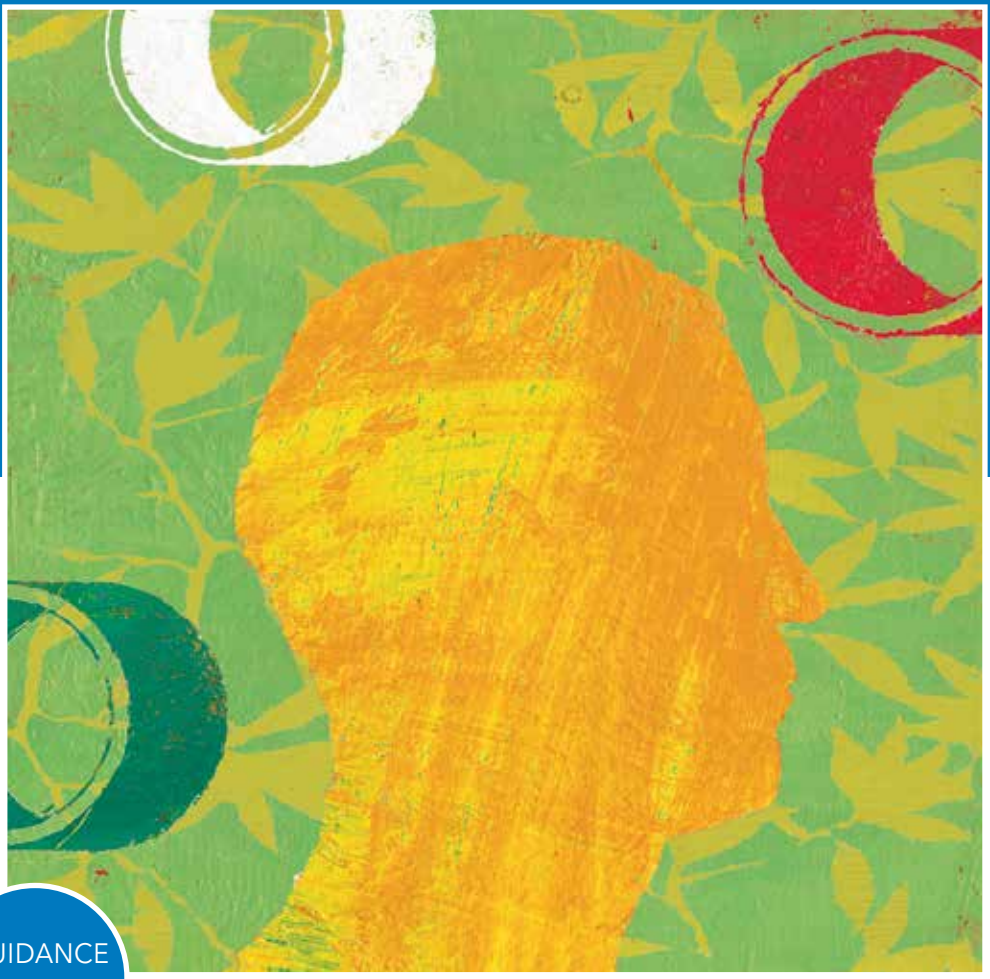
INRAE-Cirad-Ifremer-IRD
Joint Consultative Ethics Committee



GUIDANCE
14

on human needs, natural resources and preservation of the biosphere: the case of agricultural practices and soil quality

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Foreword

Since 2019, the INRAE-Cirad-Ifremer-IRD Joint Consultative Ethics Committee has been conducting an ethical review on the research work of four organisations. This work is a self-referral, -i.e., on our own initiative- and focusses on the trade-off between the fulfilment of human needs, natural resources and the preservation of the biosphere. It has based this reflection on two case studies: coastal waters (Guidance 13) and soils (this Guidance). In both cases, by taking into consideration interviews with researchers, it has endeavoured to identify areas of potential conflict and the issues at stake in existing controversies. Its Guidance notices are aimed at identifying potential issues and call for a more in-depth examination, including input from researchers.

