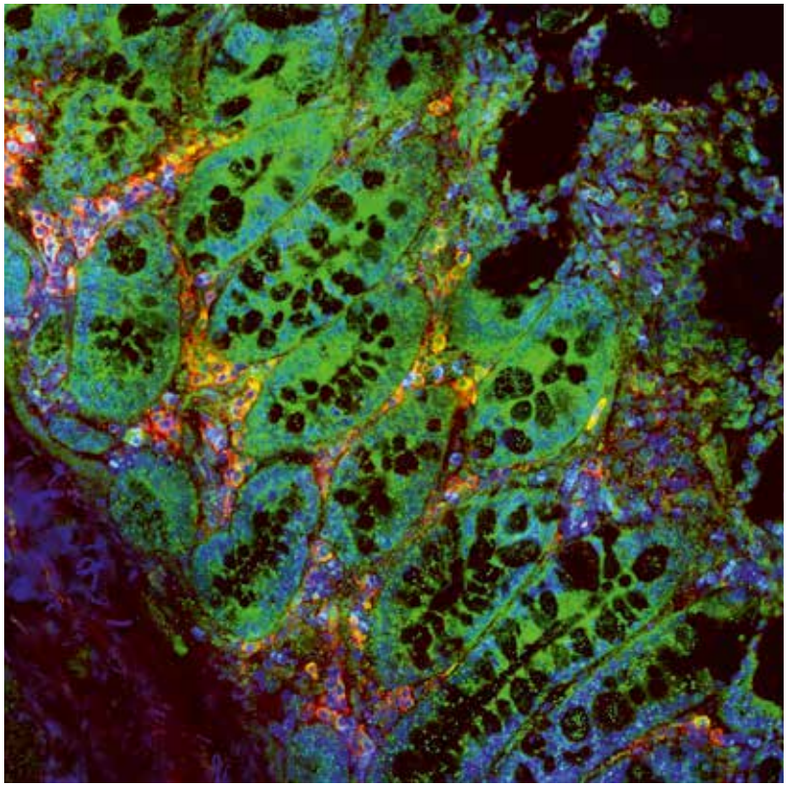
Dakar, Senegal © IRD/F. Hejoaka

The origin of AIDS. In 1987, researchers identified a virus in a chimpanzee in captivity in Gabon that was very close to the HIV-1 virus responsible for the global pandemic. To confirm this discovery in wild populations that were protected from capture, researchers analysed thousands of chimpanzee and gorilla faeces samples collected in the forests of Central Africa. This innovative method made it possible to identify the origin of the AIDS virus in the great apes of Cameroon.

Intestinal tissue from infected monkeys

© Institut Pasteur/N. Huot

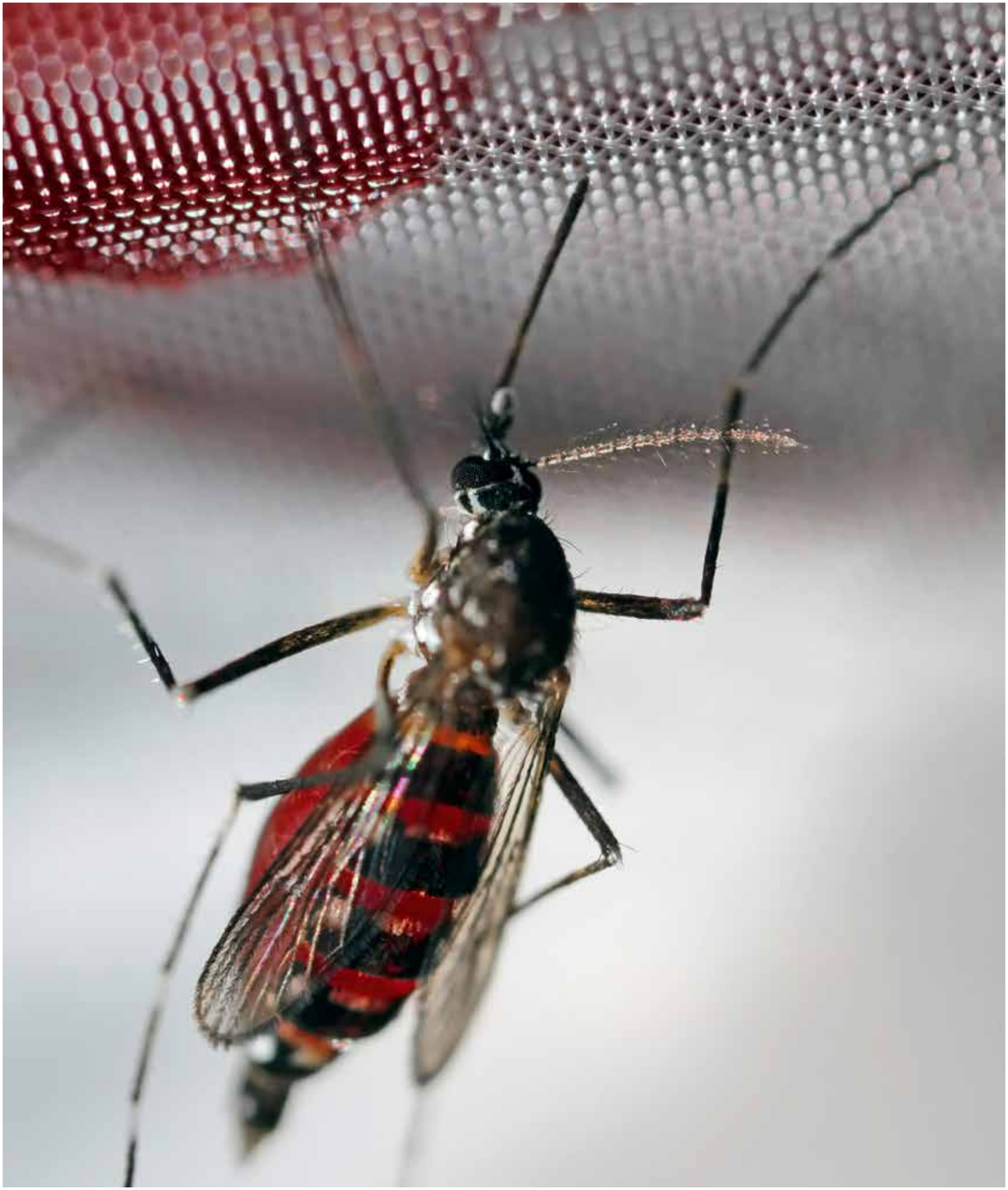




Sterilising carriers. Researchers are exploring insecticide-free control methods to combat the spread of diseases transmitted by tiger mosquitoes, such as dengue fever and chikungunya. The sterile insect technique (SIT) involves producing sterile male mosquitoes to prevent females from reproducing. To achieve this, tests were carried out in Réunion involving the mass hatching, sexing, sterilisation and release of mosquitoes in specialised units. The highly promising results show a reduction in fertility of up to 60%.
Left: **Insectarium, Réunion** © IRD/T. Vergoz
Right: ***Aedes albopictus*** © IRD/N. Rahola

A mysterious virus. Zika spread around the world in 2015, resulting in millions of infections and causing birth defects and neurological disorders in some newborns. Although little was known about this virus at the time, research has since progressed, in particular with the identification of the receptors that enable the virus to infect cells, paving the way for therapeutic approaches. Progress has also recently been made in our understanding of how the virus is transmitted by the *Aedes aegypti* mosquito.

Aedes aegypti © IRD/P. Landmann



Welcome biodiversity. Since the 1950s, the frequency of diseases being transmitted from animals to humans (zoonoses) has almost doubled. Why is this? Among the hypotheses being studied, biodiversity loss is thought to encourage the emergence and spread of these diseases. Research into Lyme disease, hantaviruses and West Nile virus has shown that areas with the greatest biodiversity have much lower levels of pathogen circulation. Preserving biodiversity offers an effective defence against the appearance of these diseases.
Left: **Saint-Gilles, Réunion** © IRD/T. Vergoz
Right: **Sainte-Marie, Réunion** © IRD/T. Vergoz

Protecting pregnant women from malaria. While malaria during pregnancy is dangerous for women, it also causes low birth weight in infants and can weaken their immune systems. Thanks to major advances in the understanding of immune mechanisms in infected pregnant women, researchers have conducted promising vaccine trials to protect them. Once developed, a vaccine could prevent 50 million cases of gestational malaria each year and save many babies' lives.
Gyabankrom, Ghana

Joseph **Kamgno**

Director General of the Higher Institute for Scientific and Medical Research and Head of the Public Health Department at the Faculty of Medicine and Biomedical Sciences, University of Yaoundé I (Cameroon)

The research carried out in Cameroon on onchocerciasis, a disease that can lead to blindness, and lymphatic filariasis, also known as elephantiasis, illustrates the value of research in Africa. In 1994, a major clinical trial led by Michel Boussinesq, an IRD parasitologist whose team I had joined at the Pasteur Centre in Cameroon, demonstrated the efficacy of repeated doses of ivermectin on onchocerciasis filarial worms. In 1996, we identified that the serious side-effects experienced by some patients were due to a strong infection by another filarial worm causing loiasis. We also mapped onchocerciasis in western Cameroon. In 2005, after completing my thesis at the University of Paris VI and with the support of the Mectizan Donation Program, I founded the Centre for Research on Filariasis. The centre focused on monitoring and training in the management of the side-effects of mass treatment of onchocerciasis in areas where the disease is co-endemic with loiasis. In terms of prevention, we developed the "LoaScope" with a number of partners, including IRD, which provides a quantitative diagnosis of lioasis in just three minutes. We also developed the Test and not Treat (TaNT) strategy to treat communities without the risk of side effects. These studies have helped public authorities and the World Health Organization (WHO) to identify and fine-tune strategies to combat onchocerciasis, meaning that we can now look to eliminate this disease with confidence.

Between 2009 and 2010, my team at the centre - now the Centre for Research on Filariasis and Other Tropical Diseases (CRFilMT) - mapped lymphatic filariasis throughout

“DEVELOP DIAGNOSTIC TOOLS FOR TROPICAL DISEASES”

Cameroon. Treatment campaigns combining ivermectin and albendazole were then launched. Cameroon is now applying for certification of having eliminated this disease! Since 2023, the centre has been known as the Higher Institute for Scientific and Medical Research, reflecting the diversification of its research fields. A centre for phase I clinical trials is being set up here, which will enable treatments for endemic African diseases to be evaluated here too. From the earliest stages, drug development must take account of the context, particularly dietary factors, which can influence pharmacokinetics. It will also contribute to the development of the traditional pharmacopoeia, some of whose substances are proving effective in the field. The idea is to include them in the traditional drug development process so that they can benefit as many people as possible throughout the world.

