1
The place and role of public research in adapting to climate change

PRESENTATION

Research plays a key role in adapting to climate change, whether by generating knowledge, mobilising expertise to support decision-making or developing solutions.

The accumulation of knowledge about the climate since the 1960s has enabled the scientific community to alert decision-makers to climate risks at an early stage. In 1988, the United Nations founded the Intergovernmental Panel on Climate Change (IPCC), which collates scientific findings to inform action. France's highly structured climate science community has actively contributed to the climate projections on which the IPCC's analyses are based.

The IPCC organises its work into three working groups that reflect the structure of French research and are devoted respectively to climate science (group 1), impacts, vulnerabilities and adaptation to climate change (group 2) and mitigation of this change (group 3). Using a variety of methods (see box), the Court has been able to draw on the work carried out by these three groups in order to trace the place, resources and roles of French public research in adapting to climate change.

The place and role of research in adapting to climate change are part of a continuum (see diagram 1). Research on adaptation targets issues directly linked to adaptation to climate change. Research for adaptation includes this research on adaptation as well as all the climate infrastructures, data and knowledge that form the essential basis for all adaptation work and informing action. Research on mitigation was also discussed, in particular to identify research at the intersection between adaptation and mitigation, which is crucial for limiting maladaptation.

With regard to research for adaptation, France plays a leading role on the international stage. However, disparities exist between sectors and territories. Even if they can be brought together within the framework of specific projects, French laboratories appear to be highly specialised, with little integration of sustainability issues, which could increase the risk of maladaptation caused by a fragmented vision of the obstacles and solutions (I).

French adaptation research has significant resources at its disposal, both in human and financial terms and in terms of infrastructure. However, these resources, which are crucial to preparing for the future, are under considerable strain (II).

Providing a wealth of diverse scientific expertise to inform decision-making, French public research is also innovating by proposing numerous solutions. Among these solutions, climate services are an essential basis for enabling stakeholders to plan ahead. However, the impact of the results of research could be enhanced by greater visibility and stronger governance (III).

Methods used to compile an overview of research into climate change adaptation

In the absence of a specific IT system, and with the help of French research organisations, in particular the French National Research Agency (ANR), the Court has developed methods for analysing the performance and resources of research for adaptation.

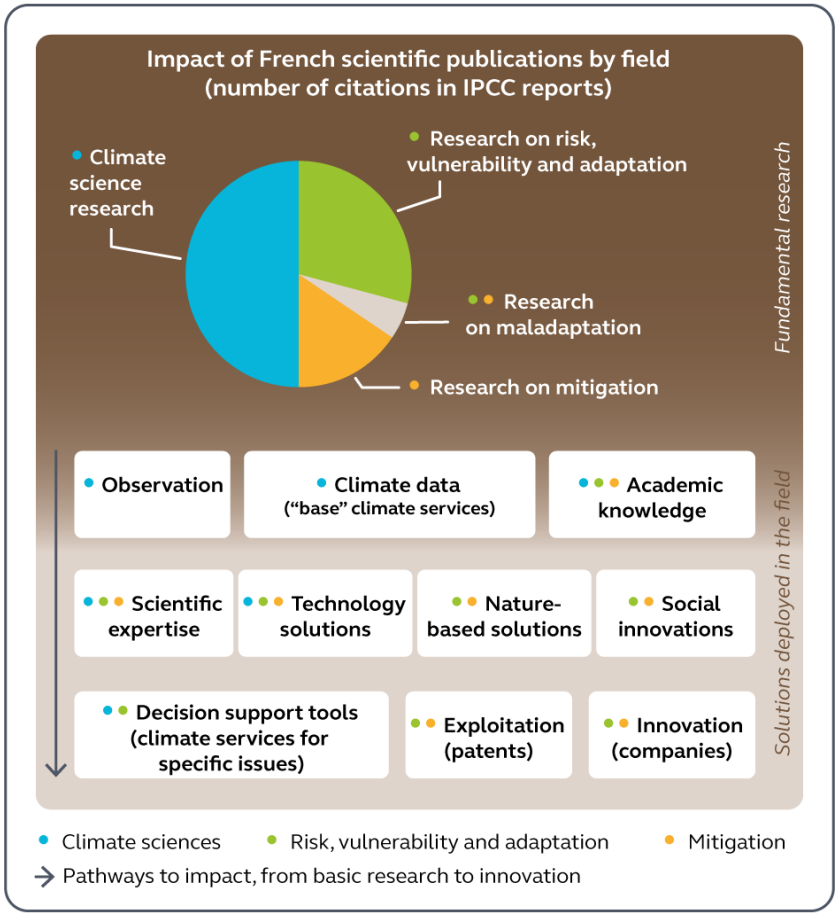
It based its analysis on over 40,000 citations of scientific publications mentioned in the three working groups reports of the 6th assessment report (AR 6) of the IPCC. These citations were harmonised and cross-referenced with open French research datasets[1]. Semantic analyses were also carried out, which, although less reliable than tracking IPCC citations, make it possible to reconstruct long series, in particular to trace funding over time.

To enable these methods to be used for other sustainability issues, in particular biodiversity and ecosystem services, monitored by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), the tools used are presented on the Court's website in the form of a methodological guide, open data and source code elements (see the international appendix below providing to the international audience a short description of the Court, an overview of the methodological guide and links to open resources with associated licences and disclaimers).

In addition to these quantitative methods, the Court gathered information from the major State funders and operators involved in research for adaptation. Interviews were also conducted with around 70 people, including in other EU Member States.

[1] In addition to the IPCC citations, the open data used includes the Hal bibliographic tool of the CNRS and the national directory of research bodies of the Ministry of Research. In order to be able to assess the scope of the analyses carried out on the basis of this open data, the Court used the InCites tool (for a fee). Hal's excellent coverage of the scope studied was verified for IPCC citations through collaboration with the ANR, which has access to raw "Web of Science" data.

Diagram n° 1 : the place and role of research in adaptation



Source: Court of Accounts
Climate sciences (in blue) is actively working on generic solutions for adaptation, such as observing the earth and making data available, mobilising the necessary expertise to facilitate the appropriation of climate projections or designing climate services with the relevant sectors. Research into impacts, vulnerability and adaptation (in green) covers a huge range of disciplines, including environmental science, climate science and the humanities and social sciences. As well as providing a wealth of new knowledge and expertise, this research is contributing to a wide range of targeted solutions for adaptation. As for mitigation (in yellow), it contributes to adaptation in the sense that it reduces the risk of maladaptation when approaches integrating adaptation and mitigation are developed in a comprehensive way.

I - France is a world leader in climate science, with a more modest position in adaptation and mitigation

French research stands out in the climate sciences and, to a lesser extent, in the fields of adaptation and mitigation (A). There are disparities between sectors and territories (B). Research potential is hampered by compartmentalisation (C).

A - The place of French work on the international stage

With a heritage dating back to the early 19th century, France plays a pivotal role in climate science. It has two major models of the Earth that can be used to simulate climate change and are the leading authorities in this field: the model developed by the *Institut Pierre-Simon Laplace* (IPSL) in Île-de-France and the model developed by Météo France's *Centre national de recherches météorologiques* (CNRM), in conjunction with Cerfacs in Toulouse.

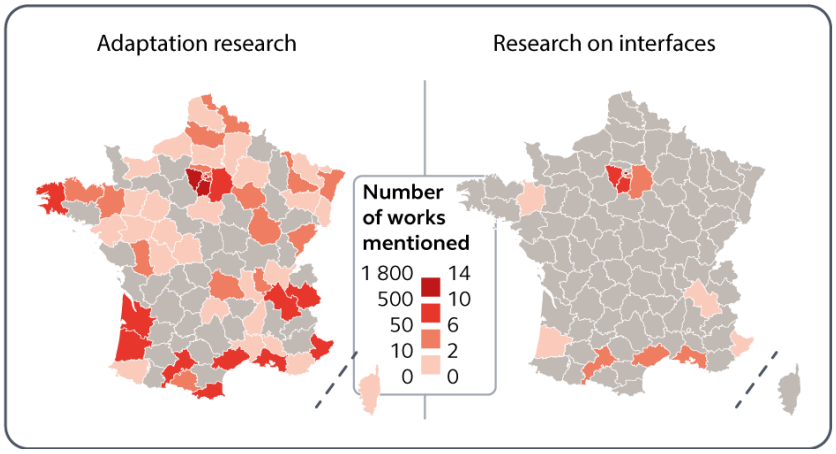
The Court's analyses of the IPCC's work show that France is a leading player in the field of climate science. It is ranked between 4th and 5th in the world, depending on the source, while it is 6th in general scientific terms. Its share of global publications cited by the IPCC is between 9.4 % and 14 %, which is higher than for all disciplines combined (4.5 %). Its weighting in the field of impacts, vulnerability and adaptation (between 5.5 % and 8.4 %) is also above average, although it is four places lower over the period 2011-2021 compared with 1999-2010. French research on mitigation, on the other hand, is less developed, accounting for between 2.9 % and 6 % of IPCC citations, putting it between 10th and 11th place.

B - National research marked by major sectoral and regional disparities

1 - Concentration of scientific capacity within a small number of territories

The climate sciences are concentrated in the Île-de-France region and around Toulouse and Grenoble. The sciences covered by the second group of the IPCC, including research on adaptation, are concentrated in the Île-de-France region, Toulouse and Montpellier. There are also secondary centres, notably in the Nouvelle-Aquitaine region. Overall, research for adaptation is fairly evenly spread (see chart 1, on the left).

Map n° 1 : metropolitan distribution of scientific capacity dedicated to the challenges of adaptation.



