Science for policy

RÉPUBLIQUE FRANÇAISE
Liberté
Égalité
Fraternité

INRAE

Info&Sols, a partnership-based system for soil knowledge and monitoring in France

December 2024

In this dossier

Prepared by Joseph Lefeuvre, Gisèle Parfait and Marion Bardy (DAPP), Antonio Bispo (Info&Sols research unit) and Pierre Renault (Deputy scientific director for Environment).

PAGE 4
Soil properties, ecosystem services and health: a fragile resource
Soil knowledge and monitoring issues in France since 1960

PAGE 5
GIS Sol and Info&Sols: streamlining soil monitoring in France

PAGE 10
An interface between science and public policy

PAGE 13
European projects to support soil ecosystem service management

Acknowledgements

In memory of Dominique Arrouays, we would like to pay tribute to his exceptional contribution to the interface between soil science and public policy, without which this dossier would not have been possible. His world-renowned commitment, knowledge, expertise and dedication will be forever remembered by the scientific community.

We would like to thank all those who contributed to this project:

Marion Bardy, Rainer Baritz, Antonio Bispo, Fabrizio Botta, Claudy Jolivet, Bertrand Laroche, Béatrice Michalland, Jérôme Mousset, Pierre Renault, Joëlle Sauter and Emmanuel Steinmann.

Science for policy collection
Dir. of publication: Marion Bardy
Dir. of collection: Gisèle Parfait
Conception: Joseph Lefeuvre, Gisèle Parfait
Photos and figures : Françoise Peyriguer
English translation : Lucy Lyall Grant
Design and layout:
EliLoCom - www.elilocom.fr
Printing : Groupe exprim
December 2024

Cover photo : ©INRAE

A. Bispo © INRAE

December 2024

In 2001, ahead of any specific public policy on soil, French public authorities and the scientific community set up the Groupement d'Intérêt Scientifique Sol (Soil Scientific Interest Group) to develop a soil knowledge and monitoring system.

Info&Sols, a partnership-based system for soil knowledge and monitoring in France

Representing the interface between water, air, rock and living organisms, soils are fragile, living environments that need to be preserved. They are at the heart of global issues crucial for the planet as well as for our own survival. But on a European scale, over 60% of soils are considered as degraded. This dossier traces the establishment of a soil knowledge and monitoring system in France, the public policies that have benefited from these scientific advances, and emerging soil-related issues.

As an essential support for human activities, soil is a natural resource providing numerous functions and ecosystem services. It is, therefore, at the heart of key global challenges for the planet and for our own survival: adapting to climate change, protecting health, preserving biodiversity and ecosystems, and ensuring food security.

Yet the threats to soils are manifold, and include sealing, erosion, contamination, declining organic matter content, reduced biodiversity, compaction and salinization.

The European Commission estimates that over 60% of European soils are not in "good condition". While the cost of degradation is estimated at almost 50 billion euros per year, the cost of inaction with regard to this degradation is estimated at 6 times the cost of action including prevention and restoration. Sustainable soil management is a clear objective of the European Commission, which is preparing a draft directive on soil health and monitoring.

A large international scientific community is dedicated to soils, and a World Soil Day, December 5, has even been

Rainer Baritz

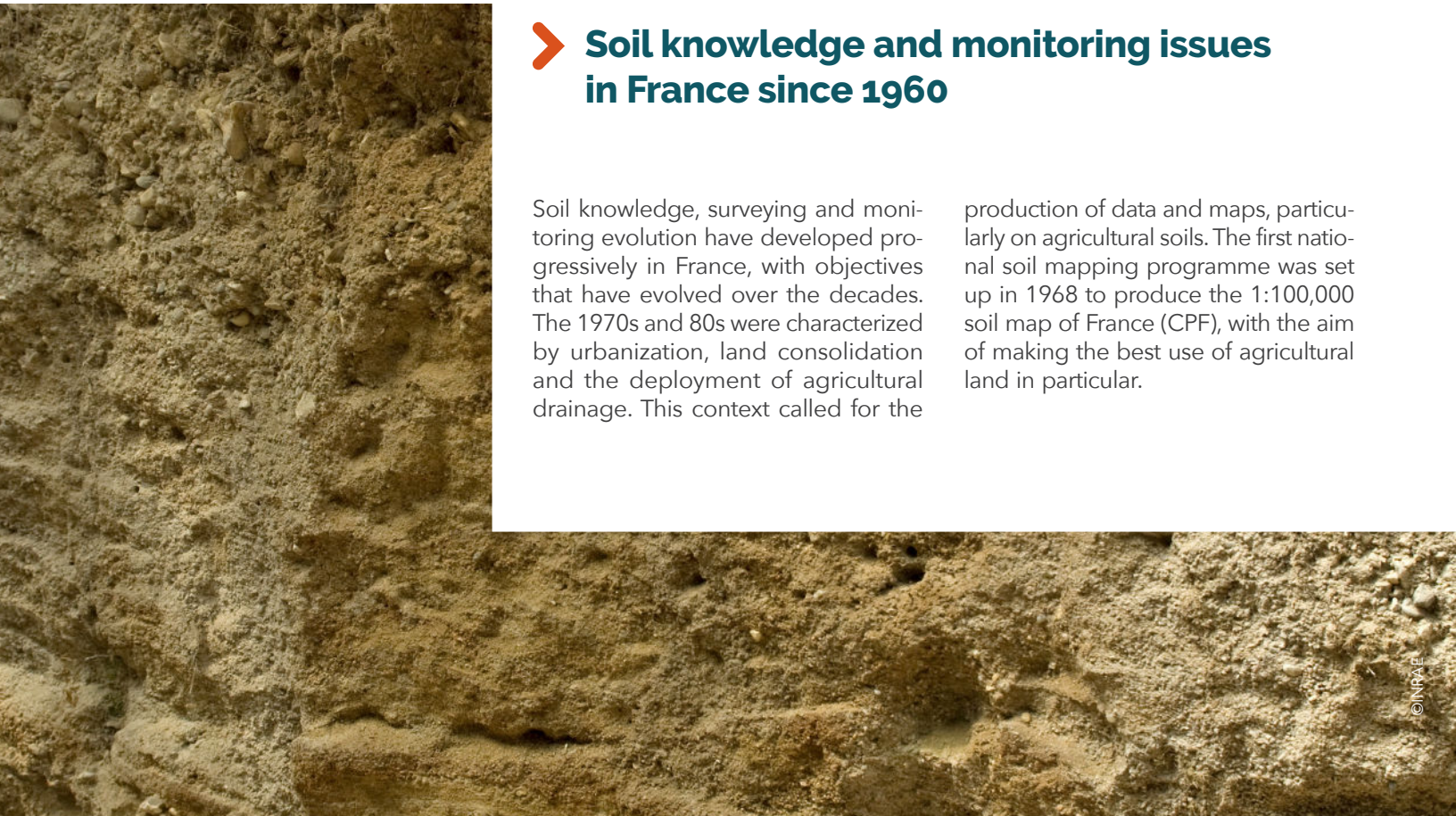
Chair of the European Soil Partnership and head of the European Environment Agency "Sol" project

