


UNDER THE DIRECTION OF AGATHE EUZEN  
BETTINA LAVILLE AND STÉPHANIE THIÉBAULT



**ADAPTING**  
TO CLIMATE  
CHANGE

**A QUESTION FOR OUR SOCIETIES**

ediSens



*Adapting to Climate Change*



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## Contents

|   |    |
|---|----|
| Preface,<br><i>Alain Fuchs, President of the CNRS</i> .....   | 11 |
| Preface,<br><i>Bettina Laville, President of Comité 21</i> .....  | 13 |
| Foreword,<br><i>Monique Barbut, Executive Secretary of the United Nations<br/>Convention to Combat Desertification (UNCCD)</i> .....  | 17 |
| General introduction,<br><i>Agathe Euzen, Bettina Laville and Stéphanie Thiébault</i> .....   | 19 |
| <b>Chapter 1: Definitions of adaptations</b>  |    |
| Adaptation: coping with climate stress and with the new conditions<br>created by climate change,<br><i>Bettina Laville</i> .....  | 25 |
| Adapting to climate change in a context of multiple inequalities,<br><i>Edwin Zaccai</i> .....  | 33 |
| Climate change adaptation, from the Rio Earth Summit to the<br>consequences of the Paris Agreement: 25 years of false starts,<br><i>Bettina Laville and Sarah Schönfeld</i> ..... | 41 |
| Role of Adaptation in IPCC Reports,<br><i>Jean Jouzel</i> .....   | 51 |
| (Mal)adaptation to climate change: start by doing well what we do<br>badly,<br><i>Alexandre K. Magnan and Virginie K.E. Duvat</i> .....   | 59 |
| <b>Chapter 2: The dynamics of adaptation</b>  |    |
| Adaptation and evolution,<br><i>William E. Banks and Francesco d'Errico</i> .....   | 69 |



Using past experience in order to better adapt?,  
*Emmanuel Garnier* .....73

Inheritance systems in a changing world: climate changes and  
epigenetics,  
*Christoph Grunau and Dominique Joly* ..... .83

Phenotypic plasticity and adaptive responses to climate change,  
*Patricia Gibert and Irène Till-Bottraud* ..... . 91

The dynamics of human societies and migratory flows,  
*Chloé Anne Vlassopoulos*.....97

Traditional societies in the face of climate change, or how to address  
multiple vulnerabilities,  
*Agathe Euzen* ..... 103

Is resilience always necessary?,  
*Robert Chenorkian and Luc Abbadie* .....111

**Chapter 3 To what extent can ecosystems adapt?**

How far can ecosystems adapt? Tropical forests  
*Elodie A. Courtois, Jérôme Chave and Martine Hossaert-Mckey* 121

Marine and continental biodiversity,  
*Gilles Boeuf* .....129

Coastal ecosystems in a context of global change, .....  
*Antoine Gardel, François Fromard and Edward J. Anthony* .....137

Agriculture and climate change: Agro-ecosystem adaptation and resilience,  
*Vincent Bretagnolle* .....147

Adaptation in drylands,  
*Monique Barbut* .....155

The Pompeii worm or how to adapt to extreme conditions  
*Françoise Gaill*.....163

Invasive species,  
*Franck Courchamp and Céline Bellard* .....171

**Chapter 4 What tools can be employed?**

Scientific tools to study the adaptation of living organisms to global  
change,  
*Dominique Joly and Stéphanie Thiébault* .....179

Towards new national policies integrating the issue of climate change  
adaptation and health risks, *Jean-François Guégan* .....189



The problematic nature of a law on climate change adaptation: A French case study — proposed legislation on adaptation in coastal regions,  
*Marta Torre-Schaub* .....199

For the creation of a Poverty-Adaptation-Mitigation financial mechanism in the Green Climate Fund,  
*Sandrine Mathy* .....209

The international adaptation finance: between hope and reality,  
*Romain Weikmans* .....217