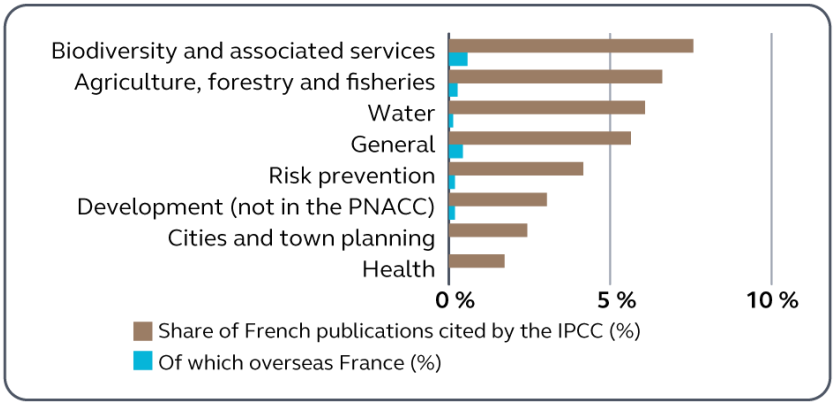
Source: Court of Accounts analyses based on citations from the IPCC (6th cycle) cross-referenced with Hal

2 - Uneven impact of research, with shortcomings in health and urban environments

French climate science has a major impact regardless of the topic addressed. On the other hand, research into impacts, vulnerability and adaptation has a variable impact depending on the sector and territory (see graphics 1 and 2 below).

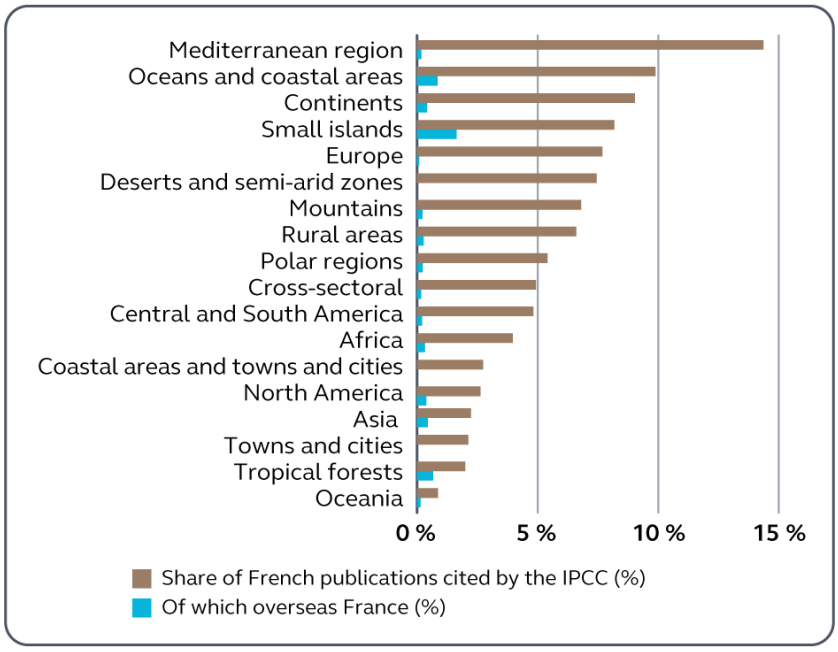
French research ranks at the highest international level in the fields of biodiversity and ecosystem services, Mediterranean areas and coastal and island areas. France is also well positioned in agricultural, forestry and water-related issues. However, it is not sufficiently well positioned in the areas of health, urban planning, cities and development.

Graph n° 1 : impact of French work on adaptation by sector (% of citations worldwide)



Source: Court of Accounts analyses based on citations from the IPCC (AR 6) cross-referenced with Hal

Graph n° 2 : impact of French work on adaptation by territory (% of citations worldwide)



Source: Court of Accounts analyses based on citations from the IPCC (AR 6) cross-referenced with Hal

Despite the major risks they face, overseas territories are poorly represented, with the exception of a few sectors and types of territory. Under the impetus of a dynamic metropolitan research structure[2], research on overseas territories is well developed for island territories. However, its weak presence *in* the French overseas territories risks slowing down the appropriation of knowledge and adaptation solutions. A targeted analysis of university sites in the French overseas territories shows that the research capacity dedicated to adaptation is better represented in Réunion and French Guiana than in the other overseas territories.

Regionalised climate projections for the French overseas territories need to be implemented rapidly in order to boost French scientific production on these territories and provide a better response to the adaptation challenges they face.

C - Potential hampered by compartmentalisation

1 - A large number of laboratories involved, often in different ways

The IPCC citations show that of the 3,451 French research laboratories, at least 7 % have contributed to research for adaptation and at least 3 % more directly to adaptation issues.

These figures reflect the strong involvement of the French community. However, the level of involvement in adaptation remains variable, with a handful of laboratories accounting for most of the IPCC citations relating to France. This phenomenon prevails in the climate sciences group. The most representative example is provided by the *Laboratoire des sciences du climat et de l'environnement* (LSCE)[3], which alone accounts for nearly 26 % of all citations for all sectors combined, and 45 % for the first group. The capacity of the second group is spread across a larger number of laboratories. The third group, which is smaller for France compared with the other two groups, is characterised by an intermediate level of concentration, with a few laboratories in the Paris region having a strong international profile.

[2] The "Littoral Environment et Sociétés" (LIENS) laboratory, under the joint supervision of the CNRS and La Rochelle University, which carried out a study funded by the ANR and whose work, widely cited by the IPCC, is devoted to small islands affected by climate change, with a global approach to the risks of erosion, submersion and degradation of coral reefs.

[3] LSCE, which is part of IPSL, is jointly supervised by CEA, CNRS and the University of Versailles-Saint-Quentin-en-Yvelines.

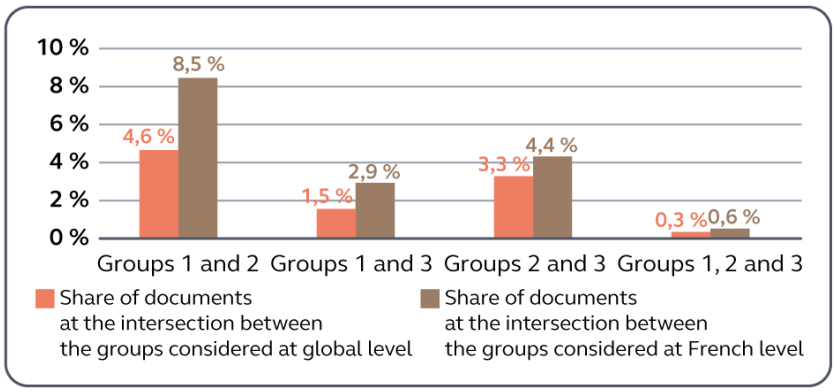
2 - Humanities and social sciences under-represented

The French research cited by the IPCC is structured along contrasting disciplinary lines. Group 1 is dominated by the climate sciences and Group 2 by the environmental sciences, with a significant weighting of climate sciences, life sciences and, to a lesser extent, the humanities and social sciences. The latter are predominant only in group 3 on mitigation. They are very poorly represented in research for adaptation, which is likely to weaken transition trajectories.

3 - Insufficient intersection between adaptation and mitigation, with risks of maladaptation

Scientific ecosystems remain compartmentalised (see graphic 3). Only the link between climate science (group 1) and risk, vulnerability and adaptation (group 2) is more developed in France. Mitigation sciences (group 3) appear to be disconnected from the other two groups, particularly the adaptation group. This weakness, which is not specific to France, increases the risk of maladaptation. There are, however, exceptions which can be detected using the method employed by the Court (see III). The limited scientific capacity dedicated to intersecting domains are concentrated in the Île-de-France region (see chart 1 above, on the right).

Graph n° 3 : research for adaptation split into silos



Source: Court of Accounts analysis of cross-references between IPCC groups
Reading key: group 1 covers climate sciences, group 2 impacts, vulnerabilities and adaptation, and group 3 mitigation. For example, "Groups 1 and 2" shows the proportion of work cited jointly by groups 1 and 2. While the approach used here does not reflect all interdisciplinary work, it does make it possible to estimate the proportion of work covering both adaptation and mitigation issues.

4 - Operators focused on climate sciences

Although some foreign players are exceptions, such as Wageningen University in the Netherlands and the Potsdam Institute for Climate Impact Research in Germany, the Court's analyses show that the international partners of French research are on the whole divided between climate science, adaptation and mitigation. France is no exception to this compartmentalisation, with a marked specialisation of its research operators in climate sciences. France's top twenty research on adaptation operators all specialise in climate science, with the exception of the French National Institute for Research in Agriculture, Food and the Environment (INRAE), the University of Montpellier and the French Research Institute for Exploitation of the Sea (IFREMER), which specialise in impacts, vulnerability and adaptation, and the Centre for International Cooperation in Agricultural Research for Development (CIRAD), the only operator specialising in mitigation.

Although they may come together within the framework of projects, French operators and laboratories appear to be specialised by discipline or sector.

II - Resources to be strengthened in the long term

France's performance in research for adaptation and, to a lesser extent, research on adaptation, can be explained by the resources deployed (see summary table below). Significant financial resources have been allocated (A), but this effort is in danger of being undermined by the pressure on scientific talent pools (B) and the lack of sustainability of research infrastructures (C).

Table n° 1 : resources for research for adaptation (in €m).