Trained as a pedologist, I was responsible for the national soil information system in Germany, similar to the GIS Sol programmes here in France. Today, as a soil expert at the European Environment Agency, I also chair the European Soil Partnership. In this capacity, I collect and summarize the opinions of national soil experts on issues raised by the FAO's Global Soil Partnership. The GIS Sol teams play an essential role in these European meeting places. They promote the French soil monitoring system as part of the European soil strategy. They also provide relevant scientific knowledge in this field: the indicators to be monitored, the definition of critical limits, the harmonization of European systems and so on. In this respect, INRAE and GIS Sol are major players in discussions on soil monitoring in Europe.

devoted to them under the aegis of the UN since 2014. The most recent French event was held in the Normandy region in 2024 on the theme of soil data and information.
In France, the work carried out since the 1990s and the creation of the Groupement d'Intérêt Scientifique Sol (GIS Sol) have enabled a national soil information system to be established, based on soil inventory and monitoring, thus anticipating the European framework.
This dossier retraces the system's development and presents public policies that have benefited from the data generated by this national system. It concludes with a discussion of soil science research issues at European level.

Soil properties, ecosystem services and health: a fragile resource

The biophysical properties of soils determine the many functions and ecosystem services provided by this environment: the supply of biomass to feed, clothe, house and heat us, as well as the regulation of nutrient, climate and water cycles, and the recycling of waste. Soils play a crucial role in the storage of water usable by plants, in the balance between water runoff, infiltration and drainage, and in the quality of surface water and groundwater... They are also home to over 50% of the world's biodiversity and are an essential resource for biotechnologies and medicines. These constantly evolving properties also affect their capacity to store carbon and regulate greenhouse gas flows. Lastly, the speed of soil formation is not on a human scale, and it is essential to protect them, use them sustainably and restore them when they are degraded. Yet soil continues to deteriorate as a result of intensive farming, deforestation, overgrazing, industrial pollution, irrigation, artificialization ("land take"), etc. Awareness of this degradation has led various international, European, national and local authorities to work towards understanding, monitoring, protecting and restoring the soil. Public policies concerning soils are developing simultaneously with the need for varied scientific knowledge ranging from inventories to monitoring their evolution and identifying the pressures to which they are exposed.



Soil knowledge and monitoring issues in France since 1960

Soil knowledge, surveying and monitoring evolution have developed progressively in France, with objectives that have evolved over the decades. The 1970s and 80s were characterized by urbanization, land consolidation and the deployment of agricultural drainage. This context called for the production of data and maps, particularly on agricultural soils. The first national soil mapping programme was set up in 1968 to produce the 1:100,000 soil map of France (CPF), with the aim of making the best use of agricultural land in particular.

By the end of the 1980s, progress on the CPF programme was too slow and all the programmes were redesigned, leading to the creation of the first national soil mapping programme, the IGCS (Soil Inventory, Management and Conservation) programme, which is still operational today. Its aim was to map soil landscapes at a scale of 1:250,000, and to consolidate all the information in geographic databases using Geographic Information Systems (GIS). In the early 1990s, this led to the creation of DoneSol, a generic geographic database of French soils.

GIS Sol and Info&Sols: streamlining soil monitoring in France

The 1990s saw the rise of environmental concerns. The 1992 Rio Earth Summit put water quality management in the spotlight, and the conventions that followed made direct links with soil management: pollution, climate change, biodiversity, erosion and desertification. The need for soil quality surveys to support the environment began to emerge. All these developments led INRAE (INRA at the time), the ministries for agriculture and the environment, Ademe (the French Agency for Ecological Transition) and Ifen (the French Institute for the Environment) to create a national partnership to manage soil mapping and monitoring programmes: GIS Sol was born in 2001. At the same time, INRAE created the InfoSol Service Unit to support GIS Sol. At the same time, INRAE created the InfoSol Service Unit to support GIS Sol.
Three major challenges were identified. Firstly, soil inventory and monitoring programmes must contribute to better organization of support for national public policies. Secondly, partners need to be better coordinated and their actions pooled as part a stable, clear structure. Lastly, a genuine soil monitoring system needs to be set up in France, representative of the soil and its uses, in order to assess the state of the soil and provide a benchmark for the long-term monitoring of its evolution.

A NATIONAL SOIL INFORMATION SYSTEM

There are no specific regulations governing soil at either national or European level, despite the fact that understanding soil is a prerequisite for many projects and laws concerning, for example, water and air quality, health, and carbon storage. Scientific knowledge and soil monitoring have therefore been structured with a view to creating a national soil information system in France, thanks to the support of ministries, agencies and scientific and regional partners.
In order to broaden the diversity of areas and soil uses, and to pool French expertise in the acquisition and dissemination of soil data, GIS Sol was joined by four new members: IRD, the French National Research Institute for Sustainable Development, (2007), IGN, the National Institute of Geographic and Forest Information (2009, ex-IFN), OFB, the French Biodiversity Agency (2019) and the French geological and mining research bureau BRGM (2021). GIS Sol's missions are varied. Its aim is to create and manage an information system about soils in France by developing a database incorporating their spatial distributions, their properties and the evolution of their qualities. To meet these needs, INRAE quickly created the InfoSol Service Unit in 2001, based in Orléans. Since 2023, the Sols research unit and the InfoSol service unit have merged into a single research unit under the name Info&Sols, which continues to implement priority data acquisition programmes: IGCS, RMQS, BDAT, BDETM, BDSolU and IFN. In support of GIS Sol, and in particular in conjunction with the joint technology network RMT Sols et Territoires, the unit is also involved in general communication and in making GIS products more visible to users.