The Institute also wants to develop diagnostic tools for tropical diseases which, because of the lack of a sufficient market, do not benefit from global research. Finally, our P2 laboratory will contribute to the inventory of viruses and bacteria present in animals and likely to be transmitted to humans, with a view to preventing new pandemics. The Institute therefore offers a workspace and a vision that will enable future generations to be trained and to fight disease.

More broadly, if we want to see Africa develop, I am convinced that we need to invest in research to find and exploit its endogenous resources to develop medicine, but also agriculture and animal husbandry, and import as few medicines and food products as possible. By cooperating with its partners on a mutually beneficial basis, Africa will be able to make its contribution to creating a better world.

Mame **Sidy Ndour**

Chief of the village of Dielmo (Senegal)

Mamadou **Sarr**

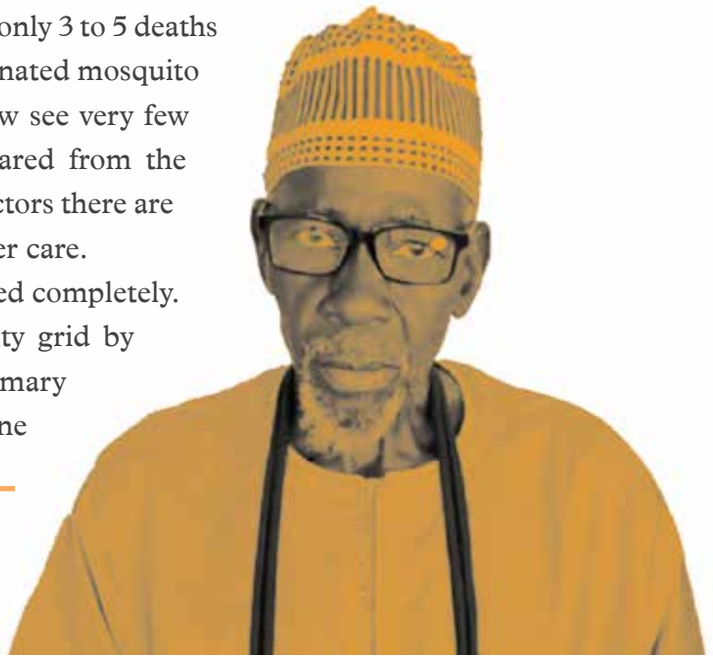
Chief of the village of Ndiop (Senegal)

Interviewed and translated from Wolof
by Cheikh Sokhna, Director of Research at IRD

Before the malaria research programme launched in 1990, children of Dielmo very often died before the age of two and the inhabitants of the neighbouring villages would avoid us. The scientists from IRD and Institut Pasteur who were carrying out the research found that it was malaria that was killing our children because of the mosquitoes attracted by the river just a few metres from the village. At the time, we didn't know that mosquitoes transmitted malaria and that their presence was due to the water in the river, which was used for growing vegetables.

There used to be hundreds of malaria cases every year among children and pregnant women. Over the last 30 years, since the people of the village, including the children, were treated, there have been only 3 to 5 deaths from malaria. Thanks to effective medicines, impregnated mosquito nets and the continued presence of doctors, we now see very few mosquitoes and, since 2018, malaria has disappeared from the village. The same goes for Ndiop. As a result, the doctors there are now monitoring other diseases to provide even better care.

The outlook for Ndiop and Dielmo has since changed completely. Both villages have been connected to the electricity grid by the programme, which also helped us to set up a primary school for our children's education. Some have gone

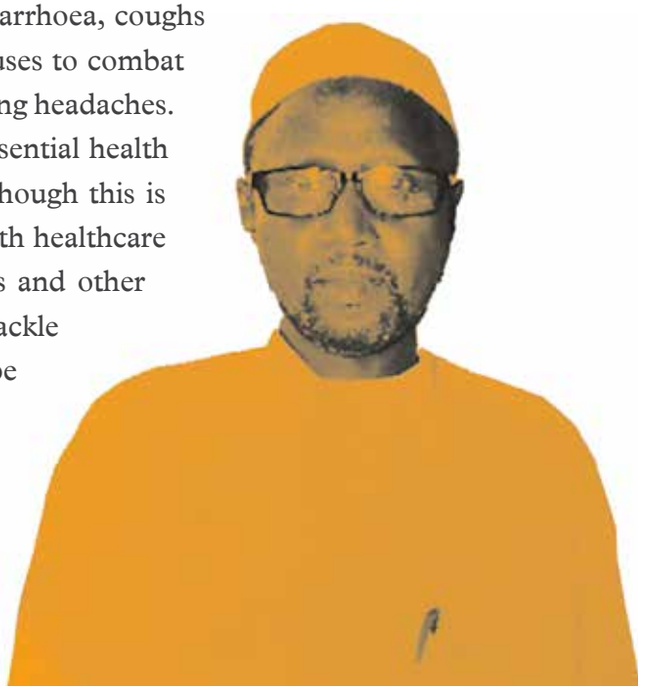


“INVOLVING COMMUNITIES GIVES RESEARCH GREATER IMPACT”

on to become teachers or nurses, whereas before no one could read or write in French in our villages.

When research produces very positive results, it’s important not only to inform the government, but also to share this information with us, as we don’t always have access to it. If communities are informed of the scientific results and are involved, the research has a greater impact. This was the case when, without waiting for directives from the Ministry of Health, children were encouraged to take a bath before going to school and to wash their hands regularly. Doctors and parents alike have found that this had greatly reduced childhood illnesses such as diarrhoea, coughs and fevers. The same is true of cementing floors in houses to combat borreliosis, a disease that, like malaria, causes excruciating headaches.

In the future, research must provide better access to essential health services, as was the case in Dielmo and Ndiop, even though this is difficult to achieve across the board. We have to deal with healthcare costs that are too high for our families, and medicines and other medical techniques are often out of reach. Finally, to tackle the shortage of health professionals, research must be combined with comprehensive health training for our young people, who will be able to take over from them.

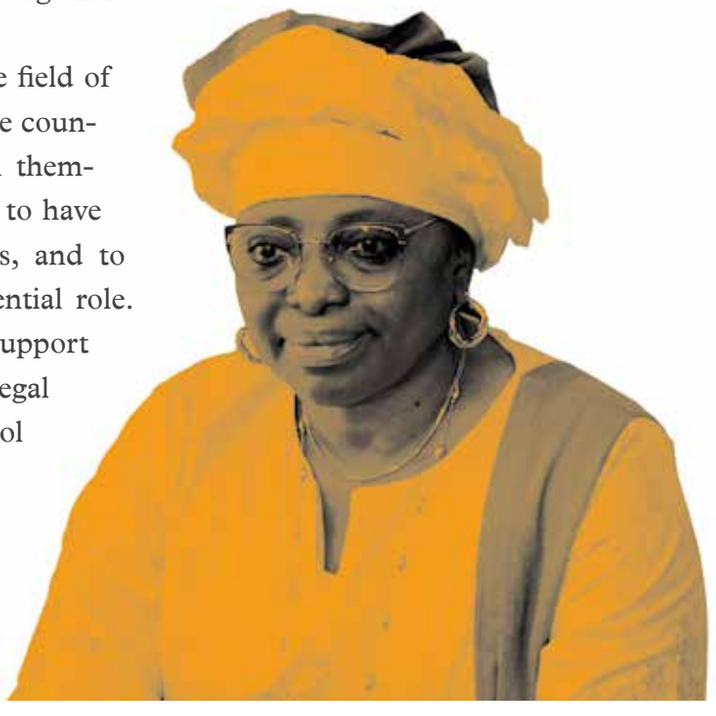


Coumba **Touré Kane**

Professor and Rector of the Sine Saloum El-Hâdj Ibrahima Niass University (Senegal)

Science is at the cutting edge in both the Global South and Global North, particularly in the current context where geopolitical changes are imposing new directions. The COVID-19 pandemic, for example, raised awareness of the impact of global changes on the emergence or re-emergence of diseases, with dramatic health, economic and social consequences.

But even before this pandemic, antibiotic resistance and the AIDS epidemic demonstrated the need for a holistic "One Health" approach. The countries of the Global South are well aware that they need to work together to develop measures to combat these different threats.



Science is also making great strides, particularly in the field of medicine, and there is increasing talk of "e-health". The countries of the Global South therefore need to position themselves, in partnership with those of the Global North, to have the equipment to detect, monitor and treat diseases, and to benefit from technology transfer, which plays an essential role. For example, as a result of my thesis at IRD and the support of the French National Agency for AIDS Research, Senegal has been at the forefront of the treatment and control of HIV infection and the establishment of a research

> **“SCIENTIFIC RESULTS MUST BE TRANSFORMED INTO POLICIES”**

ecosystem that began in 1998 with the setting up of the first molecular biology laboratory in a public hospital.

As well as training a large number of African researchers with expertise in HIV, this ecosystem has contributed to the creation of networks across the continent to monitor AIDS, tuberculosis, malaria and, more recently, neglected and emerging tropical diseases, including COVID-19. This networking gives us a global view of the risks and problems associated with health safety.

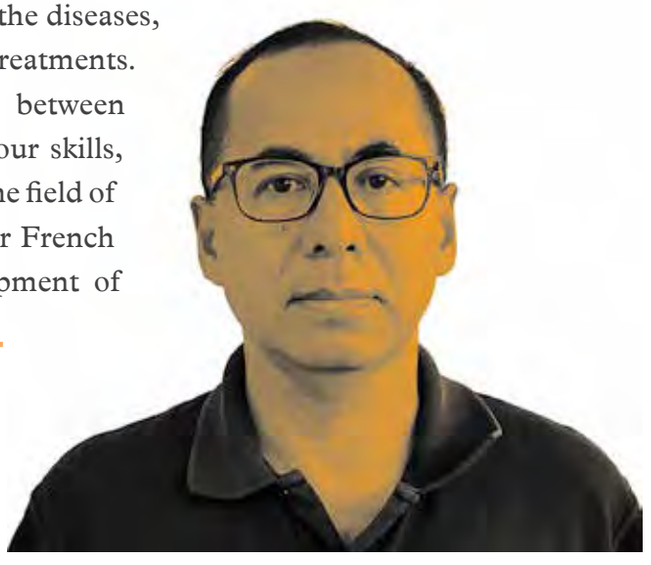
However, if we are to establish a genuine research policy, we need to bolster existing political will and funding, because too much African research depends on external funding. Senegal, for example, has validated its 2023-2032 research plan. The Ministry for Higher Education, Research and Innovation is now looking at how it can develop operational research hubs. This approach must be collegial and holistic. The scientific results must be transformed into policies and disseminated so that communities understand what has been researched and discovered, how it will be used and what impact it will have on them.