Regionalized climate projection key to adaptation  
*Antoine Bonduelle* .....225

**Chapter 5 Adaptation: a regional challenge**

Territorial planning and adaptation,  
*Vincent Berdoulay and Olivier Soubeyran* .....233

Climate adaptation strategies and plans, .....  
*Eric Brun, Jérôme Duvernoy, Sylvain Mondon and Frédéric Schafferer*..... 241

Are adaptation and resilience in the DNA of Paris?  
*Anne Girault and Yann François* .....249

Regional implementation and the existence of adaptation at local levels,  
*François Bertrand* .....257

4 per 1000, an effective climate change adaptation strategy?  
*Thierry Heulin, Christine Hatté and Luc Abbadie* .....265

**Chapter 6 Adapting through innovation**

SNCF: face to face with climate change,  
*Christian Dubost* .....275

Corporate adaptation plans or the pressure of finance, .....  
*Ian Cochran, Vivian Dépoues, Romain Hubert and Morgane Nicol*.....283

Risk management or how insurers take adaptation into account,  
*Philippe Dutertre and François Garreau* .....291

Adaptation to climate change: EDF’s perspective, .....  
*Claude Nahon, Eric Maucort and Javier Torres* .....301

Recent innovation and development in energy technologies,  
*Abdelilah Slaoui, Pascal Brault, Gilles Flamant and Sylvain David*.....309

Digital innovation as a tool for climate adaptation,  
*Mokrane Bouzgehoub* .....317



Adapting agriculture to climate variations: the case of the Sahel  
*Benjamin Sultan, Richard Lalou, Mouftaou Amadou Sanni, Amadou Oumarou and Mame Arame Soumaré* .....325

Viticulture – experimentation or adaptation?,  
*Hervé Quénol* .....333

**Chapter 7 Obstacles to adaptation**

Crisis, disaster, risk and adaptation,  
*Pascal Yiou and Aglaé Jézéquel* .....343

Could the circular economy be a solution for adaptation?,  
*Nicolas Buclet* .....351

Drivers and barriers to the practical implementation of adaptation at territorial level,  
*Guillaume Simonet* .....359

Adaptation: an ethical issue,  
*Virginie Maris* .....367

In conclusion... or in praise of flight!  
*Agathe Euzen, Bettina Laville and Stéphanie Thiébaud*..... 377

The authors.....381



# **Scientific tools to study the adaptation of living organisms to global change**

Dominique Joly and Stéphanie Thiébault

Understanding the study of global changes and their impact on the behaviour, adaptation and evolution of organisms and communities is one of the major challenges of 21<sup>st</sup> century research. Current anthropic pressures, which are at the heart of an unprecedented upheaval in the planet's resources and services, call for a paradigm shift in how scientific research should be conducted.

A foundation for Environmental Sciences, the approach combining observations (both qualitative and quantitative) and modelling is complemented by an integrated experimental approach to understand the action and feedback loops to which biological, ecological, geochemical and social systems are subjected. The relationship between observations and experimental research in the field, where there is only partial control of the environmental conditions, is essential to improve our understanding of the dynamics of natural and human-made systems and their potential for adaptation. This knowledge provides the essential ingredients for building tools to support public decision-making and managing our environment in a sustainable way.



## **Long-term observations to characterize and quantify transformations**

Observations, especially long-term ones (over a decade or century), are of great scientific value because they enable a wider understanding of the many physical, chemical, biological and human processes, as well as their interfaces, that are at work. They require sustainable, or even long-term, investment by those running research programmes.

In relation to ecology and biodiversity, long-term observations are rare but all the more valuable because they make it possible to reconstruct the evolutionary dynamics of species and communities, owing to a good understanding of the identifiable and recognisable life history traits of individuals and populations. Long-term studies are needed to understand the impact of climate change, habitat loss or the overexploitation of natural resources, which are major issues in relation to global change.