Type of resources	**Estimated amounts in €M per year**
Research projects (1/3 European Union, 1/3 National Research Agency (ANR) and 1/3 future investments)	81
Human resources (excluding research bodies)	129
Research infrastructures (operating)	149
Total research for adaptation (low estimate)	359
Total public research expenditure across all sectors (source: MESR, for 2020)	**18,100**
Share of research for adaptation (%)	At least 2 %

Source: Court of Accounts summary and estimates
The amounts for multi-annual projects have been standardised by the number of years concerned in order to obtain an annual average. Data relating to the staff of research organisations cannot be produced due to shortcomings in the IT systems.

A - Significant financial resources deployed

Globally, the European Union (EU) is the second largest funder of the work cited by the IPCC[4]. The French National Research Agency (ANR) ranks 17th or 18th[5]. In France, the EU and the ANR are the top two funding bodies. The ANR funds the production of new knowledge, in line with the second national plan for adaptation to climate change (PNACC). Future investments, which support research geared towards more practical applications, also play an important role.

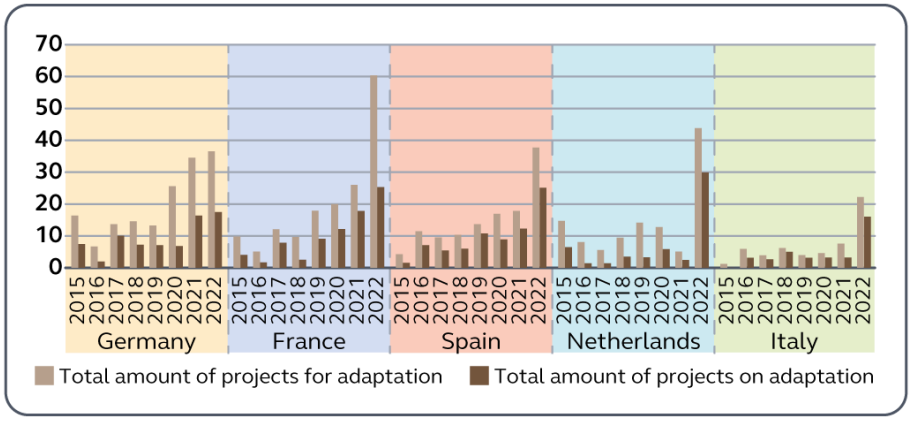
1 - Success in European calls for projects

Over the entire period 2015-2022, for France, Germany, Spain, Italy and the Netherlands, research for adaptation accounts for 4 % of projects funded by the EU[6]. For research on adaptation, the ratio is 2 %[7] of the total EU budget for research and development. The trend is towards increased funding (see graphic 4 below). For all the countries analysed, the selection

[4] Behind the American National Science Foundation.
[5] The ANR is ranked 17th according to InCites and 18th according to data from the Web of Science database provided by the ANR, restated to remove duplicates.
[6] 723 adaptation projects out of a total of 19,178 successful projects, corresponding to €619.63 million in EU subsidies out of a total of €16,825.53 million. The average European grant in the field of research for adaptation is therefore €857,000 per successful project.
[7] 384 projects totalling €328.38 million funded by the EU.

rates for these subjects are higher than average, which indicates that they receive priority support from the Commission. According to a study by the European Court of Auditors, although the Commission has adopted ambitious climate funding objectives, the target is still a long way off[8].

Graph n° 4 : european funding for research on adaptation (in €M)



Source: Court analysis based on European data sets from the MESR

With regard to successful European research for adaptation projects, France (€161.05 million) is tied for first place with Germany (€161.06 million), ahead of Spain (€121.69 million), the Netherlands (€113.72 million) and Italy (€55.68 million). In terms of research on adaptation, France is in first place among the five countries studied (€80.52 m, compared with €77.24m for Spain, €74.54m for Germany, €54.26m for the Netherlands and €36.49m for Italy). In terms of selection rates, France came first for projects in adaptation and second for projects for adaptation, behind the Netherlands.

2 - Declining national funding for research on adaptation

At national level, research into adaptation projects is supported by the ANR. Over the period 2012-2022, funding allocated to research for adaptation increased. The implementation of the law of 24 December 2020 on research planning for the period from 2021 to 2030, which increased the ANR's budget from 2021 onwards, has had a significant impact on research for adaptation as well as on all the research it supports. For 2023, the ANR's operating credits will be 7.4 % higher than in 2022, which could enable research for adaptation to be better funded.

[8] European Court of Auditors, Special Report 09/2022: *Climate spending in the 2014 2020 EU budget- Not as high as reported*. See: https://www.eca.europa.eu /EN/ publications/SR22_09.

According to analysis of an ANR database, the consistency of which was verified by the Court, research for adaptation and research on adaptation account for 3.9 % and 1.4 % of the agency's budget respectively. The second PNACC (2018 - 2022) has had no additional effect compared with the first PNACC (2011 - 2015). The increase in ANR funding is +9.6 % for research for adaptation, compared with +18.1 % for all fields. Specific funding for adaptation even decreased between the two national plans. Research into climate risks has remained stable overall. Only climate-related research has increased at a more sustained rate.

ANR funding is allocated in proportion to the number of projects submitted to evaluation committees. Insofar as there is no specific evaluation committee for adaptation, funding in this area appears to be limited. The Agency's support for research for adaptation was proportionately higher between 2010 and 2012. At that time, the "*management and impacts of climate change*" (GICC) programme was still active and provided targeted support to supplement the projects funded by the ANR, which may have played a structuring role.

Research on adaptation needs specific incentives to strengthen the scientific communities involved and the links between them.

3 - Exceptional funding as part of future investments (France 2030)

In addition to its own calls for projects, the ANR also manages the research funding earmarked for the future investment programmes (PIA), now known as France 2030. These programmes fund more application-oriented research. Most of the PIA funding relating to adaptation were concentrated on the period of the first PNACC, totalling €270 million, compared with €126 million for the second PNACC.

Of the AIP instruments, only the "Make our planet great again" (Mopga) action is described in detail in the second PNACC. Of the total €30 million of planned subsidies, it is estimated that between €13.2 million and €24.6 million will be devoted to adaptation research. Some recently launched Mopga projects have already led to publications cited by the IPCC. This interim assessment should be updated.

New instruments, known as priority research programmes and equipment (PEPR, see inset), should increase the funds devoted to research for adaptation, targeting the strengths rather than the weaknesses of the French research system. This approach, if not counterbalanced by more integrated approaches, could increase the risk of maladaptation.

PEPRs: new financial perspectives for adaptation, a reproduction of sectoral silos

As part of France 2030, the Priority Research Programmes and Equipment (PEPR) fund research in line with political priorities. According to the participants interviewed, no fewer than 11 PEPRs, representing a total of €483.2 million, or 16.1 % of the total budget allocated to all PEPRs (€3 billion), fall within the scope of research for adaptation.

Of these 11 PEPRs, eight are co-lead by the CNRS and seven by the INRAE, the two major operators specialising in climate science and adaptation respectively. These players jointly manage four PEPRs. Only one is co-led by the three main operators specialising in climate science, adaptation and mitigation (CNRS, INRAE and CIRAD). By way of illustration, the Traccs[9] and AVS[10] PEPRs fall within the direct scope of research for adaptation and will help to develop technological solutions for adaptation (optimised plant and climate services respectively).

None of the PEPRs target adaptation issues in a cross-sectoral and global manner.

B - Scientific talent pools under pressure

The funding allocated to project-based research, which accounts for a large proportion of resources, is not the whole story. To this should be added the regular funding provided by the ministry of higher education and research and operators for infrastructures, as well as permanent staff. The latter are essential for carrying out project-based research, mobilising infrastructures to produce new knowledge and solutions and, ultimately, offering high-quality expertise to stakeholders. Permanent research staff are also essential for nurturing the young talent of tomorrow[11].

[9] *Traccs PEPR (€51 million over eight years, co-led by the CNRS and Météo France), for which "the challenge is to transform climate modelling methods by improving our understanding of impacts and risks, in order to develop climate services and meet societal expectations in terms of adaptation and resilience*". See: https://www.insu.cnrs.fr/fr/PEPR-TRACCS

[10] PEPR *Sélection variétale avancée (SVA) face aux changements climatiques (Advanced varietal selection (AVS) in the face of climate change*) (€30 million over eight years, co-led by INRAE, CIRAD, IRD, CNRS and agricultural engineering schools), which aims to adapt agriculture to climate change by using varietal selection techniques. See: https://www.inrae.fr/actualites/accelerer-transitions-agroecologique-alimentaire-3-programmes-equipements-prioritaires-recherche

[11] Research-led training for PhD students who will go on to work in research or other sectors.

1 - Falling numbers of permanent staff

Analysis of a large proportion of the scientific talent pools in the area of research for adaptation at university sites shows that staff numbers are stagnating both in climate sciences (down 2 % between 2010 and 2021) and in research into impacts, vulnerability and adaptation (down 1 % over the same period). A worrying trend can be seen in the recruitment of young teacher-researchers (lecturers, down by 6 % and 4 % for the two areas), for whom the recruitment rate is lower than for established teacher-researchers (university professors, up by 7 % and 5 % respectively).

2 - After a growth phase, the training of young talent in research for adaptation has stagnated

The number of theses in the field of research for adaptation in general and research on adaptation in particular rose sharply in the early 2000s (231% and 364 % respectively between 2000 and 2010). Growth in these fields far outstripped the average growth rate for theses across all disciplines (+15 % over the same period). However, this strong growth has come to a halt since 2017-2018.

In view of the growing need for expertise in the field of adaptation, the scientific talent pools are undersized, with weaknesses identified in both the short term (permanent researchers) and the long term (young talent trained through research).