These two specific analyses have already helped the Committee address a number of general issues whose ethical significance goes beyond each of the themes studied. Three themes have emerged: the management of the "commons", the value but also the limits of the concept of ecosystem services, and the differences in approach depending on the nature and culture of the territories concerned, the North versus the South. These issues are addressed in both Guidances, but cannot claim to be exhaustive at this stage: the Committee will consider them in greater depth in subsequent Guidances.

Axel Kahn was at the origin of the Committee's approach. He set out the raison d'être in a short text that we have included as a preface to the two Guidances produced by the Committee. It is a tribute to his work as Chairman of the Committee.

Members of the INRAE-Cirad-Ifremer-IRD Joint Consultative Ethics Committee

January 2022

PREFACE

Never conceding to the irreducibility of contradictions

Humans, like all living things, need nutrients, food, water and air to live. But that is not all. Their development has required social interaction, and they have benefited from the richness of nature, the intellectual stimulation and aesthetic pleasures it has afforded. Furthermore, what modern humans have been able to use to establish their humanity will also be a determining factor in the building blocks for future generations. It is the responsibility of those involved in the present to preserve this legacy. From another point of view, our fellow human beings are certainly legitimate in their concern for themselves and their descendants but, outside of religious thought, they are not the ultimate goal of biological evolution. They are not the only living beings with intrinsic value. Responsibility, the prerogative of our species, is therefore not limited to our own species, but encompasses the living environment to which we belong. That said, are not organisations involved in targeted research activities in open environments faced with irreconcilable contradictory constraints? We must sacrifice nothing: the economic relevance of our businesses and sectors, their sustainability, the conflicting interests of the stakeholders involved, concern for future generations and also for the biosphere as such, its delicate balance and its own evolution.

An easy solution would be to accept the coexistence of different objectives, each legitimate but incompatible with the other. Depending on the circumstances, it would only be a matter of giving priority to certain objectives that are seen as priorities because they are adapted to the urgency of the moment or to the most pressing demands. Our organisations and their Joint Consultative Ethics Committee have a different, more dialectical ambition: to accept the contradictions, but aim to overcome them in the form of an innovative solution that does not deny any of the contradictory injunctions at the outset. This is not a totally utopian objective, and a few examples can be given from strategies of the fishing industry. Scallop stocks in Brittany, bluefin tuna in the Mediterranean and Atlantic, cod in the North Atlantic and halibut in the North Pacific have all been re-established under conditions that preserve the activities of fishermen today and for the future, while respecting the environment. Concern for the present and the future, and consideration for the inherent value of the biosphere have been combined.

The aim of the Ethics Committee of our four organisations is to use real-life situations as a starting point to provide governments, researchers and staff with avenues to explore in this context of divergent and seemingly irreconcilable objectives, interests and analyses. A path may exist, but identifying it requires a method, and following it requires a will.

Every year or so, the Committee will submit the fruits of its reflections and proposals to the organisations, to add weight to their own analyses and decisions. Our first Guidance document concerns conflicts over water management in coastal areas. Farmers, oyster and shellfish farmers, tourism professionals, environmentalists and industrialists all have very different, often conflicting, views and interests. What can be done, and how? We are now tackling a huge issue, that of soil. It will undoubtedly be the subject of several issues.

The long-term project we are launching may seem ambitious. This is because the importance and challenge of the tasks incumbent on the bodies whose thinking and decisions on which we are trying to shed light, require them always to combine the reality of situations with the height of their ambitions. The Committee desires to contribute to this.