Jérôme Mousset
Director of Bioeconomy and Renewable Energies at ADEME

The French Environment and Energy Management Agency (ADEME) has been involved in GIS Sol since it was set up in 2001, both in its financing and its operation, and in the valorization of its data. As a unique and reliable soil observatory in France, the GIS is an essential knowledge base to implement public policies at European, national and local levels. Thanks to GIS data, we have helped highlight the essential role of soil in strategies to combat climate change (2050 scenarios), and developed diagnostic tools (such as Aldo) for local authority climate plans. GIS Sol's knowledge is also used in the Agribalyse project on the environmental impact of agricultural and food products, and in the development of low-carbon labeling methods. As part of its missions, ADEME's soil-related activities are focused on mitigating and adapting to climate change, limiting the impact on soil health, promoting restrained use of soil and raising awareness of the essential role played by soil using its "fresque du sol" (soil fresco), translated into several languages

Claudy Jolivet
INRAE pedologist and research scientist, coordinator of the RMQS

I'm a pedologist at INRAE, and since 2001 I've been coordinating GIS Sol's Soil Quality Measurement Network (RMQS). The aim of this programme is to monitor soil evolution over time by analyzing different parameters such as carbon, pH, soil particle size, contaminants and biodiversity. In this way we can calculate carbon stocks, soil fertility, pesticide residue levels and other indicators depending on the needs of our partners or public policies. An agronomic survey enables us to link these characteristics with farming practices, and the 2,200 sites are revisited every 15 years. Requests for data are constantly increasing, and it is difficult to meet them in the very short term. In fact, the RMQS is a cornerstone programme to support agricultural, climate and environmental policies, while at the same time being a precursor in light of the forthcoming new European directive

SIX PROGRAMMES FOR BETTER SOIL MANAGEMENT

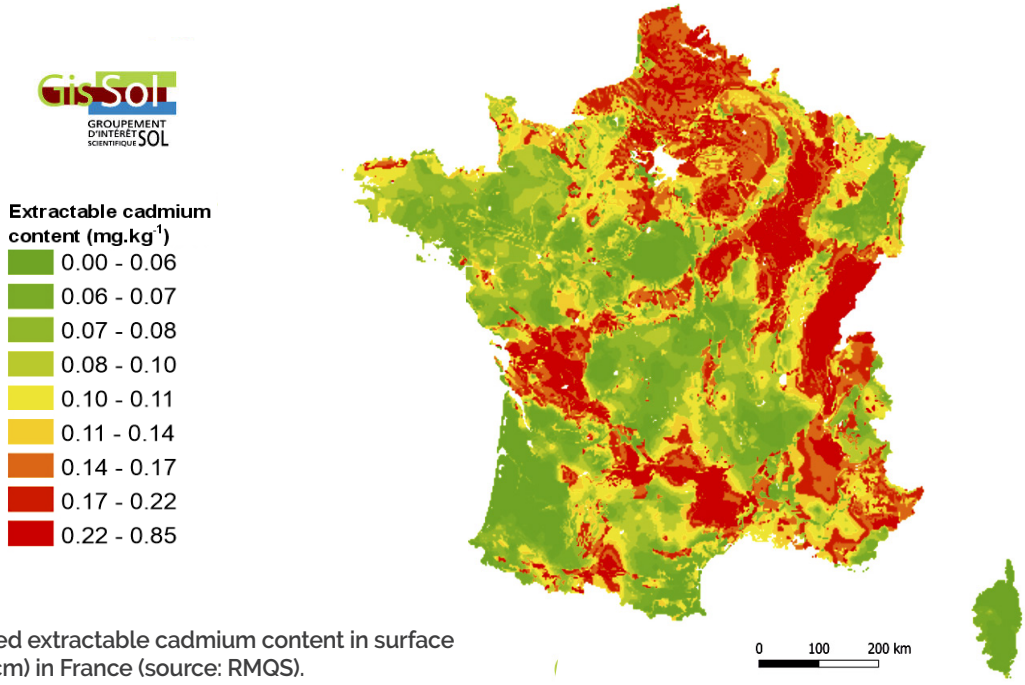
Six soil data acquisition programmes in mainland France and the French overseas territories are managed by GIS Sol. Apart from the urban soil programme (BDSolU) led by BRGM, INRAE is responsible for coordinating these programmes with various partners. The inventory of agricultural and forest soils (IFN) is developed with IGN and IRD, the RMQS soil quality monitoring programme with IRD, while capitalizing on farmland analyses (BDAT) is linked with national soil analysis laboratories. Metal trace element monitoring (BDETM) is carried out in partnership with organizations involved in the recycling of sewage sludge.

An information system is associated with these programmes to organize the collection, entry, archiving and storage of data in various databases. The data comes directly from field observations and analyses managed by GIS Sol (e.g. RMQS and IGCS) or from data collected by partners (e.g. laboratories, local authorities) and transferred to GIS Sol (BDAT, BDETM, BDSolU). A chain to extract, process, cross-reference and analyze the data collected by the various programmes has been set up; it also makes it possible to distribute the data, raw or reworked, in a variety of formats. Last but not least, the samples collected by the GIS Sol programmes, and in particular the RMQS, are stored at the CEES (European Conservatory of Soil Samples) on a long-term basis, to enable re-analyses for control purposes and/or new parameters.