C - Vital infrastructures with uncertain long-term financing

Research for adaptation requires the mobilisation of major research infrastructures to provide the basic data needed for scientific work, whether in the form of observation data on the Earth system in all its components, data simulated using computational resources (see box) or experimental data to assess the impacts of climate change.

Supercomputers, key tools for climate simulations

The Climeri-France infrastructure enables the production of benchmark climate simulations on different geographical scales. It integrates models from the *Institut Pierre Simon Laplace* (IPSL) and Météo France, making it easier to exploit climate change simulations.

Climeri-France groups together the computing resources needed to carry out the simulations, drawing in particular on the large-scale national intensive computing facility (Genci) and Météo France, as well as data storage and human resources. The total cost of this infrastructure is estimated at €12 million per year, including around €6 million in computing and storage costs at Genci. The associated publications are unusual in that they involve a very large number of authors and funders. They are widely cited and form the scientific basis of the IPCC.

Météo France's supercomputers are also used to forecast climate change on a French scale, using methods that regionalise the latest global predictions[12]. These new projections are used to update Drias Climat[13], the reference French portal for data on climate change.

Some research infrastructures are funded by programme 172, Multidisciplinary Scientific and Technological Research, of the Interministerial Mission for Research and Higher Education (Mires). Most are financed from the research organisations' own funds, which could lead to problems of sustainability.

The operating cost of research for adaptation infrastructures is estimated at least €137 million per[14], not including the cost of Climeri France (estimated at €12 million a year).

Many key infrastructures are facing issues related to their age, with no funding identified for their modernisation.

[12] Ribes and co-authors, "An updated assessment of past and future warming over France based on a regional observational constraint", Earth System Dynamics, 2022.
[13]Drias stands for "Donner accès aux scénarios climatiques Régionalisés français pour l'Impact et l'Adaptation de nos Sociétés et environnement" (Provide access to regionalised French climate scenarios for the impact and adaptation of our societies and environment).
[14] A low estimate, since many costs, particularly in terms of human resources associated with infrastructure operation, were not systematically specified by the players interviewed by the Court.

III - Scientific support for society suffering from a lack of national coordination

Scientists provide key expertise to inform decision-making. However, there remain gaps resulting from local initiatives that are developing in a fragmented way. Coordination between government departments and operators and local authorities needs to be strengthened. Research promotes innovation and offers a wide range of adaptation solutions and services. Despite the progress made, the dissemination of services and other solutions could be improved. To mitigate the effect of siloed management, a reorganisation of the governance of research activities is needed. The implementation of the next national plan for adaptation to climate change (PNACC) should provide an opportunity to establish greater coordination between the various players.

A - The vital but inconsistent role of scientific expertise in decision-making support.

The resources deployed in support of research for adaptation have made it possible to build up a structured scientific talent pools, which is essential for informing adaptation policies and investment decisions at all geographical scales.

1 - The presence of French experts within the IPCC is a major asset in decision-making support

Scientific expertise in research for adaptation is present at all levels, first and foremost through the IPCC, whose work informs the climate policies pursued by virtually all public players. France is formally represented on the IPCC by the Directorate General for Energy and Climate (DGEC), which reports to both the minister for environmental transition and territorial cohesion and the minister for the economy, finance and industrial and digital sovereignty.

Due to their influence, the French experts at the IPCC play an important role in decision-making at all levels (international, national, regional). The hierarchy observed in the standing of French experts within the IPCC is consistent with the analyses of the scientific work cited by this body, which underlines the importance for States of strengthening their research capacity in order to be in a position to have an impact in terms of expertise at international level. Increasing the French presence, with experts specialising jointly in adaptation and mitigation (IPCC groups 2 and 3),

should be a long-term priority for the 7th IPCC assessment report, which began in 2023.

2 - Regional groups of climate experts: local mechanisms that require better coordination with the national level

Over the last ten years or so, in response to the climate emergency, various joint science-society initiatives have been set up to inform decision-making as closely as possible to local issues. These bodies, which offer expertise tailored to local issues, are now known as regional expert groups on climate (GREC).

The scientific expertise provided by GRECs complements that of national operators such as Météo France, Ademe and the Cerema (French Centre for Studies and Expertise on Risks, the Environment, Mobility and Land Use). These organisations offer adaptation solutions to local authorities, although their approach is more focused on tools and structured service offerings. These players themselves also call on scientific expertise to ensure the quality of their services.

There are ten GRECs in total. Their distribution throughout the country is uneven. There are no such groups in five regions of mainland France or in the overseas territories, with the exception of Guadeloupe. These groups have different statuses and are not recognised in the same way[15]. Some have the unique feature of being attached to research bodies, which provides a framework for legitimising their expertise.

All in all, whatever their level of maturity, the GRECs do not have an institutional structure comparable to the IPCC and are not always based on the latest scientific findings. The IPCC has published an opinion stating that two GRECs claiming to be "regional IPCCs"[16] had in no way been endorsed by the international body.

The status of these groups should be harmonised at national level, if necessary under the guidance of the regions. A label could be created, subject to compliance with specifications to ensure the quality of their expertise. In line with its missions, which it carries out both at national level and with local authorities, the High Council for the Climate (HCC), which brings together many scientists involved in research for adaptation, would have the task of defining the specifications for this label and assessing the structures likely to benefit from it.

The ministry of ecological transition could provide the secretariat for the labelling process and lead the GREC network to promote the coherence of

[15] Influence was measured in terms of the number of citations of GREC websites.
[16]The "GIEC des Pays de la Loire" and the "GIEC-normand".

French expertise. Synergies could be sought, for example to carry out coordinated expert assessments for areas facing similar climate risks. The HCC could also call on the GREC network to strengthen the territorial dimension of its opinions, from a comparative perspective.

Overall, better governance of territorial expertise would encourage synergies at a time of growing pressure on the relevant talent pools. Coordination between the State and local authorities regarding the use of expertise would make it possible to avoid duplication of studies on subjects of common interest (urban, coastal, mountainous areas, etc.).

B - Examples of how French research is contributing to a range of adaptation solutions

1 - Complementary solutions

French research, depending on the specialisation of its laboratories, innovates and proposes numerous solutions for adaptation. In order to meet a specific need expressed by a particular player, sector or territory, an integration process is required to propose a coherent set of solutions. This integration process takes the form of collective expertise, consultancy or service provision, and can also be provided through research projects.

a) Technological solutions

Among the technological solutions, reference climate data portals and climate services, which are more structured and offer operational adaptation responses, form a digital foundation that is often indispensable for all other research and solutions. Numerous other technological solutions are being developed to adapt specific sectors, for example to maintain crop yields[17], improve building habitability by using more appropriate materials, or protect people's health by discovering molecules that reduce the risks of infectious diseases aggravated by the climate, as in the case of malaria. The development of these solutions has resulted in the filing of patents and the creation of innovative research-based companies.

The patents are easy to trace, as their classification includes a category relating specifically to adaptation. A study by the French High Council for

[17] For instance, numerous genetic selection techniques can be used to select plants that are resistant to heat stress (see, for example, the PEPR "*Sélection variétale avancée (SVA) face aux changements climatiques" (*Advanced varietal selection (AVS) in the face of climate change) already mentioned in section II.C).

the Evaluation of Research and Higher Education[18], based on similar monitoring, concluded that France filed 6.2 % of patent applications relating to climate change, placing it sixth globally. The latest data from the European Patent Office shows that France files 4.8 % of applications related to climate change, with a lower level for adaptation (4.2 %) than for mitigation (4.9 %). The number of patents jointly targeting adaptation and mitigation objectives is low, but France manages to do better than the overall average (5.4 % compared with 4.8 %).

Several innovative companies with a strong research and development component were identified. A semantic analysis was first applied to the open data made available by Ademe. In total, 17 funded projects were identified, out of a total of 1,174, or 1.4 % of projects. Ademe's response made it possible to confirm this order of magnitude and to identify the projects covered by the scope of the survey.

By way of example, the start-up Mycophyto, a spin off from by INRAE and the Université Côté d'Azur[19], is carrying out the MycoAgri project, funded by Ademe. The aim of the project is to develop and market mycorrhization solutions, i.e. symbioses between plants and microscopic fungi, for vines and roses. The aim is to increase the root surface area of plants, so that they are more resistant to drought and need fewer inputs (fertilisers, water).

b) Nature-based solutions

Nature-based solutions (NBS) are a set of methods for managing ecosystems with the aim of improving or at least preserving the services they provide to mankind and the environment, particularly in terms of adapting to climate change. Examples of concrete achievements in this field are provided by the "Pathways of Transformation in the Alps" (PORTAL) project[20], led by a CNRS researcher attached to the Grenoble alpine ecology laboratory[21].

PORTAL has led to the creation of a platform of nature-based solutions initiatives in the Alps[22]. This model could inspire new ways of adapting to climate risks in mountain areas. The PEPR "*Biodiversité et*

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[18] See: https://publication.enseignementsup-recherche.gouv.fr/eesr/FR/EESR15_R_53/la_position_scientifique_et_technologique_de_la_france_dans_la_recherche_sur_l_environnement/.
[19] See http://mycophyto.fr/.
[20] https://anr.fr/ProjetIA-19-MPGA-0009. This project was funded by the MOPGA programme referred to in section II.
[21] Laboratory under the supervision of Grenoble Alpes University, Savoie Mont Blanc University and the CNRS.
[22] https://portal.osug.fr/

solutions fondées sur la nature : innover avec la nature pour créer des impacts positifs pour la biodiversité, la société et l'économie" (Biodiversity and nature-based solutions: innovating with nature to create positive impacts for biodiversity, society and the economy) (Solubiod), supported by CNRS and INRAE, proposes new scientific approaches to NBS.

c) Social innovations

Social innovations include a wide range of work, such as scenario-building with stakeholders in a given area on adaptation trajectories using, for example, nature-based solutions (see box) or comparative methods of governance for adaptation policies[23]. They also relate to the way in which research is conducted in the area of adaptation, for example through the 'action research' approach[24].