Axel Kahn

Summary

This guidance takes into account the many alerts, which, in recent years, have placed «soil quality» at the centre of concerns and research. This issue, which reconceives soil as a living environment rather than as a substrate for human activity, should place research in the perspective of an ethic of care and attention, aimed at soil preservation, remediation and even regeneration. The notion of "ecosystem services" provided by soils is a way of describing the soil's multiple relationships with a multitude of beings, which are the object of care. In research practice however, the issue is often approached in instrumentalist terms, based on an inventory of the various functionalities of soils, with the aim of characterising, quantifying and measuring these various functionalities in an attempt to reconcile or compensate for them. This guidance analyses the tensions between the two perspectives – the ethics of care and the instrumentalist attitude - by presenting a number of points of conflict concerning four categories of soil. It argues against the economisation of the notion of ecosystem service, which postulates a form of general equivalence between beings and things that are, from a more moral point of view, incommensurable. This guidance therefore stresses that it is not simply a question of striking a compromise between the various ecological, economic or heritage functions of soils, or treating them as mere means to an end. It is about viewing land as a living environment shared by a multitude of entities with very disparate values. This calls for a political debate on the question: what is a good and what is good for whom? This guidance also calls for vigilance regarding the position of researchers vis-à-vis to those working in the field.

Guidance on human needs, natural resources and preservation of the biosphere: the case of agricultural practices and soil quality

I ■ Introduction

Soil is the area at the interface between the lithosphere and the atmosphere in both land and water. Although it is a thin layer measured in centimetres or a handful of metres, it plays an essential role in the lives of human populations as a key factor in agriculture and food production. It is an ecological niche with a huge diversity of organisms fulfilling important ecological functions that affect ecological balance, such as maintaining biodiversity, storing carbon and reducing greenhouse gas emissions.

The emerged part of the planet represents 29% of its surface, and 70% of this area is habitable. Not all land is soil, because soil is formed by the addition of mineral and organic matter, and can be destroyed faster than it is created. Soils are living organisms, so they are dynamic and constantly evolving. According to the IPCC's special report Climate Change and Land (2020), 12% of unglaciated land is used for agriculture, 37% for pasture, 22% for forestry, 28% is only slightly anthropised and 1% is used for infrastructure[1].

Given the constant pressure exerted by human action on the soil, preserving it must be part of the equation for future decisions taken by our society. Taking into account the effects of human intervention on soil development is a major challenge for environmental ethics.

II ■ Background

1- Soil as a support for agricultural production and the chemical paradigm

Soil is of mounting concern today. Nevertheless, the question of soil fertility and its possible deterioration is not a new one, and has been raised since the dawn of agriculture. The most successful civilisations developed around regions where the soil was well replenished by the addition of sediments rich in organic matter at each flood (The Fertile Crescent, the banks of the Nile covered in silt by the annual floods, the basins of Chinese rivers). In Central America, the loss of soil fertility forced Mayan towns to be periodically relocated.

Various practices have attempted to enhance this fertility, with increasing assistance of science and technology. The traditional practice of spreading organic residues from livestock was replaced in the 19th century by the use of nitrate-rich fertilisers, available in Chile and Peru[2]. As crops became more intensive, the nutrients provided by the soil (nitrates, phosphates, potassium, etc.) could become depleted, necessitating the use of nitrogen fertilisers, which became available in 1909 thanks to the synthesis of ammonia from atmospheric nitrogen using the Haber-Bosch process.

Although the soil was studied by microbiology researchers in the 1930s and 40s, agronomic research focused on the chemical composition of soils[3]. From 1945 onwards, the development of the "green revolution" in countries such as Mexico, Pakistan and India favoured this chemical paradigm, which was better suited to the need for standardisation to meet the pressing post-war demand for food.

At the same time, the practice of ploughing, widely used in agriculture since its earliest days, has been transformed by the introduction of powerful tractors to eliminate weeds and aerate the top layers of soil. This practice can have potentially harmful consequences, particularly for the organisms living in the soil, where they perform numerous ecological functions, some of which have only recently been discovered. In 1935, for example, the United States set up the Soil Conservation Service (later renamed the Natural Resources Conservation Service), in an attempt to curb wind erosion of the soil in the Midwest, the famous Dust Bowl that devastated agriculture[4].