A PIONEERING SYSTEM IN EUROPE

GIS Sol connects all the public policy stakeholders and considers their soil data requirements. It brings together groups from the public sector (ministries, agencies, local authorities), research (research and teaching organizations), agricultural development (chambers of agriculture, cooperatives, laboratories, etc.) and partner soil scientists. In addition to direct contributions from member organizations, a framework agreement sets out the financing of this collective by ministries and agencies, whose operations and results are assessed every 5 years. This close collaboration fosters regular meetings, enabling each participant's needs and expectations to be identified.

This body, which is unique in Europe and has no formal governance



Mapping of predicted extractable cadmium content in surface soil horizons (0-30 cm) in France (source: RMQS).

structure, distributes responsibility for its tasks among its members. In some European countries (e.g. Germany, Spain and Italy), soil inventories and monitoring rely on regional management, or are divided between different bodies, which must then be consolidated at national level.
In 20 years, this "groundbreaking" organization, centralized and managed by several people, has produced a national soil map at 1:250,000 scale, rolled out a nationwide monitoring programme, and centralized data in a national database, facilitating access to data for both public policy support and research purposes (in national and European research projects). Because of the diversity of French soils and the wealth of data, French soil and climate resources can also be extrapolated to several European countries.
GIS Sol programmes and the French soil information system are known and recognized internationally for the methodological and scientific advances they have enabled such as the recent characterization of emerging organic contaminants (e.g. pesticides, PFAS, microplastics) or soil biodiversity (with the support of ANSES, OFB and Ademe). Similarly, the European Conservatory of Soil Samples hosts samples from the European ICOS programme.

Priority data acquisition programmes

Six soil data acquisition programmes in mainland France and the French overseas territories currently provide the framework for GIS Sol's activities. Data for these programmes is collected by various regional partners and laboratories, in accordance with a quality approach and national specifications. Overall, these programmes contribute to a better understanding of soils, as well as better management and planning of soil uses and ecosystem services.

1) **The soil inventory, management and conservation (IGCS)** multi-scale French soil mapping programme is strongly committed to 1:250,000-scale soil mapping, which is now almost complete in mainland France. The inventory also supports medium-scale mapping programs (1/100,000 and 1/50,000) and reference sectors. The IGCS also supports methodological contributions to the application of soil data to various topics, and the development of methods and transfer of soil mapping through statistical modeling, notably in conjunction with the RMT Sols et Territoires.

2) **The national forestry inventory** piloted by the IGN, which collects data on forest soils that are then fed into the national system to support the mapping programme (IGCS).

3) **The RMQS (soil quality measurement network)** is based on the monitoring of 2,240 sites distributed over a 16 × 16km grid in mainland France and the French overseas territories (in conjunction with IRD). Sites are re-sampled approximately every 12 to 15 years, and all samples are retained (allowing measured properties to be supplemented as required depending on methodological advances).

4) **The BDAT (Soil Analysis Database),** the result of a partnership with certified laboratories, which capitalizes on soil test results. It disseminates statistical information aggregated over 5 years at various spatial scales (cantons, small agricultural regions, départements, regions, metropolitan France, etc.). Today, there are over 3 million records in the database and 42 million results for 30 years of analyzed data.

5) **The trace element database BDETM,** a joint project with ADEME (the French Environment and Energy Management Agency), which capitalizes on soil analyses required for land application plans (urban sludge, industrial effluents and waste, etc.).

6) **The urban soil analysis database (BDSolU),** integrated into GIS Sol in 2021 with the arrival of BRGM, with a view to determining baseline values to support urban soil diagnosis. It is based in particular on collaboration with local authorities carrying out soil condition assessments. This database thus completes the pedological coverage of France, supplementing the other databases and providing genuine continuity between urban, peri-urban, agricultural and semi-natural areas.

Joëlle Sauter
Soil & Fertility engineer, Grand Est Chamber of Agriculture and co-coordinator of the "Sols et Territoires" joint technology network

The Chambers of Agriculture in Alsace and Lorraine have been involved in the GIS Sol Soil Inventory, Management and Conservation (IGCS) programme since the 1990s. I joined the Grand Est Regional Chamber of Agriculture in 2018, where I manage the soil databases. To study a soil, our agronomists and pedologists start by describing the site and geolocating it. Auger holes or soil pits are then drilled to determine the nature of the soil and its properties by horizon. These observations are completed by soil sample analyses. The data collected serves several purposes: assessing the agronomic potential of soils, qualifying habitats for biodiversity, estimating the risk of mudslides and so on. I also run the "Sols et Territoires" Mixed Technology Network. The aim of this network is to promote GIS Sol databases to local players, and to provide feedback on their needs. Today, I can see a real awareness of the importance of soils and a growing need for information, which shows that our work is bearing fruit.

Three questions for
Béatrice Michalland

Deputy Director of Environmental Information
Statistical Data and Studies Department
General Commissariat for Sustainable Development
Ministry for Ecological Transition, Energy, Climate
and Risk Prevention (MTEECPR).

What are the Ministry of the Environment's needs in terms of soil knowledge and monitoring?

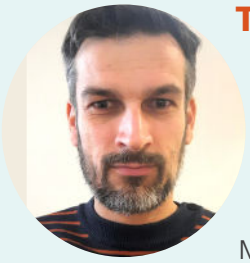
The MTEECPR has been involved with GIS Sol since it was set up in 2001; initially through the IFEN (French Environment Institute), which joined the Ministry in 2008. Responsible for gathering and making available information on the state of the environment in France, this department took an early interest in soil conditions. Today, the MTEECPR focuses not only on knowledge of soil conditions, but also on the pressures exerted on it (artificialization, pollution) and the ecosystem services it provides (carbon storage, water filtration/retention, biodiversity reservoir, etc.). Soils have been recognized in the Environment Code as an element of common heritage and their services as of common interest (Article L110-1) since 2016 with the law for the reconquest of biodiversity and landscapes. In total, five MTEECPR departments are in charge of soil-related policies: DGPR (polluted soils and sites, natural risks with erosion or landslides, etc.), DEB (nature-based solutions, biodiversity, water management), DHUP (planning/artificialization), DGEC (climate) and lastly, CGDD on environmental information and data aspects.

How does GIS Sol's work meet the MTEECPR's needs?