Such research encourages exchanges between stakeholders whose interests may diverge, in order to identify the most consensual solutions for adaptation, which are then likely to be adopted and deployed on a large scale. Social innovations are driven by the humanities and social sciences, whose involvement remains limited within the scope of the IPCC's 2nd group, which covers adaptation (I).

An example of a participatory research project to strengthen adaptation in the Alps by mobilising social innovations

Socio-ecosystems include social elements as well as closely associated biophysical elements. Through the quality of life they provide for populations, socio-ecosystems contribute to adaptation to climate change[25]. In the coming years, strengthening adaptation through nature-based solutions will require major changes in the practices that underpin the many interactions between humans and their environment[26].

[23] Bauer and co-authors, *The governance of climate change adaptation in 10 OECD countries : challenges and approaches*, J. of Environmental Policy & Planning, 2012.
[24] Compos and co-authors, *Climate adaptation, transitions, and socially innovative action-research approaches*, Ecology and Society, 2016.
[25] See: Enora Bruley and co-authors, *Actions and leverage points for ecosystem-based adaptation pathways in the Alps*, Environmental Science and Policy, 2021 (https://doi.org/10.1016/j.envsci.2021.07.023).
[26] Summary of the *Mountain paths* participatory research project, a study of ecosystem-based adaptation in the Alps (Alpine Ecology Laboratory).

Against this backdrop, developing ways of adapting alongside the stakeholders in the territories concerned is a strategic priority. This process relies on social innovations such as the formalisation of adaptation scenarios and the use of serious games. As part of the "Mountain paths" project, stakeholders in the Pays de la Meije, located in the Alps on the edge of the Écrins massif, were invited to design a desired vision for their territory in 2040 and to reflect on the strategies and modes of action to achieve it. The project, coordinated by a CNRS researcher, was financed by the ANR and PIA funds.

2 - Deployment of climate services to be stepped up

The climate projections developed by the climate sciences form the essential basis for planning and investment strategies. In order to meet operational needs, this complex data must be combined with studies applied to specific sectors and territories, with the use of "à la carte"[27] scientific expertise or with targeted climate services (see box below).

An example of French research to reduce the risk of maladaptation caused by large-scale air conditioning

A typical case of maladaptation would be the large-scale deployment of air conditioning to reduce the impact of heat waves. This solution would have two harmful consequences: on the one hand, it would increase CO_2 emissions, which would exacerbate the impact of climate change; on the other hand, it would increase the temperature outside buildings, which would be dangerous for vulnerable people exposed to it. With a view to reducing this risk of maladaptation for the Paris region, this issue was analysed by a French study cited in the IPCC reports for both adaptation and mitigation issues[28].

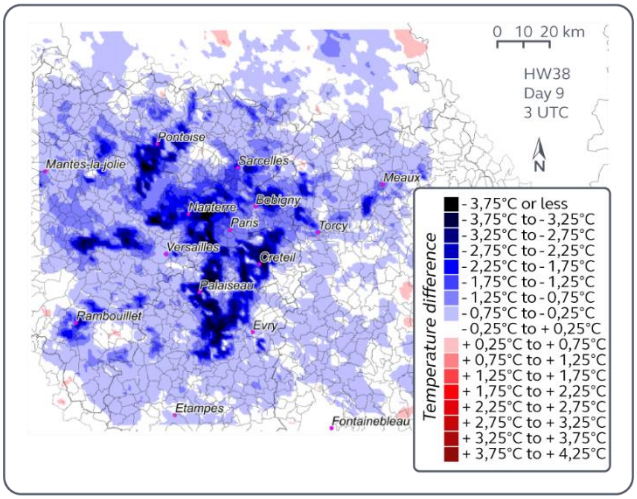
[27] See, for example, the Court's report on adapting nuclear reactors to climate change, which notes that EDF uses projections from France's two major climate models and regularly calls on scientific expertise to guide its strategic planning.

[28] See the study by Vincent Viguié and co-authors, *Early adaptation to heat waves and future reduction of air-conditioning energy use in Paris*, *Environmental research letters*, 2020 (https://doi.org/10.1088/1748-9326/ab6a24). This study is cited jointly in the reports of IPCC groups 2 and 3, which deal respectively with adaptation and mitigation (see I).

In this study, the authors simulated a scenario of air conditioning used in the city in combination with three adaptation actions: the creation of parks; the insulation of buildings and the use of reflective materials; and the implementation of effective recommendations for moderate use of air conditioning.

According to the simulations, this approach would enable effective adaptation (see the chart below showing the predicted reductions in temperatures during heatwaves) while reducing greenhouse gas emissions by around 60 % compared with a situation of poor adaptation that would simply use air conditioning on a large scale without implementing other adaptation solutions.

Cart n° 2 : reductions in predicted temperatures during heat waves



Source: study by Vincent Viguié and co-authors, "Early adaptation to heat waves and future reduction of air-conditioning energy use in Paris", *Environmental research letters, 2020*

Climate services are expanding rapidly, making it possible to provide information in a digital format suitable for decision-making support[29]. Three types of climate services can be distinguished:

- harmonised data portals, mainly operated by climate science bodies;
- diagnostic and decision-making tools for specific sectors, territories and issues, often developed at the intersection between climate

[29] See, for example, the article on climate services proposed by Vautard et al. in view of the Onerc in March 2022 (https://www.vie-publique.fr/rapport/284298-la-prospective-au-service-de-ladaptation-au-changement-climatique).

sciences and the many scientific disciplines that analyse risk, vulnerability and adaptation;

- platforms that centralise information on adaptation issues and compile data portals and diagnostic and decision-making tools, as well as other solutions.

Overall, French public research plays a significant role in 39 services. The reach of these services can be assessed because they are associated with publicly accessible websites.

a) Strategic open data portals

Two of these services account for the majority of online coverage: Drias Climat[30], launched in 2012, and the Copernicus Climate Change Service (C3S)[31], launched in 2020. These two services offer free and open reference climate data, without which other research and services relating to climate issues would not be able to develop.

France, a leading country in the field of climate services

Drias Climat, managed by Météo France, was launched in 2012 with the support of the French ministry of ecological transition. This reference data portal enjoys a high profile. Within the European Union, French research centres are well integrated into the workings of European climate services. The European Earth observation programme Copernicus was launched in 2013. It is the world's largest provider of space data and currently comprises six services that add value to this data, including a climate change service (C3S). France is the second largest user of C3S. The *Institut Pierre-Simon Laplace* (IPSL) and the Laboratory of Climate and Environmental Sciences (LSCE) are the main contributors to this service. France also participates in research programmes funded by the European Union. Sixteen of the 26 projects to develop climate services under the Joint Programming Initiative "Connecting Climate Knowledge for Europe" (JPI-Climate) include a French team, and three of them are coordinated by a French organisation.

b) Services on the rise, but with significant disparities

As of 2018, the number of climate services deployed has risen sharply, thanks in particular to a "climate services agreement"[32] signed for

[30] https://www.drias-climat.fr/
[31] https://climate.copernicus.eu/
[32] https://convention-services-climatiques.lsce.ipsl.fr/

the period 2017-2020 between the ministry of ecological transition and the CNRS, aimed at supporting the development of these services. Despite this quantitative progress, the sectoral reach of these services appears limited, except in the field of tourism with ClimSnow (see box). Few services concern teachers and private individuals, although those that do exist have a higher profile than services for other groups.

ClimSnow, a flagship climate service for decision-making support

The result of scientific collaboration between Météo France and INRAE[33], ClimSnow is operated in association with Dianeige, a private firm specialising in mountain resort development.

This service makes it possible to assess changes in snow cover under the impact of climate change. It has been applied to resorts in the Alps and Pyrenees to predict changes in snow cover in these regions over different time horizons[34].

ClimSnow is also used to provide detailed, fee-based expert assessments at the request of the stakeholders involved (ski area operators and local authorities), producing opinions on the ability of ski resorts to maintain their operations and offering recommendations on tourism strategy and infrastructure.

ClimSnow is a rare example of a climate service that combines diagnostic tools based on high-level modelling and open data with 'à la carte' support for concrete adaptation solutions, even if it is not always used to good effect by the parties involved[35].

c) Insufficient visibility for applied research and research-based solutions

The network of players associated with climate services involving France is mainly structured around the major French players in the climate sciences and the Drias Climat portal. Some GRECs play an important role with in this network.

An adaptation resource centre, planned as part of the second PNACC, has been set up by the ministry of ecological transition, Cerema, Ademe and

[33] CNRM and LESSEM respectively.
[34] Source: figure taken from François et colleagues (2022), 35th annual conference of the International Association of Climatology (IAC).
[35] See the chapter in this report on The impact of climate change on mountain tourism stakeholders.

Météo France. The centre receives 10,000 unique visitors a month, an increase of 15 % over one year. However, despite this momentum, its structuring role appears to be of secondary importance in the climate services network. A comparative analysis with the French centre's European counterpart confirms this low level of recognition for the French portal. The relative influence of Drias Climat appears to be much greater (see table 2 below).