## **The technological revolution of experimenting on ecosystems**

Besides observation, there is only one solution for understanding the complexity of systems and their potential for adaptation: experimentation. Experimentation is a major scientific challenge, especially in relation to ecosystems, because it requires expertise in the functional, adaptive and evolutionary dynamics of complex systems, as well as the monitoring and measuring of the associated physico-chemical and biological parameters. This transformation of research objects is accompanied by a technological revolution involving major changes in the spatial dimension of tools, in monitoring and measuring accuracy and in the diversity and complexity of analytical instrumentation. It allows basic, qualitative and quantitative research to be documented in order to respond to environmental challenges.





In environmental sciences (its field of expertise), the Ecology and Environment Institute of the CNRS (the French national centre for scientific research) has thus developed a ground-breaking scientific strategy by putting in place innovative tools distributed throughout France and its overseas territories, with the objective of: (1) promoting and stimulating first-class basic research in global ecology in order to respond to social demand in terms of environmental engineering, expertise, environmental remediation and, more broadly, sustainable development issues; (2) providing researchers with unique tools for observing and experimenting within the national and international landscape; and (3) covering the relevant spatial and temporal dimensions to address the issues related to the functioning and evolution of socio-ecosystems, as part of interdisciplinary research into environmental sciences.

### *Ecotrons*

Current research tools are classified according to additional gradients between observation and experimentation, and incorporate the interactions between people and the environment at different timescales. They offer a wide range of possibilities for forcing biotic and abiotic parameters, which are analogous to natural and completely artificial systems. Among them, the *Ecotrons*<sup>1</sup> are the most advanced and complex tools. They measure the states and activity of living organisms present in ecosystems as well as the integrated assessment of that activity, particularly with regard to biogeochemical cycles. Environmental monitoring and real-time measurements make it possible to test quantitative hypotheses or operating models. It is also possible to study several interacting factors within a statistical inference framework. Ecotrons thus offer a conceptual and technological breakthrough to address theoretical questions about the structure and dynamics of ecosystems, as well as more traditional questions about their sensitivity and adaptation to environmental changes. They help find solutions to current environmental issues by simulating, for exam-

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1. <http://www.ir-ecotrons.cnrs.fr/?lang=en>



-ple, pre-industrial climates or those predicted by the IPCC scenarios for the year 2050 or 2100.

### *Metatron*

Other tools, unique in the world, such as the Metatron<sup>1</sup>, study the response of species (adaptation or non-adaptation) to climate change and to the fragmentation of their habitat, in a semi-natural environment. A collection of 48 cages, each measuring 100 m<sup>2</sup>, are connected to each other by double-entry corridors. The entire arrangement is controlled remotely by software that allows precise control of parameters such as temperature, humidity or solar radiation (Figure 1). The objective of this apparatus is to describe the movements and demographic flows of the species being studied (insects, reptiles or small vertebrates) depending on variations to the environmental parameters. An equivalent instrumented device for aquatic ecosystems, the Meta-aquatron, is currently being developed. Consisting of 144 pools, each measuring 1.8 m<sup>2</sup>, linked together by 2-metre long corridors, its objective is to describe the movements and demographic flows of species as a function of temperature, eutrophication or reduced water flow rates. This apparatus will be enhanced with an equivalent aerial system in which domes will be placed over each pool. The domes will be linked by aerial corridors. In this way, it will be possible to study concurrently the responses of terrestrial and aquatic species to environmental pressures.