Finally, in a One Health approach that also addresses climate change, we need to develop collaborative research platforms so that we can also work holistically with animal, human health and environmental stakeholders, not forgetting communities, because successful monitoring needs to be implemented at community level.

Theeraphap **Chareonviriyaphap**

Professor in the Entomology Department,
Faculty of Agriculture, Kasetsart University (Thailand)

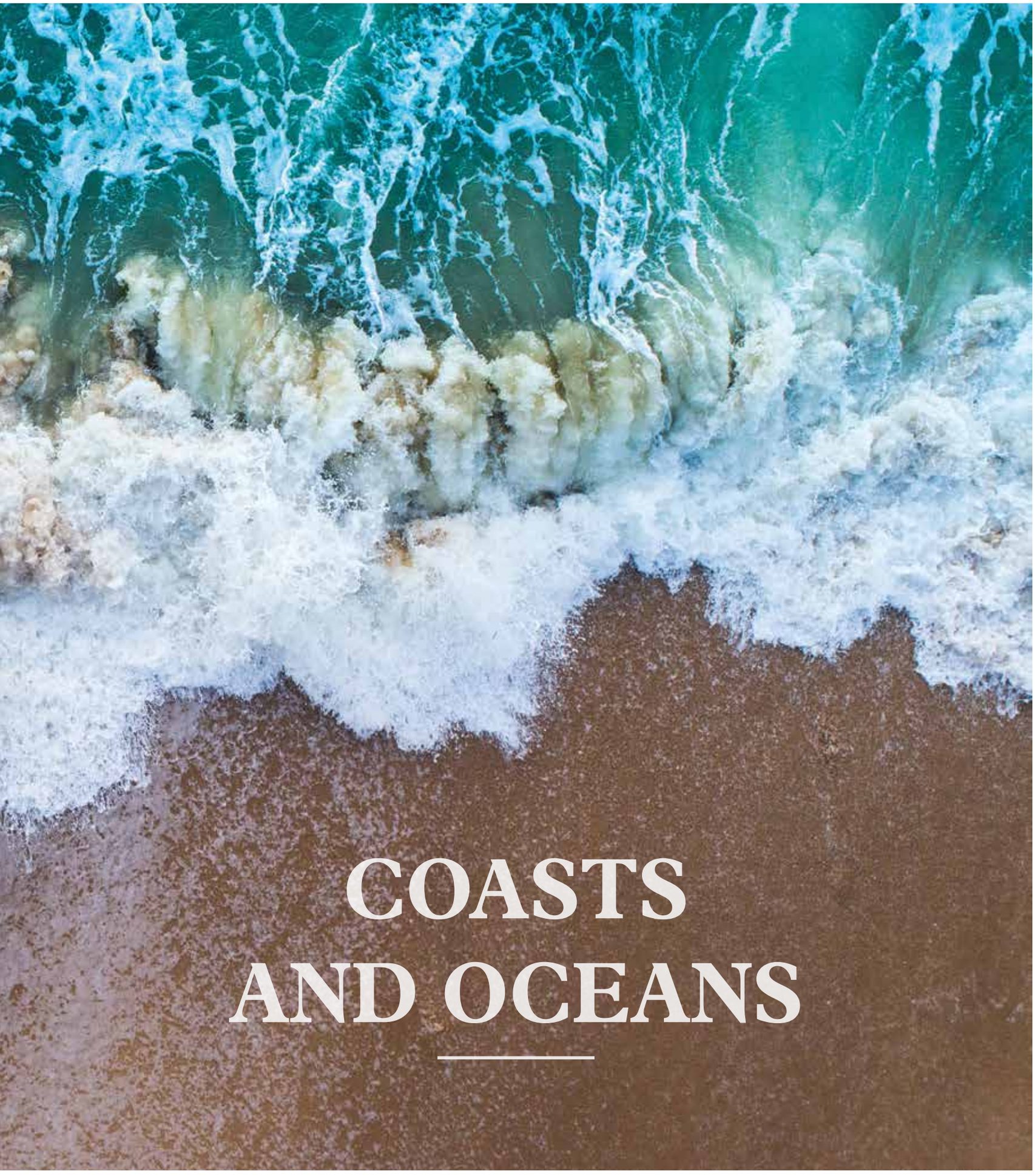
In twenty years of working with Professor Sylvie Manguin from IRD, we have acquired complementary skills and knowledge through research, which has had a major impact on certain areas of sustainable development in my country. Our collaborative work has involved collecting mosquitoes in the field, with a view to later identifying in the laboratory the vector species and pathogens they carry, and mapping the hotspots where these vectors are present, where they can transmit the parasites or viruses responsible for the diseases, and where they acquire resistance to insecticide treatments. Through exchanges of researchers and students between Thailand and France, we have been able to share our skills, transfer technology and enhance our capabilities in the field of medical and molecular entomology. Specifically, our French colleagues enabled us to benefit from the development of



> **“WE HAVE PAVED THE WAY FOR FUTURE GENERATIONS OF RESEARCHERS”**

molecular technologies in France and, later, helped us to set up a new laboratory here in Bangkok, where we use a number of biochemical and molecular techniques to identify mosquito species and pathogens. Being able to do this work here, so close to the field, is key. It is crucial to be able to identify the right species in order to control diseases, because this tells us where the vectors are concentrated and what their dynamics are on our territory. Of course, international collaboration is never easy: we have had to learn about our cultural differences, which can sometimes be an obstacle. I myself have become aware of the heavy administrative workload required by French research! After decades of partnership, we can say that not only have we forged a successful collaboration, but we have also paved the way for the next generation of young researchers who will travel between our two countries, continuing our projects and developing new ones in the service of science and sustainable development.

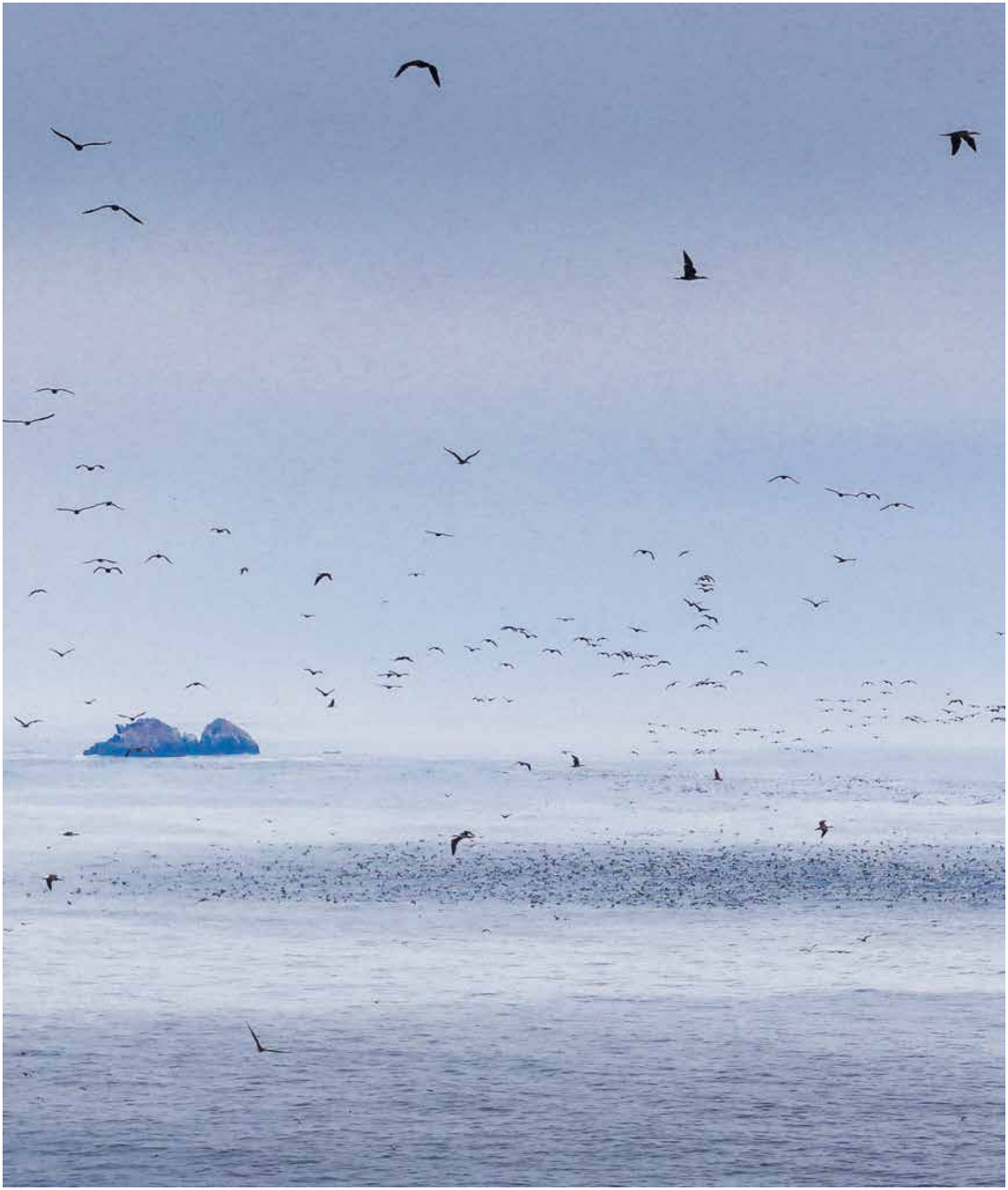
Bình Thuận, Vietnam © T. Tuan Viet



COASTS AND OCEANS

The oceans and their coastlines are essential to the sustainable development of humanity. Ocean waters, which cover two-thirds of the globe, are our main climate regulator and a reservoir of biodiversity that guarantees food security and human well-being. Faced with the combined pressures of climate change, overfishing of marine resources and urban development in coastal regions, scientists are working on several fronts, from the high seas to estuaries. They are working to decipher the complex interactions between the ocean and the climate, to understand how these socio-ecosystems function and to assess their resilience. This knowledge, as we discover here, can be used to develop strategies for more sustainable and equitable management of the ocean and its coastlines.