Table n° 2 : comparison of the influence of key climate services for France and the European Union

Nature of service and associated indicators	**French service**	**European Union (EU) counterpart service**
Information platform	adaptation-changement-climatique.gouv.fr	climate-adapt.eea.europa.eu
Influence	109	1,353
France/EU ratio	8.1%	
Harmonised data portal	drias-climat.fr	climate.copernicus.eu
Influence	1,129	2,752
France/EU ratio	41.0%	

Source: influence (number of website citations) calculated with Ubersuggest in June 2023. France accounted for around 17 % of the EU's GDP in 2019[36], which provides a reference value for interpreting the ratios presented above.

Regardless of the changes envisaged by the supervisory bodies, the platform proposed by France to guide adaptation strategies could play a more central role by including a more exhaustive identification of research projects and players, as well as a hierarchical ranking of the services offered on the basis of feedback from users and usage statistics.

C - Improved interministerial coordination required

In addition to its responsibilities within the IPCC, the ministry of ecological transition coordinates the PNACC. As such, the second PNACC requires the ministry of ecological transition to co-lead the "knowledge and information" aspect of this action plan with the ministry for higher education and research, in conjunction with the other ministries and operators. Many of the actions planned have been implemented in silos. The most striking example is the financial support provided by the ANR, an agency that

[36] https://france.representation.ec.europa.eu/qui-sommes-nous/la-france-dans-lue_fr

essentially supports fundamental research. However, this funding model has not made it possible to focus resources on research on adaptation.

The ANR and the ministry of ecological transition do carry out joint work, but only to track the funding devoted to research on adaptation a posteriori. Adaptation research, which by definition is interdisciplinary or[37] even transdisciplinary[38], is more difficult for researchers to promote. The incentives offered by scientific institutions (in terms of funding, recruitment, publication and evaluation) are still dominated by the disciplinary excellence model. This type of research needs to be coordinated and given specific direction to encourage the structuring of a scientific community that brings together several sectors and boosts the production of knowledge, experts and solutions for adaptation.

There are effective tools and methods for stimulating this type of research, particularly in the agricultural sector[39] and in the fields of the environment, energy and land-use planning[40]. However, apart from a few fruitful collaborations between sectors, French innovation models are still largely structured by sector and therefore by ministerial portfolio. The new priority research programmes and equipment deployed under the aegis of the General Secretariat for Investment, such as the Traccs project for climate services, are no exception to this model.

The development and implementation of a national research strategy on adaptation issues by the ministry of higher education and research (MESR), in support of the more general PNACC carried out by the ministry of transport, energy and communications (MTE), would give impetus to this field of research and provide better guidance for funding, particularly in the context of the PEPRs.

Overall, the ministry of higher education and research should support a research strategy targeting adaptation issues. Greater coordination between the various players should be sought with a view to the next national plan for adaptation to climate change.

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[37] Interdisciplinarity refers to research conducted by researchers from different disciplines.

[38] Research is transdisciplinary when it is conducted by academic researchers and non-academic actors.

[39] INRAE explained that, for the agricultural world, a range of actors, projects and tools facilitate the transition from the production of knowledge to the deployment of innovations in the field, in liaison with the stakeholders concerned.

[40] The ministry of ecological transition has a scientific and technical network of specialised operators, including Météo France, Ademe and Cerema, which facilitate the scaling up and translation of research knowledge into operational applications.

CONCLUSION AND RECOMMENDATIONS

France is a world leader in research for adaptation, particularly in climate science and research into ecosystem services, Mediterranean areas, coastal areas and small islands. It is also well positioned in agricultural, forestry and water-related issues. On the other hand, it lacks scientific expertise in the areas of health, urban planning and cities, as well as in the field of development, where it is under-resourced in the overseas territories, and in issues relating to maladaptation. In addition, this research remains compartmentalised between sectors.

French success stems from the substantial resources deployed over a long period of time, although there are risks associated with increasingly stretched human resources, insufficiently targeted funding for research on adaptation and difficulties in funding research infrastructures. Some scientific talent pools, which are sometimes in great demand, may not be able to meet the growing demand, despite the increase in 'exceptional' funding available in these areas. Overall, the resources deployed could soon prove insufficient to meet the needs generated by the transition.

Under the impetus of the main players in the climate sciences and sectoral research institutes, digital climate services are beginning to be deployed with a view to adaptation, albeit with varying degrees of success. The visibility of these services, like that of the much wider range of solutions for adaptation and French scientific expertise, suffers from shortcomings and could be enhanced. The governance of research for adaptation could be strengthened by better linking the national level with the profusion of local initiatives that are progressing in a fragmented fashion.

The Court makes the following recommendations:

1. *develop a national strategy for adaptation research to support the national plan for adaptation to climate change (ministry of higher education and research);*
2. *rebalance resources in favour of research on adaptation, with particular emphasis on health, cities, overseas territories and areas where adaptation and mitigation are shared (ministry of higher education and research, ministry of ecological transition and territorial cohesion);*
3. *create a label for regional climate expert groups and include them in a network coordinated by the ministry of ecological transition (ministry of higher education and research, ministry of ecological transition and territorial cohesion, High Council for the Climate);*

4. *set up research dashboards and a map of the expertise available to all players on adaptation to climate change and other scientific issues relating to climate and biodiversity (ministry of higher education and research, ministry of ecological transition and territorial cohesion);*
5. *prioritise climate services, tools that offer decision-making support based on climate projections, according to their use and user feedback (ministry of ecological transition and territorial cohesion).*

Responses received at the date of publication

Recipients with no comments

The Chairman and Chief Executive Officer of the National Centre for Scientific Research (CNRS)
The President and Chief Executive Officer of Météo France

Recipient who did not respond

The Minister for Energy Transition

RESPONSE FROM THE MINISTER FOR ENVIRONMENTAL TRANSITION AND TERRITORIAL COHESION

The State deploys observation, expertise and research capabilities. These various components need to be aligned, as the Court of Accounts points out, not forgetting innovation, education and the territorial aspect.

While the minister for higher education and research provides overall coordination, I share the concern that research should support public policy. The bodies under the authority of my ministry are thus positioned to focus on research and expertise in support of action. F*or example, Météo France, a key player in the field of climate data and services, Cerema, which works on reducing vulnerability and promoting more resilient territorial development, and the* Université Gustave Eiffel *(UGE), which works on sustainable adaptation of towns and territories.*

You highlight the contribution of several research programmes (PEPR), supported by France 2030, to adaptation issues. This is due to the nature of the subject, which is at the intersection of very wide-ranging issues, both technological and societal, such as the resilience of societies and urban adaptation. I will take care to ensure that my ministry is able to draw valuable lessons from the convergence of these different areas of work.

RESPONSE FROM THE MINISTER FOR HIGHER EDUCATION AND RESEARCH

First of all, I would like to thank the Court of Accounts for the in-depth and original work it has carried out on a subject that has become a major public policy issue. While research was clearly at the root of early identification of climate change, the predictive studies and scenarios it has developed have also made it possible to anticipate its negative effects and the risks it poses to our society and, more broadly, to humanity as a whole. As the Court's report rightly points out, research must play a particular role in identifying the issues, quantifying the phenomena and finding solutions to deal with situations that we know are inevitable.

The ministry of higher education and research (MESR) commends the high quality of the work presented in this section of the 2024 annual public report. This work is based on original, in-depth analyses of the bibliometrics relating to the reports of the Intergovernmental Panel on Climate Change (IPCC), a global centre of scientific expertise on climate. These methods of analysis, developed in conjunction with the

French National Research Agency (ANR) and fed by national databases, make it possible to better qualify at international level the position of French research in the climate sciences and in the fields of adaptation and mitigation. They make it possible to identify the most active regions, the least well-represented themes and the work to be carried out at the intersection between these different areas.

Given the interest of these developments, my department has already taken the initiative of examining, with the Court and the ANR, the extent to which these methods of analysis could be used to constitute a tool for regular monitoring of French scientific production in the various fields of research on climate and even biodiversity.

The overall assessment of the work produced through the Court's investigation shows that our national research system is of the highest international standard, contributing significantly in terms of quality and visibly in terms of impact to the reports produced by the IPCC.

I share the Court's conclusions regarding the exceptional influence of French research on climate, biodiversity, agronomy, hydrology and forestry. On the other hand, the fields of health and urban planning associated with climate change unfortunately appear to be lagging behind.

While the MESR has expressed reservations about the methodology used to qualify research at the "intersection", it also shares the assessment of persistent compartmentalisation between different fields and the significant risk of maladaptation that may result. There is also a lack of research in the humanities and social sciences, which should be a driving force in identifying vulnerabilities and developing adaptation and mitigation solutions that can be understood and implemented by all players in society. Interdisciplinarity, the foundation of sustainability science, is essential.

In response to the Court's analysis attributing the change in the ANR's funding of research on adaptation to the discontinuation of the "management and impacts of climate change" programme, it should be noted that the ANR continues to fund projects of excellence, initiated by researchers, some of which may target the issue of adaptation.

In addition, the France 2030 programme funds exploratory research programmes proposed by researchers or backed by national acceleration strategies, in the latter case proposed by an entire industry. Under France 2030, 22 priority research programmes and equipment (PEPR) are contributing to the environmental transition:

- *3 are strictly dedicated to the climate and are funded in the amount of €156 million;*
- *8 are dedicated to mitigating climate change and are funded in the amount of €451 million;*
- *the remaining 11 deal with these two themes as well as adaptation to climate change, and are funded in the amount of €432 million.*

The Court uses the example of the ANR's funding of projects dedicated to adaptation to note that the National Plan for Adaptation to Climate Change (PNACC) has not had the expected effect on the Agency's programming. It believes that research for adaptation should be led jointly by the ministries responsible for ecology and research. It is clear that the PNACC, due to its sectoral nature and its operational dimension, is not a relevant framework for research programming. It could, however, better identify the issues facing research to enable its operational deployment.