The Soil Inventory, Management and Conservation (IGCS) programme now provides a 250,000-scale map of dominant soils for the whole of France. The systematic soil quality measurement programme (RMQS) helps establish the state of French soils, and enables their evolution to be monitored. It's made up of 2,240 points that provide a general knowledge tool, which needs to be supplemented by an understanding of the relationship between uses, practices and condition over time. This is the focus of the 2nd monitoring campaign, which began in 2016 and should be completed in 2030. When more precise data are needed to guide a PLUi (town-planning), for example, GIS Sol data are insufficient. But GIS Sol can offer local actors its expertise especially since it has numerous local partnerships. Thanks to GIS Sol, we have an impressive network of pedologists and geologists, and close ties with chambers of agriculture. I share the directorship of GIS Sol with the MASAF (Ministry of Agriculture, Food Sovereignty and Forests), so we work closely together and share our priorities. This helped prepare France's position on the European draft directive on soils, currently being negotiated.

What are today's scientific requirements to protect soils?

To give just one example, climate change mitigation requires more carbon storage in soils (the 4 per 1,000 initiative) and forests. But we still need to work out how to boost this storage and where to do it. Where are the soil erosion risks that could complicate this storage? How can we help forests through good forest soil management to better resist the effects of climate change? There are numerous questions. For its part, the European directive on soil monitoring and resilience will provide soil-quality objectives. Initially, this will, above all, involve monitoring and disseminating best practices for sustainable soil management, but eventually, in order to restore good soil health, actions will be proposed. This challenge will require a major collaborative study between GIS Sol and the ministries concerned. In the short term, GIS Sol is mobilized on the one hand to work out how to ensure good sampling of monitoring points to meet the directive's ambitions, and, on the other, to define thresholds to characterize good soil health in France.



Three questions for
Emmanuel Steinmann

Head of the Water, Soil and Circular Economy Office
Sub-Directorate for Environmental Performance and Territorial Development
Competitiveness and Environmental Performance Department
Directorate General of Economic and Environmental Business Performance
MASAF (Ministry of Agriculture, Food Sovereignty and Forests)

What are the issues for the MASA (Ministry of Agriculture and Food Sovereignty) for better soil knowledge and monitoring?

Since 2023, I've been in charge of the Water, Soil and Circular Economy Office. Our Sub-Directorate has co-chaired GIS Sol with the French Ministry of Ecological Transition since its creation in 2001. Soils support plant growth and thus the production of our food and biomass, whether in agricultural or forestry areas. Sustainable production in a context of climate change requires healthy soils capable of supplying nutrients and retaining water for plant growth, as well as storing carbon, notably through the still poorly understood biodiversity they harbor. The data produced by GIS Sol is therefore essential for designing public policies to preserve and improve the health of our soils. Improving soil knowledge also helps protect agricultural soils from artificialization: knowing where good agricultural land is enables local authorities to make planning choices to preserve it.

The convention with GIS Sol has just been renewed - what changes of direction does this involve?

GIS Sol manages the soil information and monitoring system. It's responsible for data production and collection, as well as data enhancement. INRAE has won a call for projects from the "digital and data investment fund for ecological planning" to improve data dissemination tools. The Soil Analysis Database (BDAT) collects more than 100,000 soil analysis data sets per year from laboratories so that we can monitor the evolution of carbon in agricultural soils. Securing the legal status of data is also essential for their dissemination, as some are produced by GIS Sol and others are recovered from analysis laboratories or other partners. The Ministry advocates sharing these data so that they can be useful to as many people as possible, while guaranteeing their "anonymization", for example by distributing them at a relevant geographical scale, to preserve the trust of people who allow us access to their land to carry out sampling or who share their soil analysis data with us. Developing these data requires considerable resources and the continuation of the work carried out by GIS Sol, and MASAF has therefore renewed its confidence in this structure.

What might the forthcoming European directive bring?

At the moment, soil is not the subject of a dedicated EU public policy, although there are specific regulations to protect soil from polluting inputs, for example. The directive will set a new monitoring goal, with a clear objective of restoring soil health. INRAE's Info&Sols team has built up a wealth of experience, giving us a head start in implementing surveys and enabling us to anticipate the future requirements of the European directive. While adjustments to monitoring programmes will undoubtedly be necessary, with a reinforced goal, this directive will be an opportunity to highlight the concern for soil health that involves us all, and create an impetus to facilitate awareness and commitment to soil restoration actions by those in charge of soil management.

An interface between science and public policy

Although the guiding principles or general philosophy of soil protection and monitoring are not yet enshrined in law, more and more public policies are moving in this direction, in particular by using the work of GIS Sol and Info&Sols. The legal elements that require soil data and information are:

– civil law, with property rights or easements,

– rural law, applied to farming or protection against erosion,

– town planning law, dealing with land use or the management of its scarcity,

– health law, supporting measures to protect drinking-water catchments.

Soil data, initially mainly agricultural, has since been extended to forest soils, so-called "semi-natural" soils, urban and peri-urban soils, and contaminated sites, facilitating integrated land and soil management.