Fertile waters. In many coastal regions, particularly in Peru, South Africa and the Gulf of Guinea, there are upwellings of cold, fertile water, which are essential for fishing. Scientists are studying the highly variable nature of these upwellings. Simulation models, developed jointly with researchers in the Global South, now enable the international scientific community to better understand and monitor the dynamics of these phenomena, which are vital to the economies of coastal countries.
Pacific Ocean, Peru © IRD/Y. Tremblay



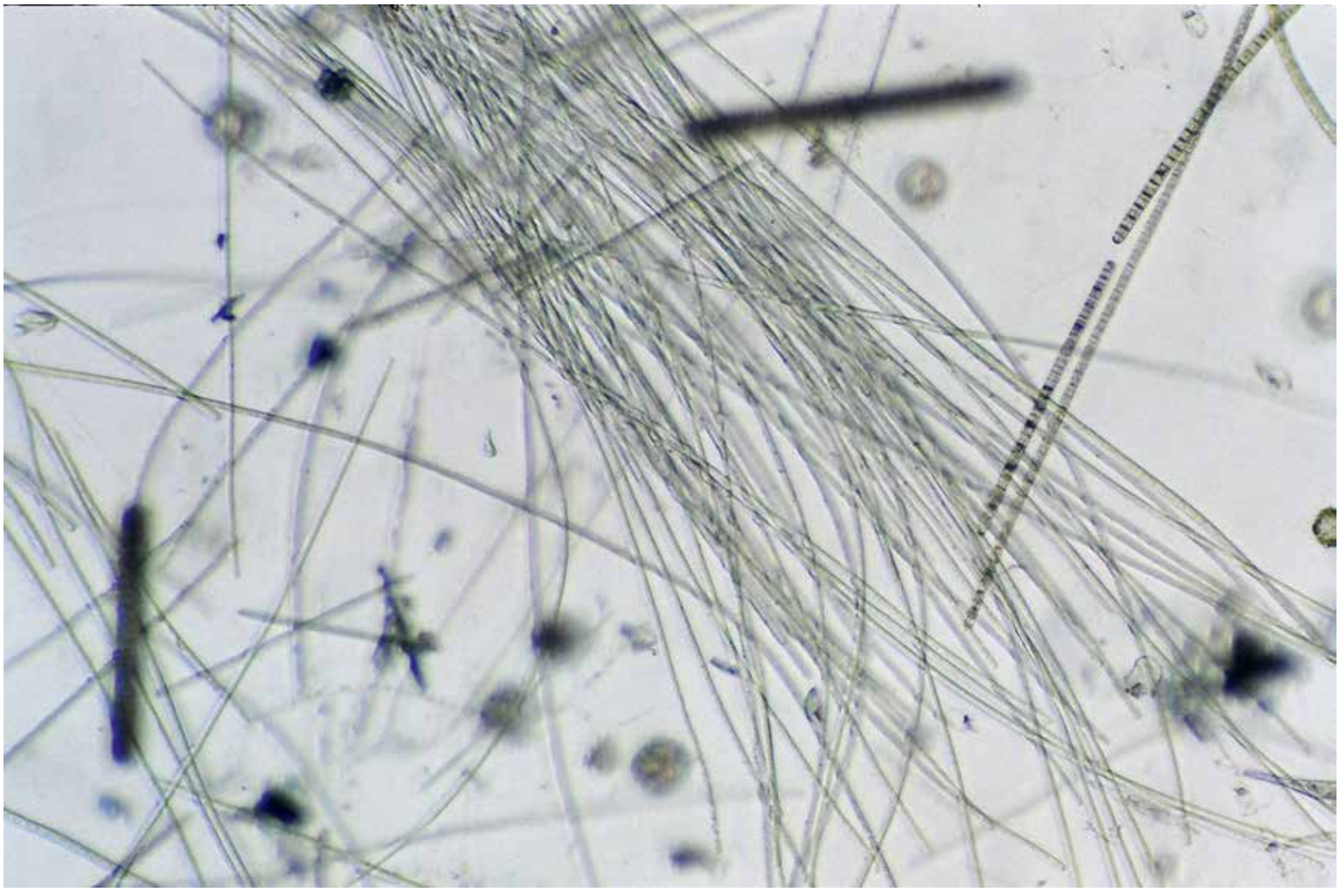
Beneficial protected areas. For the first time, researchers have shown that marine protected areas in Madagascar protect not only fish, but also mature coral reefs. The benefits are more pronounced the older the marine protected area, the smaller its size and the higher its level of protection. However, the result is much less conclusive for juvenile coral reefs. Conservation measures need to be strengthened and adapted for these future generations.
Crinoid © IRD/P. Laboute

Reciprocity. Coral islands are home to unique biodiversity, including some of the world's largest colonies of tropical seabirds. In the Pacific and Indian Oceans, these birds have been shown to play a key role in keeping coral reefs healthy. These benefits are reciprocal, with the guano enriching the islands in nutrients and the birds using the reefs to breed. But little is known about these seabirds, which confirms the importance of international research networks dedicated to studying these species and environments.
Coral microfragment © IRD/N. Job, mission Cacao

Left:
Overfishing *vs.* the survival of seabirds. Is overfishing disrupting the reproductive success of seabirds? Data on 14 bird species and 483 years of cumulative observations have given us a precise answer to this question: when the abundance of forage species (sardines, anchovies, etc.) falls below the threshold of a third of the maximum stock observed over the long term, the reproduction of coastal birds is compromised. This result has been decisive in integrating the optimal harvest threshold for pelagic fish into fisheries management policies.
Off the coast of Chimbote, Peru © IRD/A. Bertrand

Right:
Ultra-reactive Peruvian fishing. Fish productivity in the marine areas off Peru and Chile, driven by the Humboldt Current, is subject to great climatic variability: El Niño episodes can lead to the collapse of certain species, with a major economic impact. To provide Peruvian fishermen with the best possible support, scientists have set up innovative tools for observing fish stocks in real time. By adapting to climatic phenomena, fisheries management in Peru has become unique in the world for its ability to react.
Off the coast of Lima, Peru © E. Benavides

An eye on El Niño. El Niño is a major climatic phenomenon related to the interaction between the ocean and atmosphere in the intertropical zone. It contributes to the formation of cyclones and influences rainfall and productivity in certain ocean areas. These events often have devastating impacts on communities, activities (fishing, agriculture, etc.) and infrastructure. Research has provided a better understanding of El Niño, and in particular of the key role played by the central Pacific in regulating this climatic phenomenon.
Rio Santiago River, Peru © IRD/P. Baby



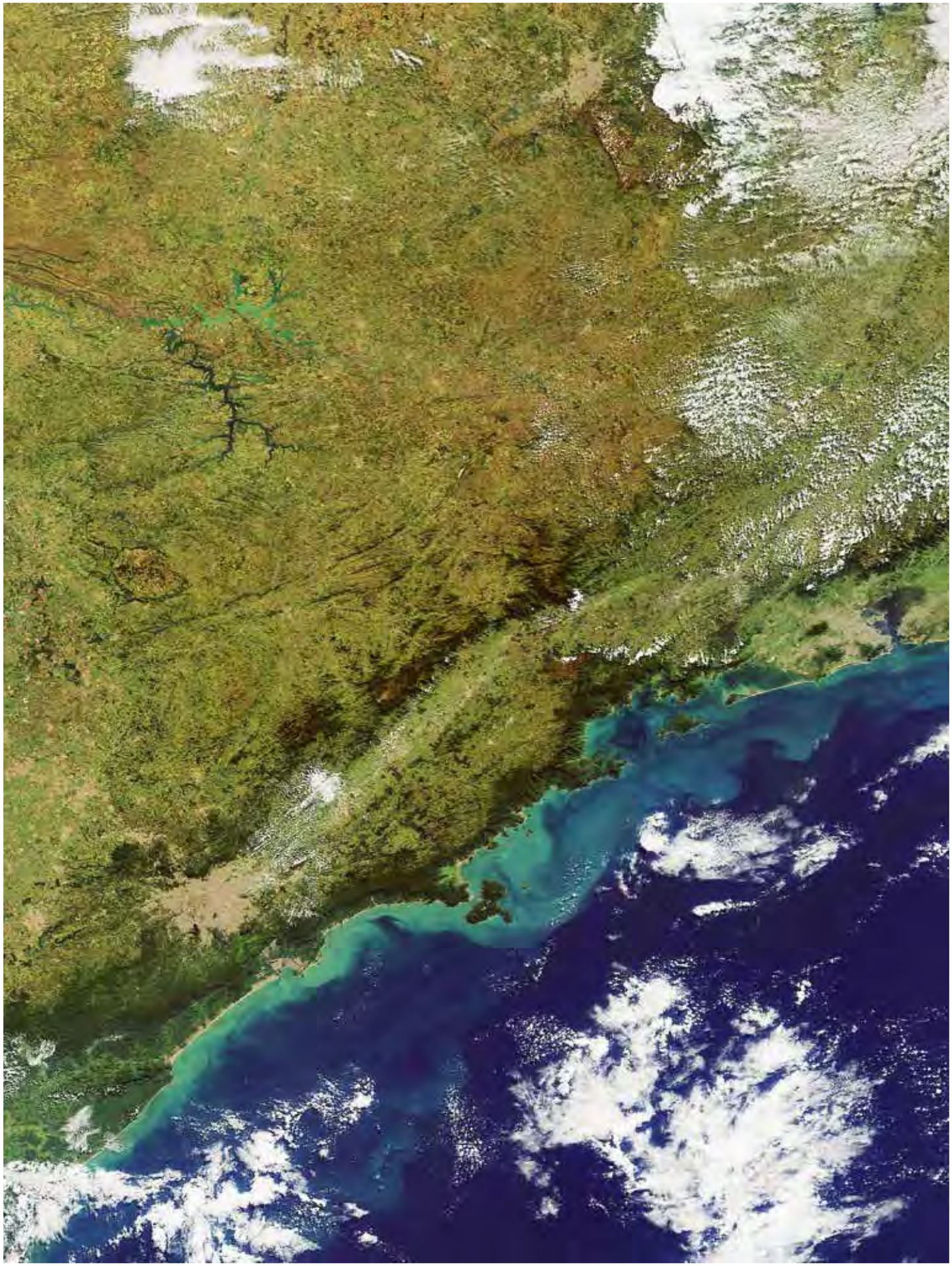
A carbon sink. Thanks largely to phytoplankton, the ocean absorbs around a third of the CO_2 emitted by humans into the atmosphere, and plays a major role in climate change In tropical oceans, which are poorer in the nitrogen required for plankton growth, the effects of this biological sink appear to be less pronounced. However, research in the South Pacific has revealed the presence of certain species of plankton known as "diazotrophs", which are capable of trapping carbon in deep waters. This is a major advance, even though much remains to be discovered about these complex mechanisms.
Trichodesmium © IRD/C. Dupouy