In recent years, the General Secretariat for Investment has provided major programmatic and financial support for the State's strategic priorities, among which the climate in all its dimensions, including issues related to adaptation and mitigation, figures prominently. The PEPRs providing the knowledge that will be produced as part of the contributions expected from research could be identified in the PNACC 3 with a view to answering the questions it sets out.

Following on from the publication of the report commissioned by the Minister from Mr Philippe Gillet, the coordination and programming of research into issues of major societal concern, such as adaptation to climate change, will be entrusted to programme agencies. On 7 December, the French President announced the creation of these agencies, which will operate under the auspices of the main national research bodies.

In addition to these considerations, I would like to draw your attention to my comments on the four recommendations addressed to me.

Recommendation 1 is to "develop a national strategy for adaptation research to support the national plan for adaptation to climate change".

As indicated above, the various PEPRs producing knowledge in support of adaptation to climate change will be explicitly mentioned in the PNACC 3 and the expertise thus developed can be mobilised as required. This is the first way in which research can support the PNACC.

As far as the direction of research on this theme is concerned, the President of the Republic has entrusted the French National Centre for Scientific Research with the role of programme agency on the theme of climate, biodiversity and sustainable societies. The agency's remit will be to define the priority research topics to be included in the programming of

these themes, including adaptation to climate change, and to oversee their implementation where necessary. It is within this new programming framework that the production of a national roadmap for climate change research could be proposed.

Recommendation 2 is to "rebalance resources in favour of research on adaptation, with particular emphasis on health, cities, overseas territories and areas where adaptation and mitigation are shared".

The Sustainable City Solutions and Innovative Buildings programme is a PEPR that focuses on urban adaptation, with a clear emphasis on health-related issues.

The new programme agency supported by the CNRS, mentioned above, and the programme agency dedicated to health supported by the National Institute for Health and Medical Research, provide the framework for the emergence of projects in these two areas.

Recommendation 3 is to "create a label for regional climate expert groups and include them in a network coordinated by the ministry of ecological transition".

The MESR could support the ministry of ecological transition and territorial cohesion if it decides to study the implementation of this proposal in conjunction with the High Council for the Climate.

Recommendation 4 is to "set up research dashboards and a map of the expertise available to all players on adaptation to climate change and other scientific issues relating to climate and biodiversity".

The national low-carbon strategy, the MESR's Climate and Biodiversity Plan and the PNACC 3 include a "knowledge production" component designed to advance our understanding of the climate, its evolution in terms of risks, and the possibilities for mitigating it while adapting to its inevitable consequences. Monitoring these actions via a comprehensive dashboard is problematic due to the different timescales inherent in research and its exploitation (around 5 years are needed for a publication).

However, the Court of Accounts' methodological work could be used to develop a mapping of the themes to be monitored over time, with an associated bibliometric system, in order to be able to report on the knowledge produced. A feasibility study will enable us to see what action could effectively be taken on this mapping project. The mapping of expertise is most likely to fall within the remit of the scientific and technical network (network of environmental research operators) led by the ministry of ecological transition and territorial cohesion.

RESPONSE FROM THE SECRETARY GENERAL OF THE SECRETARIAT GENERAL FOR INVESTMENT (SGPI)

The Court lists 11 priority research programmes and equipment within the scope of research for adaptation (PEPR). In fact, 20 PEPRs are specifically linked to transition and adaptation issues, with a cross-disciplinary approach that avoids the disciplinary silos mentioned in the report, details of which can be found in the appendix.

These numerous funded projects are complemented by actions to support the early stages and further development of research in areas such as mobility, decarbonisation of industry and renewable energies, with average budgets of €20 million per project.

In addition, the SCPI is funding a "research at risk" initiative, which aims to improve the means of detecting and accelerating new scientific discoveries, and to support research whose potential applications are broader than initially anticipated, requiring a rapid, custom response. Part of this €500 million funding package is being used to set up programme agencies within national research bodies. Their purpose is to respond to a number of comments made in the report, in particular the need for national oversight of research programmes that are deemed strategic due to their high societal impact and/or national interest, particularly in areas in which greater coordination between research players, on the one hand, and between ministries to clarify the mandate given by the State, on the other, is essential. These include:

- *the "climate, biodiversity and sustainable societies" programme agency, led by the CNRS (in conjunction with IFREMER and IRD), responsible for improving understanding and prediction of the functioning of the Earth system and treating climate, biodiversity and human societies as interconnected systems (with a particular focus on the acceptability of the solutions emerging in response to climate change);*
- *the "agriculture, sustainable food, forests and natural resources" programme agency, led by INRAE;*
- *the "carbon-free energies" programme agency, led by the CEA.*

Finally, we should mention that through the "higher education, research and innovation ecosystems" component of France 2030, we are providing structural support for research establishments and universities, with schemes such as the "Initiatives of Excellence" (Idex), "Science/Innovation/ Territories/Economy Initiatives" (Isite), and "Excellence in all its forms", making it possible to fund fundamental research through long-term programmes, a growing proportion of which is devoted to the challenges of environmental transition. The amount earmarked for this area, excluding PEPR and Research at Risk, is €4 billion in the France 2030 budget.

RESPONSE FROM THE CHAIR OF THE HIGH COUNCIL FOR THE CLIMATE

In response to your referral of 23 November 2023, and in accordance with Articles L. 143-6 and R 143-13 of the French Financial Jurisdiction Code, below is the response of the High Council for the Climate to the draft section entitled "The place and role of public research in adapting to climate change", which is to be included in the Court of Accounts' 2024 annual public report. For ease of reading, the various aspects are grouped by category.

Observation and data series

Building up long series of data is essential for reliable impact monitoring and for producing and calibrating targeted climate projections. In general, too little attention is paid to the challenges and needs of observations and observatories as a complement to modelling. Meeting the need for general or thematic observations could be highlighted as a key factor in improving the representativeness of assessments and projections, whether in terms of physical impacts or general or sectoral vulnerabilities.

Assessing vulnerability and adaptation needs

The systematic establishment of vulnerability assessments covering the whole of the national territory in metropolitan and overseas France should make up for the lack of a national inventory covering observed trends, impacts, model assessments, impact and risk projections, impacts avoided by adaptation, losses and damage, etc. Similar national reports are produced in other countries (e.g. USA). They make it possible to monitor losses and damage and adaptation needs at different levels in order to establish a framework. For the establishment of such an inventory in France, the CNRS/INSU, in a context of declining national funding, appears to be a logical player to structure research on adaptation as an extension of its structuring role in climate sciences. Regional funding should also be examined in order to establish diagnoses based on cutting-edge, evolving scientific knowledge and involving the various disciplines concerned in the climate sciences and beyond.

Human resources

Although France's main strengths are reflected in the section, we feel it is important to draw attention to the concerns regarding the recruitment shortfall about which several laboratory directors have expressed concern and which has recently been reported in the press.

Upstream of recruitment issues, the M2 adaptation training programme should be considered to ensure that the topics covered in initial training are relevant to the adaptation needs identified (in addition to section B2).

Decision-making support and climate services

"The vital but inconsistent role of scientific expertise in decision-making support" must encompass climate and socio-economic aspects and be regularly updated with the latest impact data for the purposes of translating research into improved decision-making support for both the public and private sectors. Vulnerability is often a weakness of the French approach, which focuses on exposure and hazards. As an extension of research activities, the development of a range of consultancy services capable of taking full advantage of the results and products of research represents an important dimension in the wider consideration of adaptation needs.

Financial resources

Relevant research on adaptation must be based on cutting-edge, evolving knowledge derived from fundamental research in the climate sciences, which must continue to be strengthened. There is also a need to deploy essential additional resources in the various impact areas, in particular civil protection and land-use planning. "Rebalancing resources" should not mean reducing the resources of some to increase those of others.

Analysis method

Monitoring French participation in international conferences on adaptation also reflects the international visibility of French research. The digital base should be linked to the "digital and ecological planning" roadmap coordinated by the SGPE.

Comments on wording

(Box in C/ Vital infrastructures with uncertain long-term financing) It is preferable to use "global projections" rather than "predictions". It would be more appropriate to use the term "representativeness" rather than "hierarchy" to refer to the position of the French experts.

Elements that could be given greater prominence

The first point relates to the scope of the disciplines identified, which tends to underestimate the dimensions of land-use planning, sustainable development, risk prevention, crisis management and governance

traditionally dealt with in France in the geographical sciences, economics, management sciences, sociology and political science. This bias means that the contributions of internationally recognised French players in research on adaptation, such as the IRD, IDDRI, geography laboratories and BRGM for soil and coastal issues, are not particularly visible. Once the scope of the study has been broadened, a comparison of research efforts in France with comparable countries would be relevant. European policy on research on adaptation would benefit from a better description.

The second missing point concerns territorial initiatives, both at the level of local or thematic observatories (e.g. GREC, highly disparate scopes and roles to be evaluated, co-production of knowledge? collective and transparent evaluation? appropriation by local authorities?) and structures transposing the functioning of the IPCC at a dedicated geographical scale (e.g. MEDECC for the Mediterranean region).

The third point would be to look more closely at the issue of maladaptation, which deserves to be developed in greater detail (for example, the focus on heatwaves in densely populated urban areas without addressing the additional demand for electricity, which needs to be brought into line with an energy strategy), and other examples, particularly those relating to dykes (BRGM).