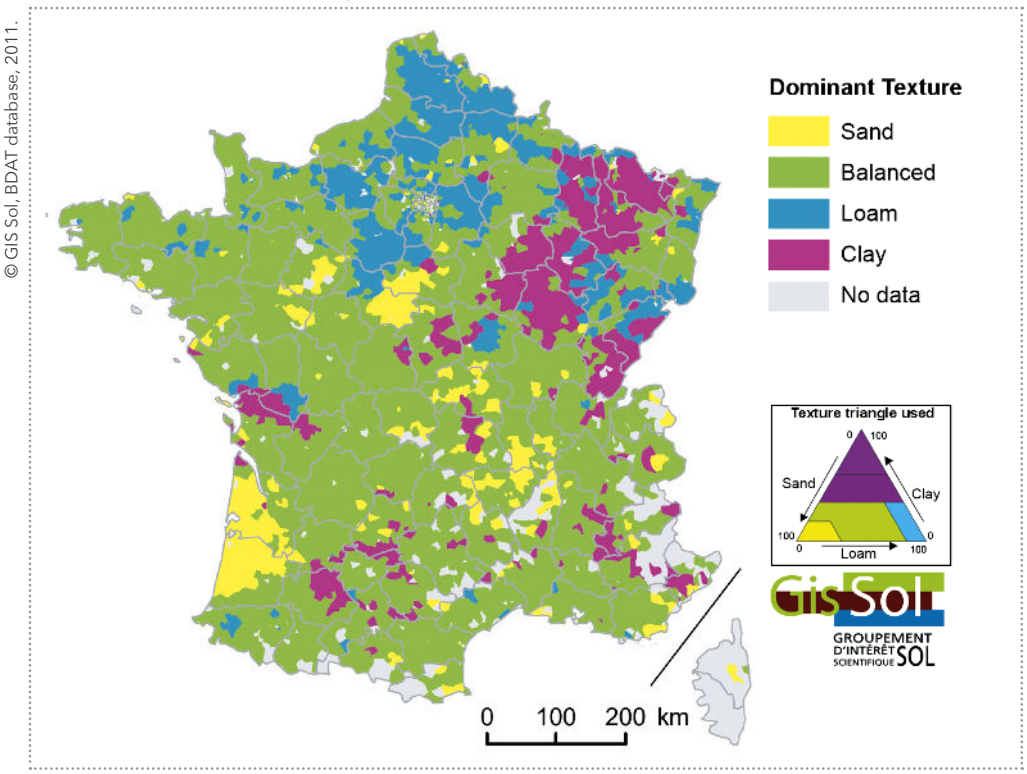
The data is used by public decision-makers, land managers and scientific researchers for a variety of purposes, including modeling and forecasting soil evolution, soil protection, and the evaluation of the ecosystem services rendered.

QUALIFYING SOILS: 40 YEARS OF INRAE RESEARCH

To qualify soils, we need to know their condition, their functions and the services they provide. It is also necessary to characterize their evolution (changes in state), the pressures and threats to which they are subject, and in some cases the impacts of their degradation on other environments. Robust, reliable indicators are needed, based on solid scientific foundations, with transparent methods for calculation and data utilization. National and international scientific papers have been published on these topics by INRAE scientists, including in top-level journals such as *Nature Communications*, Science *Advances*, and *Global Change Biology*.

The development of more precise mapping methodologies at high spatial resolution, coupled with modeling, enables us to produce soil multifunctionality maps describing and spatializing their ecological functions and the ecosystem services they provide. In this way, in addition to traditional indicators of soil condition such as pH, density or carbon content, we can now add indicators of soil functions, such as carbon sequestration potential.

The study "Soil quality: towards an indicator system for public policy", published in 2024, was led by INRAE's Department of Collective Scientific Expertise, Forecasting and Studies and commissioned by ADEME, OFB and the GIS Sol founding ministries. This study made it possible to bring together and make available to public policymakers the scientific resources available on how to assess soil quality and health. In particular, it specifies the operationality of the main indicators



Map of the dominant texture of the upper horizon of agricultural soils by canton (source: BDAT).

selected and the methods used to assess them.
Together, these studies and advances have been made possible by the enormous body of knowledge that INRAE has produced through its soil research. The theoretical and technical tools developed by INRAE have been essential for various public policies such as:

– revising the classification of less-favored areas for the Common Agricultural Policy,

– including the soil component in the annual accounting of greenhouse gas emissions carried out by the Interprofessional Technical Center for Studies on Atmospheric Pollution (CITEPA),

– pioneering the development of national atlases of the bacterial and fungal diversity of French soils, in support of biodiversity policies,

– contributing to a better definition of the "soil-geochemical background" for many contaminants, notably in the context of policies to rehabilitate polluted sites,

– contributing to global mapping efforts carried out within the framework of the FAO/United Nations Global Soil Partnership,

– contributing function indicators and multifunctionality indexes to the ZAN (Net Zero Artificialization) policy resulting from the Climate and Resilience Act of 22/08/2021,

– taking account of soil artificialization when drawing up SCOT, PLUi or PLU (local town planning),

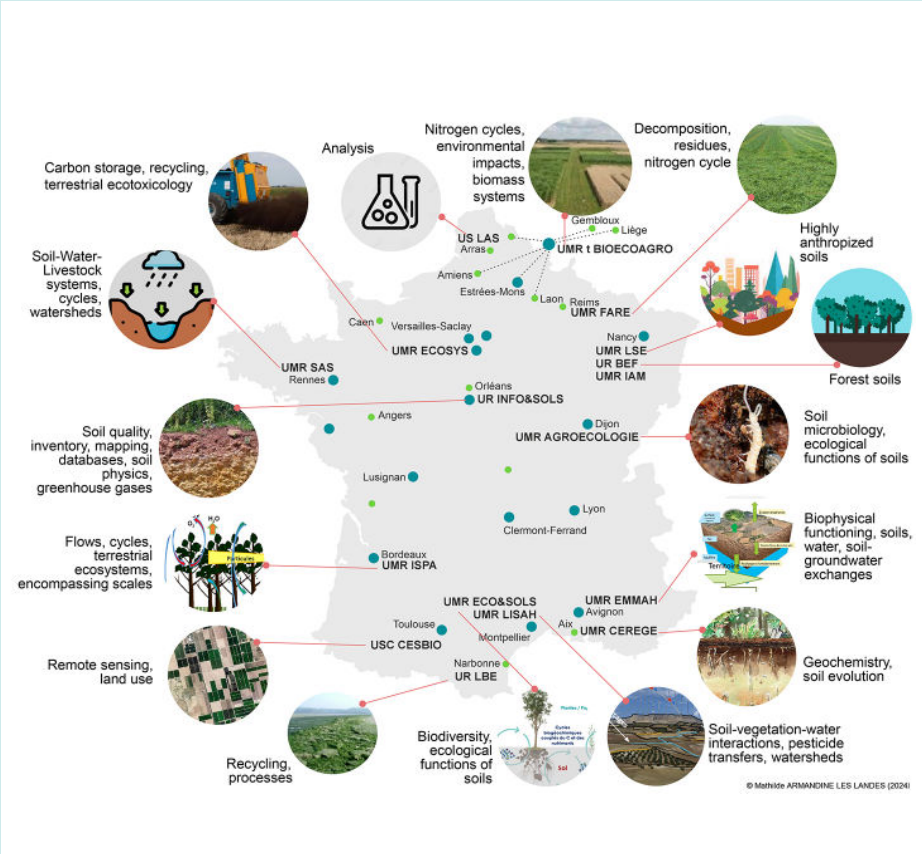
– supporting local decisions affecting forestry areas, natural parks, watersheds or agricultural activities.