Previous page:
Losing the benefits of mangroves. Mangroves undeniably provide a number of services: coastal protection, carbon sequestration, spawning grounds, supply of firewood and food, and more. These benefits are being threatened by reforestation campaigns that use a single mangrove species, to the detriment of biodiversity and the use of mangroves by local communities. Researchers are calling for the spontaneous reconstitution of these fragile ecosystems by restoring bio-hydrological conditions, and for projects to be taken on by local communities.
Kourou area, French Guiana

Opposite:
Destructive rafts. Tuna fishermen use up to 100,000 fish aggregating devices (FADs) a year to increase their catches. Almost half of these wooden and plastic rafts sink or run aground on the coast. To reduce this pollution and the risk of overfishing, researchers have proposed a strategy combining a ban on FADs in specific areas and their recovery, in response to the need to control this practice and make it more sustainable.
Yellowfin tuna

Left:
Buoys to the rescue. In the tropical Atlantic, a network of buoys known as PIRATA transmits a wide range of measurements in real time, including water temperature and salinity at different depths, wind strength and direction. PIRATA is an essential tool for understanding climate variability at different spatial and temporal scales, and has been used to determine that the temperature of the waters in the Gulf of Guinea drops a few weeks before the start of the monsoon season. This information is extremely valuable to West African farmers.
Atlantic Ocean © IRD/L. Weppe

Right:
Under the watchful eye of satellites. The SWOT satellite observes lakes, rivers and stretches of ocean to gain a better understanding of the dynamics of the oceans and surface waters. With a resolution 10 times greater than previous technologies, it provides small-scale monitoring of ocean currents and eddies, which can turn the world's climate upside down by modulating sea surface temperature and CO_2 absorption. A recent campaign off the coast of Brazil confirmed the satellite's data on the circulation of waves and currents in an area of great biodiversity.
South-east coast, Brazil © European Space Agency



Super corals. Corals are particularly vulnerable to global warming and could become extinct by 2100. However, some reefs can withstand a more acidic, warmer and less oxygenated environment. The Bouraké reef in New Caledonia, for instance, is home to around fifty resistant species that would die elsewhere. The proximity of the mangrove, symbiosis with unicellular algae or the presence of certain resistance alleles could explain this exceptional adaptation. If this resistance can be confirmed, the best genetically armed species can be propagated in more damaged areas.
Left: **Coral and hawkfish** © IRD/E. Folcher
Right: **Coral and *Mulloidichthys vanicolensis*** © IRD/J.-M. Boré

Jihad **Zahir**

Professor and researcher in Computer Science
at Cadi Ayyad University (Morocco)

“AI FOR PRODUCING INDICATORS OF MARINE BIODIVERSITY”

Scientific research in the field of artificial intelligence (AI) at Cadi Ayyad University today has three main strengths: multidisciplinarity, qualified staff and a diverse range of national and international collaborations. For example, the multidisciplinary NAWRAS project that I am coordinating with Marie Bonnin, Director of Research at IRD and a specialist in environmental law at the Marine Environmental Sciences Laboratory, aims to use AI to understand and assess the role of law in protecting the oceans. Similarly, the Artificial Intelligence for Marine Ecosystems (AIME) project combines several disciplines to produce AI-based indicators of marine biodiversity. An increasing number of young Moroccans are going into AI-based professions, and the expertise is there. Finally, another strong point is that we are multilingual. Our command of French and English as well as Arabic makes it easier for us to communicate and integrate into international teams. The overall outlook is therefore positive. However, our access to significant computing resources, which are essential for AI, and to scientific literature, is still limited. Projects also often come up against red tape, which can slow down their implementation.

Flávia **Lucena-Frédou**

Professor at the Federal Rural University of Pernambuc (Brazil)

“DEVELOPING ENDURING RELATIONS BETWEEN COUNTRIES OF THE GLOBAL SOUTH”

My university has been working with IRD for more than twenty years. Over the years, we have developed a very successful partnership. On a personal level, it has enabled me to do a postdoctorate in France, to meet many scientists specialising in Brazilian marine ecosystems and to form a research network. On top of this, campaigns at sea have been organised, thanks in part to the French research fleet. French researchers have also been posted here in Brazil. We worked together to build what in 2018 became the LMI Tropical Atlantic Interdisciplinary Laboratory on Physical, Biogeochemical, Ecological and Human Dynamics (TAPIOCA), now recognised as a centre of excellence for marine sciences in the tropical Atlantic. In addition to the ground-breaking scientific knowledge we produce on the marine ecosystems of northern and northeastern Brazil, more than a hundred students have been trained at this hub so far. Some of them have gone on to obtain doctorates in one of our two countries, they have learnt each other’s language, in France they have been introduced to techniques that are not widely used here, such as acoustics, and young French scientists have come to do their fieldwork in Brazil. The exchanges are mutual and constructive, and continue to attract new partner institutions. We would also like to develop more enduring relations between countries of the Global South as part of our partnerships with IRD, for example with Africa, which has marine environments similar to ours. Finally, what would be the point of all this knowledge if it wasn’t disseminated? Throughout this collaboration, we have been keen to pass on a scientific culture to schools, fishermen and local communities; we have also worked with national and regional media. This is a must.

Carmen **García Dávila**

Executive President of the Research Institute of the Peruvian Amazon and co-coordinator of the Observatory of the Biodiversity of the Amazon rainforest in Peru

Scientific research has and will continue to contribute to the production of knowledge and technologies for the sustainable development of the Peruvian Amazon, which covers more than 60% of Peru's territory. In the 1980s, scientific research provided the technologies needed to develop fish farming of species of commercial interest in the Peruvian Amazon, marking the start of a socially, economically and environmentally sustainable activity. This activity has also helped to reduce fishing pressure in the natural environment. The Research Institute of the Peruvian Amazon (IIAP), founded over forty years ago, has been a major pillar in the production of around 120,000 tonnes of fish flesh, contributing to the food security and economic development of the Amazonian people. In addition, more than fifteen years of scientific partnership between IIAP and IRD have recently made it possible to propose a new technological package for the reproduction and captive breeding of catfish. This will further diversify the supply of fish and reduce fishing pressure on natural populations of this species of high economic value throughout the Amazon biome.

Meanwhile, the Amazon is currently facing unprecedented levels of land occupation, resulting in a degradation of Amazonian ecosystems and the environmental services they provide. This comes with high levels of deforestation due to the expansion of agricultural land, domestic pollution and

“REACH KEY PLAYERS IN SUSTAINABLE DEVELOPMENT”

an increase in the illegal extraction of gold from watercourses, all of which results in increased pressure on flora and fauna resources. Scientific research in the Amazon, which dates back at least a century, has a fundamental role to play in sustainable development by conserving forests. We wanted to know why most of this research had not served as guidelines for the sustainable development of this biome, whose main economic activities continue to be purely extractive. We realised that over the last few decades we had only been sharing knowledge within restricted scientific spheres, without developing the capacities and mechanisms to reach the key players in the sustainable development of this area, such as government agencies and the local communities. Our biggest challenge remains closing these communication gaps. This was one of the motivations for creating, in collaboration with IRD, between 2011 and 2021, an international joint laboratory to promote research on Amazonian ichthyofauna (LMI EDIA) aimed at improving our understanding of its biodiversity for the sustainable development of its exploitation. Another successful example of the contribution of science to sustainable development in the Peruvian Amazon is the production by IIAP and IRD, over two decades, of a wealth of scientific information on the conservation status, population genetics, life history traits (periods of reproduction, growth, migration), among other parameters, of the main fish stocks in the natural environment. Most of this information has been shared by IIAP with stakeholders (Direpros, etc.) and local communities to be used as management tools for these resources, which are one of the main sources of protein and economic income for people living in the Amazon.

Dorothy Wanja **Nyingi**

Director of the Ichthyology Department of the National Museums of Kenya and coordinator of the Kenya Wetlands Biodiversity Research Team

I started working with IRD in 1999, when Jean-François Agnèse, an IRD researcher specialising in tilapia, one of Africa's most economically valuable fish, was posted to Kenya. I did my Master's and PhD under his supervision between 2002 and 2007 at the Montpellier 2 University. Working in his laboratory taught me what a good collaboration is all about. Although I was still inexperienced, he made sure that I became a competent researcher by giving me access to modern techniques and laboratory equipment. Our collaboration resulted in numerous publications on tilapia ecology. After obtaining my PhD, I started working with Stéphanie Duvail, a geographer and director of the PALOC joint research unit, working in Kenya on East African wetlands. The fact that she was a woman in the scientific field had a big impact on our work in Kenya. In addition to our joint research work, we developed human capacities together that opened up more promising prospects for young women scientists. Working together, we created a research team on the biodiversity of Kenya's wetlands. In the past, we had great difficulty in retaining young women in our research programmes. We live in a male-dominated system, where educated women are discredited and may feel unfit for marriage and family life. On top of this, because career policies are designed for men, women are disadvantaged in their career progression, when they become mothers, for example. As a result, we have "lost" many high-quality women scientists along the way. Starting in 2011, our team, jointly led by Stéphanie and myself, developed scientific methodologies for studying wetlands and co-supervised many students. We encouraged young women to take

“ENCOURAGE YOUNG WOMEN TO TAKE UP SCIENCE”

up science by setting an example and encouraging them to follow in our footsteps. We discussed ways of boosting self-confidence, and tackled obstacles such as lack of family support by finding funding for scholarships. We almost reached a 1:1 ratio in our projects, whereas in 2011 there were only two women for every six men. My colleague has since returned to France, but our work together continues with the help of the systems we have put in place and the women we have mentored, who are now taking on more important roles. Thanks to this fruitful collaboration, in 2016 I was honoured to receive the French government's *Palmes Académiques* for my work on fish biodiversity and aquatic ecology! My hope is that the work we have begun will constitute a key turning point in IRD policy, particularly for the advancement of women in science. How can the Institute support women on an equal footing with men in the countries it works with? A programme to break down gender barriers needs to be set up and included in every project. IRD is indeed working towards this for its own staff: in 2014, I was invited to join IRD's Parity Committee, where I had the opportunity to share some of the gender issues in Kenya. Another key area of focus for the future is technology transfer. While capacity building has been successful in terms of postgraduate scholarships, there is still a tremendous lack of equipment and laboratories! If we create laboratories in Kenya, our scientists, on completing their postgraduate studies, will be able to advance collective research more effectively than by having to return to foreign laboratories to continue their research. Many foreign scientists are used to returning home with their equipment, even after having trained Kenyan scientists to use it. As part of our work with the National Museums of Kenya, we campaign to retain this equipment as a sign of genuine and equitable collaboration in which both partners have a shared vision of capacity building that allows them to work on an equal footing. This is an indispensable element of sustainable international scientific research.