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1. <http://moulis.preprod.lamp.cnrs.fr/spip.php?rubrique40>



*Figure 1. View of the metatron at the experimental ecology station at Moulis (Ariège), © D. Joly.*

### *Ecology Stations*

The Ecology and Environment Institute of the CNRS is also developing a network of experimental Ecology Stations<sup>2</sup> distributed across France and its overseas territories. Its mission is to provide research facilities in the short, medium and long term that are accessible to the scientific community, to acquire general and multidisciplinary knowledge of the relationship between the dynamics, development and functioning of ecosystems. The aim is to propose scenarios for the conservation and management of natural resources in relation to the needs of human societies. Introduced over a long period of time (the oldest dates from the 1960s), the stations are installed at the heart of different types of ecosystems – terrestrial and aquatic (freshwater and seawater), continental and coastal, alpine, tropical and temperate – and encompass most biotopes. This network

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2. <http://www.cnrs.fr/inee/outils/stations-ecologie-exp.htm>



of experimental stations makes it possible to bridge the gap between ecosystems studied under controlled conditions that are necessarily smaller in size, such as those studied in ecotrons, and natural ecosystems. With its instrumented devices (for monitoring vegetable plots, for example) and the complementarity of its biomes, the network of stations allows differing degrees of climate and anthropic pressures on ecosystems to be studied (Figure 2).



*Figure 2. The flux tower at the Lautaret Alpine Station (SAJF) measuring energy and material flows in the soil-snow-vegetation-atmosphere continuum, © D. Joly.*



## **Observation and experimentation at the heart of socio-ecosystems**

### *Zones Ateliers*

Integrated in some cases for several years within the French regions, the “Zones Ateliers”<sup>1</sup> put research at the centre of public and economic action. They represent a mechanism combining the observation of socio-ecosystems with experimentation in natura and with local stakeholders (farmers, managers and decision-makers). The aim of the “zones ateliers” is to build an integrated research environment (biosciences, geosciences, physico-chemical sciences, human and social sciences), over a long period of time, to answer basic ecology questions, but also to respond to current societal challenges in the context of global changes. They are the place to co-construct questions and transfer the results to managers and society, in close partnership with local stakeholders. They are involved in all natural and human-made ecosystems (marine, forest, mountain, Africa savannah and Antarctic), distributed across the entire latitudinal range (from the tropics to the poles) and are also targeted at regions that are highly impacted by human activities (rural farmland, towns, water catchment basins). Research programmes, deployed to specific sites within the “zones ateliers”, analyse, on the one hand, the integrating and iterative processes of the interactions of human processes on the environments (and vice versa) and, on the other, the identification and quantification of ecosystem services. This analysis is used to assess the consequences of anthropic actions over short or long timescales and provides an understanding of the sustainability, resilience and adaptability of these systems.

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1. <http://www.za-inee.org>, which are French representatives of LTSER platforms



### *Human-Environment observatories*

The last in this range of tools devoted to the study of anthropic pressures on the environment are the Human-Environment observatories<sup>1</sup>. These are designed around a structural event of human origin that has a massive impact in ecological, economic and social terms. They are centred around a founding event that seriously disrupts the current structure and balance (for example, building a bridge or shutting down a mine). They represent an interdisciplinary tool supporting knowledge about interactions between humans and their environment, the analysis of their vulnerability and the dynamics of their transformation. The human-environment observatories carry out the assessment of the changes and effectiveness of interventions, in order to test specific solutions and support public decision-making. Developed at the national and international level, they respond to the ecological and social challenges of global change for sustainable development.

All these national observation and experimentation tools have a requirement for data quality, instrumentation efforts, sustainability and accessibility of information. All of which are essential for building an integrated research environment considering the complexity of systems being studied and especially their dynamics in response to environmental changes. In the age of information regulation, in particular from the French “Digital Republic” Law of 7 October 2016 and the European data access directives, these mechanisms should also be supported by information systems that satisfy the recurrent issues of sharing, interoperability between databases and how representative the data are, in synergy with the national and international initiatives in the areas concerned. Digital optimization in support of these tools is carried out by the joint CNRS and MNHN services facility, the Biodiversity Ecology Environment Societies Database<sup>2</sup>. Work is carried out in accordance with ISO standards and the European INSPIRE directive.

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1. <http://www.driihm.fr/en>  
2. <http://bbees.mnhn.fr/>



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