DIVERSIFIED PRODUCTS AND USERS

The Info&Sols research unit is a point of direct contact for a wide range of users of soil data to inform policy, land-use planning, research and resource management. In 2022, the geo-servers recorded almost 1 million actions for the Agroenvgeo database (https://geodata.inrae.fr/datahub/news), and 2.5 million for the BDAT database, with almost 9,000 files downloaded. The report on the state of France's soils

INRAE's longstanding and highly diversified scientific research on soils

INRAE researchers have studied soil science through a wide range of related issues, some of which are independent of those raised by GIS Sol. Of INRAE's 14 research departments, AGROECOSYSTEM alone conducts research into soil biodiversity and microbiology, organo-mineral associations and terrestrial ecotoxicology. Soil science is also involved in a wide range of research projects: the study of plant-soil-microorganism interactions and root architecture in the BAP (Plant Biology and Improvement) department, and mycorrhizal symbioses and forest soils in the ECODIV (Ecology and Biodiversity) division.
With almost 10,000 articles listed on the HAL platform under the keyword "Soil", over 6,000 conference papers, almost 2,000 theses and over 500 books, not to mention student dissertations and various reports, INRAE's scientific output in the domain of soils is considerable. On the same HAL portal, no fewer than one hundred keywords in French and English are associated with soil sciences. From microscopic scale to macroscopic interactions and phenomena, soils represent a fast-growing field of research at INRAE, and are constantly shaking up our knowledge in many domains.



INRAE soil research units

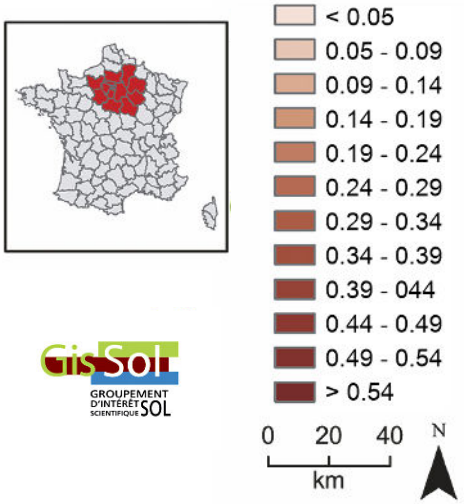
© Mathilde ARMANDINE LES LANDES (2024)

Fabrizio Botta
Deputy Head of the National Phytopharmaco-vigilance Scheme at ANSES

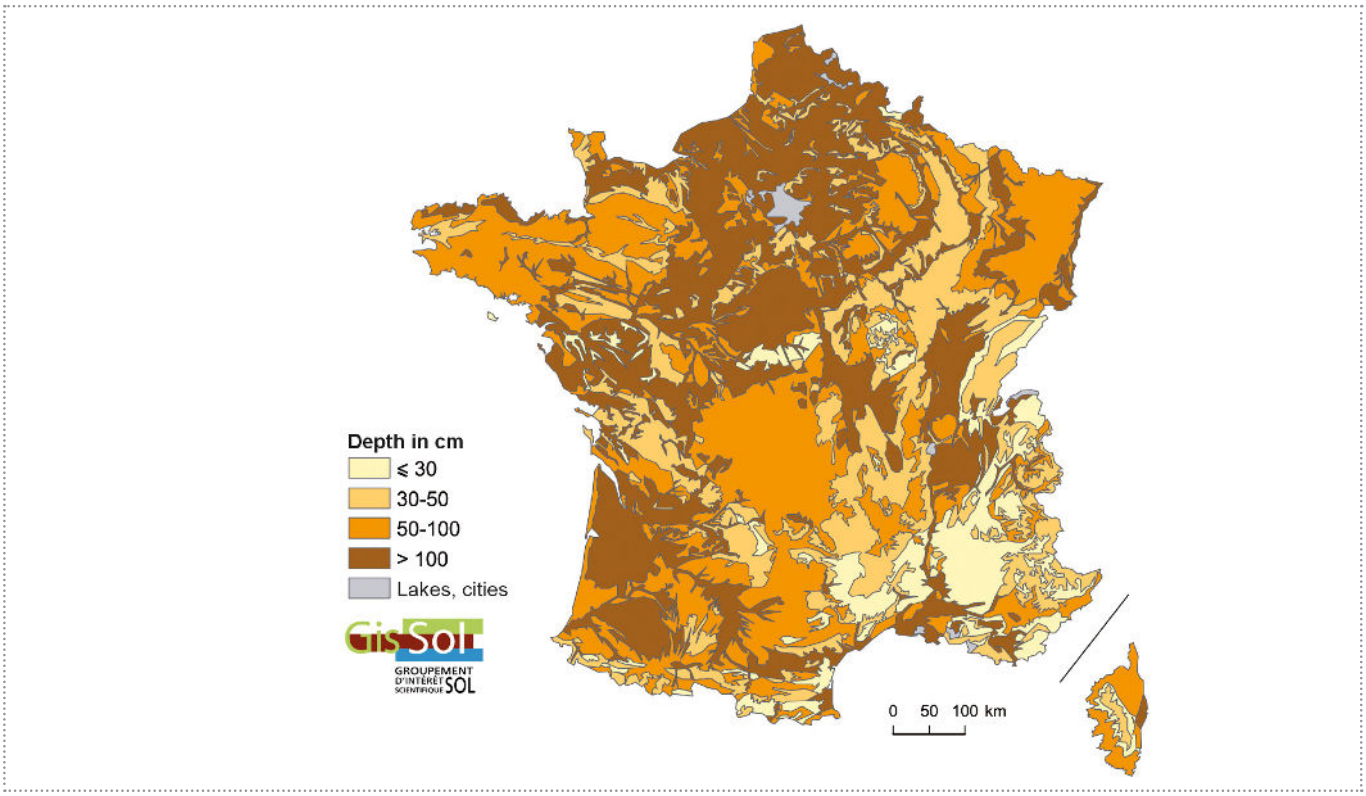
Since 2015, Anses has been coordinating a national phytopharmacovigilance scheme, the only one of its kind in Europe. This system provides a wealth of data on the presence of phytopharmaceutical residues in the environment, exposure, and their possible effects on living beings and ecosystems. All this information is used to alert us to risky exposures, and to ensure that measures are taken to remedy the situation. We commissioned the PhytoSol prospective study from GIS Sol, via RMQS (its soil quality measurement network). This gives Anses access to invaluable data on the presence of residues in soils, cross-referenced with cultivation surveys of farmers. These data are used in the evaluation of plant protection products in France, in the form of summary fact sheets, each dedicated to a specific active substance.