West Bengal, India © S. Shibani Chattopadhyay

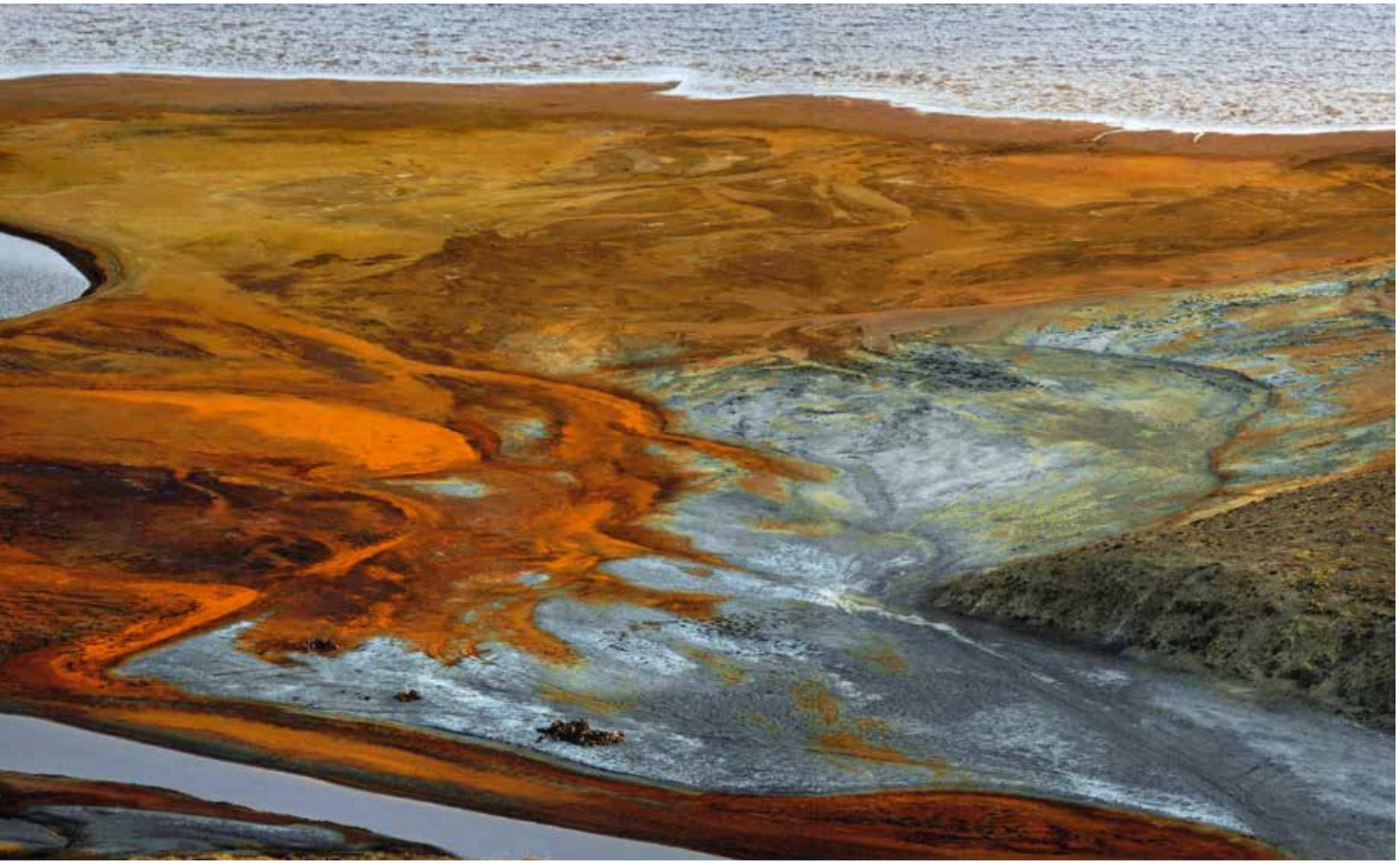
LAND AND WATER

Soil and subsoil resources are a potential source of growth for developing countries. But their extraction often causes major environmental and health problems including water contamination and atmospheric pollution, as well as major socioeconomic inequalities. Can these georesources be extracted sustainably and equitably? This chapter illustrates how advances in science are making it possible to develop resources in a way that is more respectful of the environment and of people's health. These pages also reveal the contribution research is making to a better understanding of natural and man-made hazards, and to actions to reduce and sometimes prevent the associated risks, thereby reducing people's vulnerability.

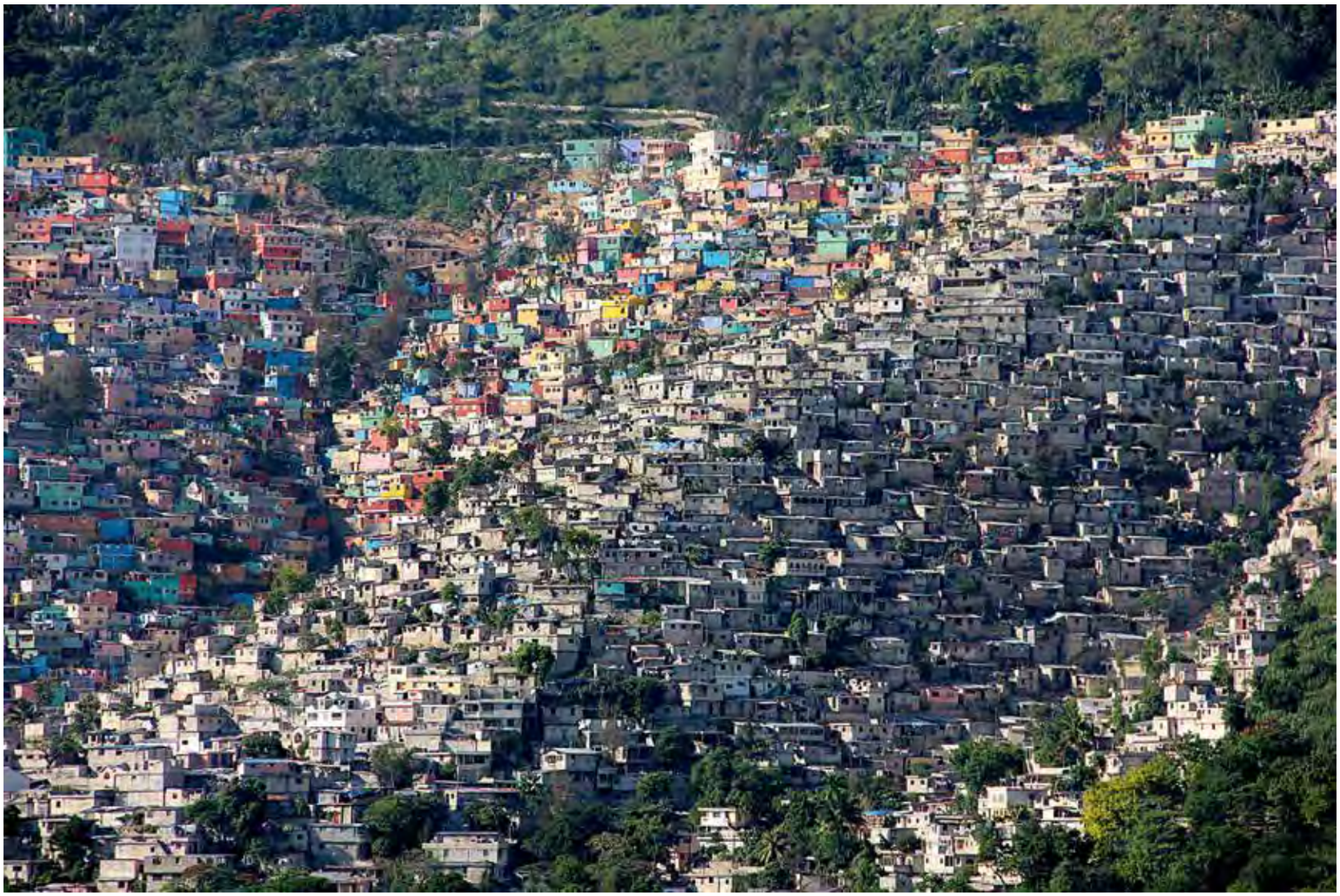
Modelling lava flows. Vulcanology is set to make major advances with the development of a new instrument, the viscometer, for measuring the viscosity of lava. Initially tested in a temperature-controlled oven, this instrument, the only one of its kind in the world, can be used to model the propagation of lava flows right from the start of an eruption. Beyond the scientific benefits, the aim is to better assess the risks posed by active volcanoes and thus reduce the dangers to people and infrastructure.
Kilauea volcano, Hawaii © IRD/J.-P. Eissen

Voracious bacteria. *Mesotoga* are bacteria capable of living in natural environments at high or low temperatures. They have also been discovered in environments that have been severely degraded by certain industrial activities and contaminated by heavy metals, hydrocarbons or organochlorines. Scientists have come up with the idea of combining the only two known Mesotoga species with another bacterium. These bacterial pairings are destined for success, as they are capable of breaking down chemical contaminants through "bioremediation", making them less toxic for the environment, or even harmless.
Milluni Lagoon, Bolivia © IRD/O. Dangles and F. Nowicki