Finally, the last point relates more broadly to issues of fair transition and the need for research into the governance of climate action to better protect the most vulnerable, particularly in terms of access to water resources in periods of persistent water stress, or risk management and prevention.

RESPONSE FROM THE CHAIRMAN AND CHIEF EXECUTIVE OFFICER OF THE FRENCH NATIONAL RESEARCH AGENCY (ANR)

I would like to thank you for the draft section to be included in the Court of Accounts' 2024 annual public report on the place and role of research in adaptation to climate change.

I would like to emphasise the quality of the work carried out by the Court, as well as the quality of the interactions established between the Court and the ANR on methodological aspects, enabling the Court to develop methods for analysing the performance and resources of French research for adaptation to climate change.

With regard to the ANR, the Court rightly points out that "over the period 2012-2022, funding allocated to research for adaptation increased".

Taking into account the commitments made in the research programming law, particularly concerning the initial allocation and funding for the Carnot programme, the share allocated to generic calls for projects increased from €758.2 million in 2022 to €761 million in 2023, i.e. an increase of 0.8%.

In the subsequent paragraph, the changes mentioned by the Court should be correlated with the periods analysed, which are not specified and cannot under any circumstances relate to 2023, the results of which could not be known at the time of the review.

The Court states that "ANR funding is allocated in proportion to the number of projects submitted to evaluation committees". The ANR does not dispute this observation of a past situation resulting from a constrained budgetary context. When selection rates are below 20%, as is also the case for the ERC, funding agencies generally apply identical selection rates for the various selection committees. The increase in resources allocated to the ANR under the research programming law will enable this approach to change.

The Court then deduces that "insofar as there is no specific evaluation committee for adaptation, funding in this area is automatically reduced". This assertion is debatable, as it could imply that if a committee had been dedicated to adaptation, projects of lesser scientific quality could have been funded. Moreover, a dedicated committee would not necessarily be suited to the necessary interdisciplinarity and to the fact that, as the Court points out, research on adaptation to climate change must form part of a continuum of research that takes the form of different thematic committees or different funding instruments, and involve very different approaches and very different areas of technology.

The ANR agrees with the Court's observation that "research on adaptation needs specific incentives to strengthen the scientific communities involved and the links between them". These incentives are based on international, European, national and regional actions and are part of several levels of actions implemented by the ANR:

Supporting French teams in international research consortia

For the past year, the ANR has co-chaired the Belmont Forum (with RCN, a Norwegian funding agency). Created in 2009 at the initiative of the US National Science Foundation (NSF), the Belmont Forum is an international consortium of funding agencies from around thirty countries, playing a key role in supporting research into global change, and climate change in particular. The Belmont Forum has supported more than 150 research projects, involving some 1,000 scientists from 90 countries, focusing on integrated approaches, particularly to the impacts of and adaptations to climate change.

Playing a leading role in European partnerships

Horizon 2020 and now Horizon Europe partnerships are based on collaboration between the European Commission and national funding agencies. In particular, the ANR is involved in long-term partnerships between Europe and Africa, as well as in a dozen new partnerships, many of which focus on adaptation to climate change.

Supporting excellence at national level

Through two levers:

- *Implementation of France 2030 programmes ("directed-programmes" lever): as highlighted by the Court, 11 PEPRs relate to research on climate change, in particular adaptation to climate change.*
- *Support for young researchers and interdisciplinary collaborative projects ("investigator-driven projects" lever): 80 % of the projects in the action plan are in line with at least one of the 17 United Nations Sustainable Development Goals, and a third, which are highly interdisciplinary, are specifically geared towards major transitions (sustainability sciences, environmental and ecological transitions, energy transitions, one health, etc.).*

Organising regional partnerships and co-funding to meet local needs

As the Court emphasises, one essential aspect is the regional dimension of research and expertise to meet specific local needs, involving the various stakeholders (local authorities, associations, etc.). Particular attention must be paid to the overseas regions. Following the mobilisation of research on overseas issues related to adaptations to climate change, in particular regarding Sargassum, involving and co-financed by Ademe, the local authorities of Martinique and French Guiana, and the Guadeloupe region, an initial action was followed by a second call extended to funding

agencies that are partners of ANR (the Brazilian agency Facepe, Connacyt from Mexico and NWO from the Netherlands). A programme on biodiversity and protected marine areas in the Indian Ocean was set up and coordinated by the ANR, co-financed by the AFD and involving the National Research Foundation of South Africa, the National Research Foundation of Kenya, the Mozambique National Research Fund and the Tanzanian Commission for Science and Technology, and open to teams from the Comoros, Madagascar and Mauritius.

This strategy of mobilising scientific expertise and research to meet specific regional needs in mainland France is also one of the agency's priorities. A programme on the impacts of climate change on regional ecosystems will be set up in 2023 by the ANR, in partnership with the Pays de la Loire and Normandy regions, focusing on adaptations to river flooding, the deterioration of water quality and the local impacts of rising sea levels.

With regard to the exceptional funding provided as part of the Investments for the Future programme, which has become France 2030, the Court notes that the funding was concentrated on the period of the first PNACC (€270 million) rather than the second (€126 million). It should be noted that these amounts correspond to commitment authorisations and not payment appropriations. All the projects financed during the first PNACC were still active during the second and therefore received part of their funding after 2015, when the first PNACC came to an end.

Appendix for international readers

Presentation of *Cour des comptes* (France): who we are and what we do?

Established in 1807, the *Cour des comptes* (also referred to as "Court of accounts" or Court in the text) is the supreme audit institution (SAI) for France overseeing the use of public funds at the national level. It is independent from the Government and Parliament. It has financial jurisdiction and is in charge of auditing, issuing rulings and certifying the State and Social Security accounts, as well as contributing to the evaluation of public policies. The Cour des Comptes, whose role is described in article 47-2 of the French Constitution, contributes to citizen information through its public reports.

The Cour is independent of public authorities. Within the framework provided by French law, it freely defines its work program, possesses control powers both documentarily and on-site, freely adopts its conclusions, and enjoys editorial freedom. Engaging in public debate through its publications, it aims to be useful to decision-makers and citizens alike and actively contributes to improving public management and its outcomes.

Opportunities related to developed methods and shared open data

In order to stimulate new uses in a perspective of general interest, the source code elements associated with the most important methods and the main associated datasets are provided in a digitally exploitable format (see summaries and links below).

This approach is part of the Court's international cooperation policy with the supreme audit institutions (SAI) of other countries as well as its scientific cooperation policy with major French research operators.

It is thus possible to adapt the method presented here for other countries and groups of countries. Beyond direct applications, other potential applications include, for example, extending the analyses to the upcoming works of the 7th IPCC assessment report or to the publications of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) on biodiversity-related challenges.

Disclaimer

The elements provided do not necessarily reflect the positions of third parties such as the Intergovernmental Panel on Climate Change (IPCC).

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Composition of the open electronic archive accessible on the Cour's website https://www.ccomptes.fr/en/publications/annual-public-report-2024 :

- **Guide "Cahier_MethodesEtDonnees_Recherche_Adaptation_RPA_2024.docx"**: this methodological guide presents the detailed methods and data used in the chapter of the Cour des Comptes' 2024 annual public report regarding the place and role of public research in adapting to climate change. The detailed results underlying the observations formulated succinctly in the chapter are also presented. These results serve as examples of applications of the methods developed here.

- **Folder "elements_from_IPCC_reports**": this folder enables the reproduction of the chapter's observations based on the analysis method of citations from the Intergovernmental Panel on Climate Change (IPCC) works in its 6th Assessment Report (AR6) and associated metadata on harmonized bases, as well as on the semantic approach derived from the IPCC glossaries and corpus. The files associated with this folder are provided in a digitally exploitable format under a "CC-BY-NC 4.0 " license to stimulate new uses for general interest. Note that only non-commercial uses

are authorized by the CC-BY-NC 4.0 license[41], and these elements are subject to the disclaimer mentioned above. Contents of the folder are as below:

  - File "ipcc_ar6_reports_doi_citations.csv" containing harmonized citations of type "DOI" from the three main reports of the three groups of the IPCC's 6th assessment report (the harmonization method is detailed in the methodological guide);
  - File "ipcc_ar6_reports_keywords_in_titles.csv" which gathers keywords extracted from the glossaries of the three main AR 6 IPCC reports and hierarchized with citation metadata (see the guide for more details).

- **Folder "mots_cles_adaptation_analyses_semantiques"**: this folder includes all the elements necessary to reproduce the semantic analyses implemented in the report. The source code elements and associated keywords are provided in a digitally exploitable format under the "GNU General Public License v3.0"[42] to stimulate new uses for general interest. Potential

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applications include, for example, scientometric analyses to track a country's influence (here applied to France) or the monitoring of funding associated with research for adaptation and research on adaptation. Contents of the folder are as below:

- Script that can be executed with the free software R called "Script_AnalysesSemantiques_Recherche_Adaptation_RPA_2024_v20240304.R" and that allows the production of semantic filters based on keywords;
- Sub-folder "OpenData" which includes a copy of open data from the French National Research Agency (ANR) at the time the analysis was conducted by the Cour des comptes and serves as an example for the use of semantic filters.

Other keywords can be easily added by users. Different sources can be mobilized to enrich semantic searches. See, for example: keywords extracted from the glossaries of the three main reports of AR 6 of the IPCC (see file proposed on the Court's website reserved for non-commercial use); the study by Nalau and Verall (2021) "Mapping the evolution and current trends in climate change adaptation science," Climate Risk Management, https://doi.org/10.1016/j.crm.2021.100290.