and its French and English summaries were widely downloaded and quoted. Info&Sols coordinates 40 partners common to RMQS and IGCS: engineering firms, chambers of agriculture, associations, agronomy school research units, as well as around thirty laboratories via the BDAT programme. Info&Sols works closely with the RMT Sols et Territoires (https://sols-et-territoires.org), a joint technology network created in 2010. The RMT produces tools to facilitate the dissemination and appropriation of GIS Sol data by a wide range of players: local authorities, conurbations, watershed management structures, educational establishments, associations, etc. These exchanges and collaborations help to coordinate studies, develop synergies and identify future research needs.

Info&Sols is also responsible for general communication regarding GIS Sol's various activities (e.g. website, report on the state of France's soils, etc.), and for ensuring that GIS products are visible to users. The research unit develops "Sol" data visualization tools (Geosol) and offers directories of its databases (Refersols, Applicasol, Repedo). Lastly, it also promotes other national soil information: data tables, web services interoperable with GIS mapping tools and maps.



Mapping of mercury distribution in Paris Basin soil surface horizons (source: BDETM).



Map of average soil depth in mainland France (source: IGCS).

European projects to support soil ecosystem service management

The progress made on soil mapping and monitoring has enabled both tools and indicators/thresholds to be developed as well as advancing fundamental research. GIS Sol's challenge is now to:

– move from providing data on the morphological, physical, chemical and biological properties of soils to providing data on indicators of soil functions and services,

– propose a repository of models to be implemented to estimate these indicators, and provide support in their use,

– propose a data offering that is easier to access, more operational and adapted to local contexts,

– integrate uncertainties into soil monitoring databases.

For several decades, INRAE scientists have been conducting research to qualify soils by employing the conceptual framework of ecosystem services: characterization of soil conditions, threats, functions and services. These studies, carried out as part of national projects (ANR SoilServ, MUSE and DESTISOL, collective expertise) and European projects (Landmark, SIREN, SERENA, EJP SOIL, BENCHMARKS), have resulted in numerous publications and applications with partners (city and regional councils, etc.).

Over the past few years, GIS Sol itself has provided support for the construction and deployment of indicators for certain soil functions, based on measurements and observations of various soil properties: the concentrations of contaminants, nutrients, organic carbon, pH, in vegetation and the environment. Work has also been carried out on indicators such as erosion risks, usable water reserves and soil biodiversity.

Since the 2000s, the European Commission has been emphasizing the importance of nationally structured soil monitoring. Its desire, expressed in two draft Soil Framework Directives, is to assess the state of soil health on a European scale. Setting up a large-scale monitoring system will enable us to re-establish a good state of soil health in order to meet tomorrow's ecological, economic and health challenges. INRAE scientists are working hard on this scientific project, which will potentially involve defining subdivisions, new indicators and thresholds on the eve of a Directive scheduled for 2025■

DOCUMENTARY SOURCES

GIS Sol website: presentation, tools, usage examples of the IGCS, RMQS, BDAT, BDETM database. http://www.gissol.fr

Dominique Arrouays, Marion Bardy, Nathalie G. Munier-Jolain, Ariane Gaunand, Laurence Colinet, *et al*. Système d'information sur les sols de France. [ASIRPA] auto-saisine. 2014, 14 p. (hal-01603434)

D. Arrouays, Pierre Stengel, Isabelle Feix, B. Lesaffre, Valéry Morard, *et al*. Le GIS Sol, sa genèse et son évolution au cours des vingt dernières années. *Étude et Gestion des Sols*, 2022, 29, pp. 365-379. (hal-03815433)

Pierre Renault, Chantal Gascuel, Isabelle Cousin, Véronique Antoni, Antonio Bispo, *et al.* Des propriétés des sols aux indicateurs de la qualité des sols, en appui aux politiques publiques et en réponse aux besoins de la société. *Étude et Gestion des Sols*, 2023, 30, pp. 207-222. (hal-04018969)

Claude GITTON (CGEDD), Gérard FALLON (CGAAER), Étude de parangonnage sur les dispositifs d'information concernant la qualité des sols agricoles, rapport CGEDD 013156-01 et CGAAER n° 19104, June 2020

Carol BUY (CGAAER), Frédéric SAUDUBRAY (IGEDD), rapport CGEDD n° 014442-01, CGAAER n° 22068, Évaluation du groupement d'intérêt scientifique sur les sols (GIS Sol), April 2023

Isabelle Cousin, Maylis Desrousseaux, Sophie Leenhardt. Soil Quality: towards an indicator system for public policy. Summary of the INRAE study report. INRAE. 2024, 10 p. hal-04798285

Soil description (texture, structure, color, etc.) by horizon in a reception pit.

Direction de l'Appui aux Politiques publiques
Centre Headquarters Antony
1, rue Pierre Gilles-de-Gennes
92160 Antony

Join us at :

https://www.app.inrae.fr/

Institut national de recherche pour l'agriculture, l'alimentation et l'environnement

RÉPUBLIQUE FRANÇAISE
Liberté
Égalité
Fraternité

INRAE