A chain of mercury contamination. The mercury of natural origin and the mercury used in gold mining have two different isotopic signatures, making it possible to distinguish the origin of this toxic metal which, once released into the environment, spreads through the food chain, particularly via contaminated fish. A study carried out in French Guiana near small-scale gold mines shows the impact of gold mining on mercury contamination (in water, soil, sediment, fish and people). The innovative results call for targeted preventive measures to be introduced for at-risk indigenous populations, particularly pregnant women, and for support for the adoption of mercury-free gold mining techniques.
Haut Maroni, French Guiana © IRD/P. Dumas



Freshwater saturated with microplastics. Microplastic pollution is closely monitored in the oceans, but much less so in freshwater. And yet microplastics can contaminate freshwater on a massive scale, as a team of researchers has found in the Saigon River. Nets used to collect plastic particles show a concentration 1,000 times higher than in other rivers, particularly those in countries of the Global North. The cause lies in the poor management of plastic waste from domestic use or discarded by the textile industry. This high level of contamination is a source of concern for the Vietnamese authorities.
Hô Chi Minh City, Vietnam © IRD/J.-M. Boré



“Citizen” seismometers. Since 2019, seismologists in Haiti have been relying on data from 15 seismometers hosted by volunteers from the general public. This system, with seismometers evenly distributed across the country, is crucial for detecting and measuring earthquakes. It supplements the information provided by temporary scientific stations. The data is published in near-real time on a website accessible to all. This unique detection system helps local authorities to take emergency action by identifying and mapping tremors and aftershocks.
Port-au-Prince, Haiti © IRD/M. Morell

Using AI in seismology. Scientists are turning to artificial intelligence (AI) to detect the warning signs of earthquakes. The idea is to feed algorithms with quantitative observations, in particular those resulting from the analysis of gravitational waves, which were recently discovered to be a better indicator of earthquakes than seismic waves. The end goal of this research is to improve earthquake prediction and tsunami warning systems.
Muisne, Ecuador © IRD/Agence Nan/J. P. Verdesoto

Next pages
Top:
The health impacts of air pollution. Contributing to over 7 million premature deaths a year, air pollution is one of the five major health risk factors. Scientists have shown that some fine particles are more harmful than others because they generate increased "oxidative stress" in lung cells. This oxidative potential is a qualitative indicator of the health impact of fine particles. This is a major issue in urban areas, where fine particles are not only the most concentrated, but also the most harmful to people's health, especially babies and young children.
Hanoi, Vietnam © IRD/J.-M. Boré

Bottom:
Systems of the past for the future. Domestic wastewater treatment plants alone will be unable to meet the needs of the world's growing population. With this in mind, researchers have optimised traditional filtration systems using gravel, microorganisms and plants. By controlling the flow rate in the filtration system, for example, they have been able to recover water that is rich in nitrates and can therefore be used as fertiliser. This is an advantage when it comes to creating parks to provide cooler air, particularly in African cities.
Antananarivo, Madagascar © IRD/ ONG Hardi, T. Vergoz

Right:
The challenge of coastal submersion. Ghana faces two cumulative vulnerabilities along its coastline. On the one hand, the ocean level is rising (by around 3 mm per year), while on the other, the coasts are subsiding (by around 4 mm per year). Scientists are attempting to quantify the impact of overexploitation of groundwater, changes in land use, oil extraction and urbanisation on coastal subsidence, allowing protective measures to be developed.
Grand-Lahou, Ghana © Wikipedia/Willav FR

Detecting water in the ground. Detecting water resources in the African subsoil is essential to meeting the population's drinking water needs or for agricultural purposes (80% of the water drawn). A method developed by researchers in Africa can be used to detect sandy underground zones, the main storage sources for drinking water, and to assess the volume available. Agricultural irrigation is now managed using tools for modelling evapotranspiration and water balance according to the type of crop, fed by satellite data. This is valuable information in the hands of farmers.
Dierma region, Burkina Faso © IRD/M. Bournof

Fragile deltas. River mouths are fragile ecosystems and coveted socioeconomic areas. In the western Indian Ocean, the construction of dams upstream of deltas for hydroelectric, agricultural and industrial uses is having a major impact on the natural environment and leading to conflicts. Researchers are analysing the environmental effects of these infrastructures using interdisciplinary and participatory approaches in order to guide decision-making, in particular to defend the right of access to water for the most vulnerable.
Mahajanga, Madagascar © IRD/Didem, R. Rijasolo

Véronique **Yoboué**

Professor and Vice-President in charge of cooperation at the Université Félix-Houphouët-Boigny (Côte d'Ivoire)

In my field of study, which is air pollution, research plays a crucial role in identifying the sources specific to Africa and understanding the health, socioeconomic and environmental impacts. Scientific analyses allow us to assess the significance of each source factor, enabling mitigation policies to be put in place to reduce the impact.

For example, combustion is a major source of pollution in Africa: it accounts for over 60% of domestic energy, which in turn contributes to over 50% of fine particle emissions. Based on this observation, in collaboration with the aerology laboratory in Toulouse, we demonstrated that the use of "more modern" ovens improved the lung health of a group of women working as fish smokers. These ovens require less wood and coal than those used in the traditional technique, and the smoke is evacuated via a chimney. This positive health impact also has socioeconomic benefits, both for the state, which will spend less on medical care, and for the women, who will earn a better living by buying less wood and producing smoked fish that is less polluted and suitable for export. Calculating the emissions caused by improved combustion also makes it possible to assess the positive effect of this solution in the short and medium term. The environmental impact can therefore be modelled.

© Cames

“SCIENCE KNOWS NO BORDERS”

As this example illustrates, science can provide arguments to support the political decision to scale up. But, in my view, it also has a role to play in educating and raising awareness among the public about their day-to-day activities - in this case, smoking fish - when they contribute to polluting the atmosphere and making us ill. The approach therefore should be ecosystemic. It needs to involve scientists, including social scientists, political stakeholders and civil society, because the introduction of any new technology requires adaptation, which is often the most difficult aspect for the people concerned.

More broadly, regardless of the field, science is essential for promoting sustainable development. However, funding for research remains a major problem in the Global South, where there is also a lack of infrastructure and technical capacity.

And yet, science knows no borders. My fellow researchers must therefore move towards more international collaboration with the countries of the Global North, which are better funded, and increasingly include the countries of the Global South. Such collaboration will enable us to enhance our research capabilities. African countries must also understand that they need to invest in supporting the science conducted by our researchers, so that they can find solutions adapted to our territories. I am optimistic about this because the funding is there. We are gradually making progress, taking things step by step. But these are still only small projects. When it comes to science, Africa really needs to wake up!

Thi San Hà **Phan**

Researcher and member of the advisory committee of the Centre of Asian Research on Water at the Ho Chi Minh City University of Technology (Vietnam)

There is an African proverb that says: "If you want to go fast, go alone. If you want to go far, go together". This statement resonates well with the situation in developing countries. Take the example of the Mekong Delta, a vast plain in the south of Vietnam. The delta is the country's largest rice granary and a crucial centre for aquaculture and fruit growing, feeding not only the Vietnamese population but also foreign countries through export. But it is currently facing unprecedented challenges. With the construction of hydroelectric dams upstream on the Mekong, water flow and sediment transport downstream are decreasing by the day. The dams also hinder fish migration, jeopardising livelihoods in countries downstream and creating risks of malnutrition for impoverished communities that depend on fish as a vital source of protein. The Mekong Delta also faces other problems such as rising sea levels, land subsidence due to excessive groundwater extraction, coastal and riverbank erosion and excessive sand extraction.

“APPLIED RESEARCH IS VERY IMPORTANT FOR LOCAL SOLUTIONS”

Collaborations with major institutions in Europe, in particular support from IRD, have enabled promising progress to be made. The results of extensive research have highlighted various problems facing the Mekong Delta with sound and convincing breakthroughs, attracting worldwide attention. These joint research efforts have led the Vietnamese government to tighten regulations on sand extraction in the delta, and effective solutions have been implemented to prevent coastal erosion in certain key coastal areas. Despite these positive results, scientific endeavours in Southeast Asia face a number of obstacles. These include the fact that decisions are often influenced more by economic and political objectives than by sustainable development objectives. Another obstacle lies in the fact that scientists seeking to establish their position and reputation often have to publish articles that are scientifically and technologically innovative. However, these criteria do not necessarily fit with the sustainable development objectives of a region or a country. Applied research is very important, for example, for the conservation of fauna and flora in a given region or ecosystem, the mapping of groundwater resources with a view to optimal use, or the search for local solutions to help farmers earn an income while also protecting the environment.

Silvana **Hidalgo**

Volcanologist, former director of the Geophysics Institute at the National Polytechnic School (Ecuador)

The issue of earthquakes and volcanic eruptions is crucial in our country. We have 80 volcanoes, a very high density for our territory, which has seen the eruption of five volcanoes on the continent and four volcanoes in the Galapagos over the last twenty-five years. Collaboration between IRD and the Geophysical Institute in Quito began with the mapping and detailed study of Ecuador's volcanoes, which has continued recently. As former director of the Geophysics Institute at the National Polytechnic School, and having completed part of my studies in France, including my doctorate in Clermont-Ferrand with the support of IRD, I can attest to the importance of this collaboration in training the managers of our institute and enabling it to function well, both in the past and still today. This collaboration, which began with a number of projects, was subsequently organised as part of the LMI Earthquakes and Volcanoes in the Northern Andes (*Séismes et volcans dans les Andes du Nord*, SVAN.) For almost ten years, from 2012 to 2022, many students were trained in France and several returned to our country to work at the institute. We don't have a Master's programme or a doctoral school here in Ecuador. It is therefore easy to see why training our students in France is essential and will continue to be so. There is a growing

“INTERNATIONAL COLLABORATIONS, A NEW LEASE OF LIFE”

demand for qualified people to work on hazards such as earthquakes and other natural phenomena. Another benefit of our exchanges with IRD has been to better position ourselves on the research scene. Our collaboration, which has always placed our two countries on an equal footing, has helped us to offer research topics and programmes, as well as expertise, in addition to volcanology study sites. We are now recognised as an expert institute dedicated to the study of volcanoes and earthquakes in the country, but also in Latin America. This partnership also helped us to open up to other research structures and to look at our work from the perspective of other disciplines, working with anthropologists and sociologists, for example. One project, called Éclair, was launched last year by a young university professor who had trained in France with the support of IRD. The project studies crater lakes and how they are perceived by local populations, the beliefs that are attached to them, etc. One of the aims will be to set up an information centre to inform local communities about how volcanoes work and the risks they pose for the region. The main obstacle to the development of our research and the resulting applications for our country is, of course, the budget: funding for research and education in general has been in decline for several years, and we are now feeling the effects of a reduction in our working capacity. International collaborations, such as those with IRD, can give us a new lease of life, but budget restrictions are not confined to our own country, and there are growing difficulties worldwide in funding research projects.

Claude **Borna**

Director of the Sèmè City Development Agency (Benin)

“AN INNOVATION HUB FOR BENIN”

Africa cannot limit itself to frugal models of innovation. It has become crucial to develop research and development infrastructure that meets international standards in order to boost the competitiveness of the country’s businesses and provide opportunities for its dynamic and talented young people to flourish.

The Beninese government’s flagship project, Sèmè City, is an innovation hub housing higher education establishments, research centres and incubators. Sèmè City aims to make its future campus an experimental platform for smart cities, encouraging the development of innovative solutions in areas such as waste management, bioclimatic construction and mobility. We are placing particular emphasis on the use of artificial intelligence tools to collect and exploit data on these community innovations, as well as on the production of new applications using artificial intelligence (AI).

Co-creation, promoted by Sèmè City, fosters collaboration between students, researchers, entrepreneurs and partners, including IRD. This vision of Africa is one where education, research and innovation converge for sustainable and prosperous development.

Adèle **Rayangnéwendé Ouédraogo**

Winner of the IRD Innovation Trophies,
researcher at the Institut de Recherche en Sciences Appliquées et Technologies (Burkina Faso)

“CONTRIBUTING TO THE SUSTAINABILITY OF AGRICULTURAL PRODUCTION”

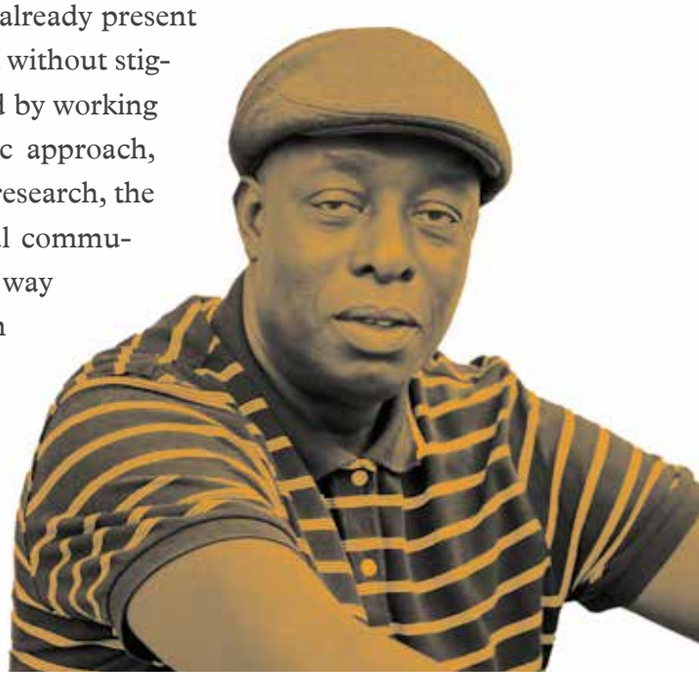
Burkina Faso is a country of the Sahel with very poor, degraded soils. However, various water and soil conservation techniques optimised by research have contributed to the sustainability of agricultural production. Thanks to the traditional zaï method (holes enriched with organic manure) and half-moon-shaped pits, combined with stone walls, farmers are obtaining acceptable yields on previously barren soils. Organic fertilisation has been facilitated by the development of composting methods. Similarly, a considerable amount of effort has gone into promoting agroforestry, a system that combines tree management with a variety of crops. But there are still difficulties. Some of these practices are very laborious, which limits their adoption. Farmers need to be able to mechanise them. Due to the lack of available biomass in sufficient quantities, organic fertilisation is rarely used in cereal and cotton crops, for example. For this reason, we are working on the recovery of organic household and agro-industrial waste. More broadly, however, our laboratories are seriously lacking the equipment and technologies they need to pursue their research and make an effective contribution to the country’s sustainable development.

Mamadou **Diol**

Cultural coordinator, Kaddu Yaraax association (Senegal)

> **“THE ARTS AND SCIENCE FEED OFF EACH OTHER”**

Researchers often use theatre because this method of social intervention enables them to model a community issue - already present in Senegal or encountered elsewhere - holistically, without stigmatising anyone, using the local language and codes. And by working with researchers, the actors take on board the scientific approach, which leads them to focus above all on the results of the research, the uncertainties that remain and the experience of the local communities. Through these interactions, theatre becomes a way of popularising science, while the scientific approach produces knowledge that influences the way actors approach texts, including the classics dealing with water, climate, drought, pastoralism and so on. In other words, the arts and science feed off each other.



Kieu **Thi Kinh**

Lecturer at the University of Danang
and founder of local NGO Building Up Sustainability (Vietnam)

“RESEARCH PROMOTES INCLUSIVE AND EQUITABLE DEVELOPMENT”

In the Global South, and in Vietnam in particular, research has played a crucial role in helping to understand and address the specific environmental, social and economic challenges facing these countries, including the advancement of sustainable technologies and improved access to essential services such as solid waste management and recycling techniques. It has also promoted inclusive and equitable development. Scientific cooperation and the sharing of knowledge have also facilitated the exchange of good practice and feedback, accelerating the achievement of sustainable development goals in our communities.

However, if we want to strengthen the role of science in achieving these goals, we must tackle the main obstacles and adopt strategic measures. These include increasing funding and resources for sustainable research, promoting inter- and transdisciplinary collaborations, and investing in education and capacity building for young researchers. Open access to research data and results (which is still in its infancy in Vietnam), combined with evidence-based decision-making and integration by policy-makers, increases the transparency and effectiveness of research. Ethical considerations, the engagement and awareness of the scientific community, and technology transfer are also essential to ensure that sustainability initiatives prioritise equity, inclusion and innovation. In my view, many scientists in Vietnam do not yet have enough influence on the transformation of society because of the constraints mentioned above.

POSTFACE

The photographic experience

The human species has developed a sense of sight, the two most important characteristics of which are colour vision and forward vision. This sense provides us with around 50% of the information we need about our environment, and has proved essential over the millennia for finding our bearings in space and finding food. Our vision defines the way we interpret the world and has enabled us to survive throughout evolution. We have even used images to represent our daily lives on stone, cloth and clay. Using natural tools and dyes, we have consciously sought to immortalise what is important to us. Pictorial interpretation established itself and travelled with us across seas and continents, perfecting itself and finding in each era different reasons and perspectives for capturing the tangible and intangible realities we now call culture and heritage.

We live on a changing planet, and photography - one of the most advanced means we have of documenting our time on Earth - has very recently become more widely used than ever before. Although the distribution is not uniform, there is now at least one smartphone for every human being. This means that, statistically, each and every one of us is a potential photographer with the ability to document moments from everyday life, whether personal or professional, to move hearts and consciences and, in some cases, to use this medium to call for action, all at the click of a button. Be it a mother's

tender embrace of her child weakened by malaria, recognition of the precarious work of miners in inhospitable tunnels at 5,000 m altitude, or faithful documentation of the retreat of forests and glaciers, images always have an impact and can generate fleeting or profound feelings, sensitise and mobilise groups of people, or lead people to fight for crucial human causes.

From a scientific point of view, photography has largely, if not completely, succeeded in simplifying difficult concepts and making them more accessible and comprehensible to a wide audience. The birth of a star or its death in a black hole, which are initially embodied in mathematical conjunctions and complex equations, can be instantly understood in a single image containing all the necessary information through a series of ordered pixels. A few photographs can explain the ethology of a microscopic living being and easily summarise what, in a specialised book, would require an entire chapter.

Humans' connection and disconnection with nature has been told in photographic stories that have provoked admiration or desolation depending on how we manage our relationship with Mother Earth. A subject, an idea and a means of expression - that is all we have needed for millennia to capture and share our fleeting passage on Earth, what we call "life".

Olivier Dangles
French National Research Institute for Sustainable Development

Rafael E. Cárdenas
Pontificia Universidad Católica del Ecuador

Two worlds meet. For a reptile like the Galapagos marine iguana *(Amblyrhynchus cristatus*), a human visit is a daily event. For tourists, it may be a unique moment that they are desperate to capture in a photograph and in the depths of their memory. These two ways of remembering a common moment will be used to share their unusual experience with others.
Santiago Island, Galapagos, Ecuador © PUCE/R. E. Cárdenas

Waorani man and palm *(Socratea exorrhiza*). Several mathematical approaches have been developed to quantify the relationship between populations and the environment. One of these, the I = PAT equation, states that the environmental impact of the human population (I) can be described as the product of three factors: the size of the population (P); the population's affluence impacting its consumption of resources (A); and technology (T), which defines the environmental impact per unit of consumption. This photo reflects the three variables in this equation.
Ecuador © IRD/O. Dangles, F. Nowicki/*Une autre Terre*

Most of the photos in this book come from the IRD photo database, which contains almost 80,000 photographs taken by IRD scientists in the field during their research work in Africa, Asia, Latin America, the Mediterranean, the Middle East, Oceania and the French Overseas Territories. This unique iconographic heritage is freely accessible at: https://multimedia.ird.fr/

The texts in this book are based on the following publications:

- IRD Le Mag (https://lemag.ird.fr/fr);
- *Science and sustainable development. 75 years of research in the Global South.* Marseille, IRD Éditions, 2019;
- *Biodiversity in the Global South. Research for a sustainable world*. Marseille, IRD Éditions, 2020.

Photoengraving: IGS-CP

Printed by Escourbiac, Graulhet, France on Gardapat Bianka paper (135 g)

Legal Deposit : January 2025

How does research contribute to sustainable development in the Global South? This book highlights 80 major scientific breakthroughs in response to the many challenges facing the countries of the Mediterranean and tropical regions in these times of globalisation.

Illustrated with magnificent photos taken on every continent by IRD researchers and photographers from all over the world, it offers a fascinating journey to the heart of the major issues facing the world today, such as the fight against climate change, preventing pandemics, anticipating risks, preserving biodiversity and the fight against inequality and for greater social justice. Throughout the book, scientists and development stakeholders share their views on the vital role interdisciplinary research plays in building a desirable future together.

This book is intended for a wide readership, and was published to mark the IRD's 80th anniversary. It illustrates the commitment of science in both the Global North and Global South on all fronts of sustainable development.

IRD Éditions

28 €
www.editions.ird.fr
ISBN : 978-2-7099-3060-4