Today, soil conservation is a global issue, although it seems to be more prevalent in industrialised countries. It is a major problem for human and environmental health, because excess nitrates and

1 https://www.ipcc.ch/srccl/download

2 The success of Justus von Liebig's book "Chimie organique appliquée à la physiologie végétale et à l'agriculture" (1840, translated into French in 1841) spreads a simple message: inputs and outputs must be balanced. For so many quintals of wheat, so many kilos of manure... The chemical paradigm focuses on the need to supply minerals, nitrogen, phosphorus and potassium, known as NPK..

3 Following the discovery of penicillin, several pharmaceutical laboratories began prospecting for microbes or fungi in the soil with a view to producing new antibiotics. This is how Benjamin Duggar discovered *Streptomyces aureofaciens*, which produces aureomycin by fermentation.

4 At the same time and for similar reasons (plus overgrazing), the Water and Forestry Administration set up Soil Defence and Restoration departments in Morocco and Algeria under French rule

phosphates contaminate water, sometimes preventing human use or encouraging the uncontrolled growth of organisms in lakes and rivers. In addition to these direct effects, the use of synthetic fertilisers also has a negative impact on the climate: in France, emissions from the production and use of nitrogen fertilisers account for 10% of total national greenhouse gas emissions[5], expressed in CO_2 equivalent. Nitrous oxide (N_2O) emitted during the spread of these fertilisers has a high global warming potential, significantly higher than that of methane and 300 times that of CO_2. It has also been shown that ploughing can have adverse effects on the balance within the soil biota, particularly the microbiota, a balance that we shall see is crucial to soil restoration. Soil degradation was recognised as a major problem by academic circles in the 1990s, as well as by international organisations. In December 2012, the FAO created the *Global Soil Partnership*[6] . Since then, there have been increasing alerts as soil degradation accelerates: according to the FAO, 24 billion tonnes of fertile soil are lost every year. In 2015, the FAO declared that 33% of all soils were degraded as a result of intensive use by agriculture and urbanisation, or as a result of pollution[7]. This is a key issue for public policy, as soil plays a role in several of the major challenges facing our society: erosion, climate change[8](desertification, CO_2 storage), loss of biodiversity[9], food security and the health of ecosystems and human beings. It is hardly surprising, therefore, that soils feature prominently in Sustainable Development Goals[10]. At a national level, in 2019 France Stratégie published the report "*Objectif Zéro artificialisation. What steps can be taken to protect the soil?*". In spring 2021, the European Parliament took up the issue[11]. The Climate and Resilience Act of 22 August 2021[12] includes provisions aimed at halving soil artificialisation within ten years, which is defined as damage to biodiversity and soil functions: "*Artificialisation is defined as the lasting alteration of all or part of the ecological functions of a soil, in particular its biological, hydric and climatic functions, as well as its agronomic potential by its occupation or use*."

2- The return of microbiology and the emergence of the soil as a living environment to be protected

Soil microbiology had become marginal in research institutes in the first half of the twentieth century. However, in the 1960s, it was back on the agenda of forestry research, which revitalised soil science with an emphasis on optimising production.

Research on soil has shown that the composition of soils around the world varies greatly, and that this variability has a significant impact on the productivity of different agricultural regions. In general terms, soils are made up of 45% minerals, 25% water, 25% air and 5% organic matter. The mineral components of soils are formed from the erosion of rocks. The presence of certain elements, such as metals, influences the agricultural quality of soils. Although organic matter accounts for the smallest proportion of soil, research shows that it plays a key role in soil richness. The organic components present in the soil include micro-organisms such as bacteria and fungi, as well as the root systems of plants and creatures such as worms, insects and small vertebrates. A large part of the research work on soil biology is aimed at identifying and understanding these species, their interactions and their role in cultivated plants and, more generally, in ecosystems. This work is particularly committed to soils at the interface between the land surface and river and marine environments.

The concept of the living soil has been enjoying a second revival since the 1990s and especially since the 2010s, thanks to massive sequencing techniques that have revealed an exuberant and highly diverse world[13]. Millions of species coexist and interact there: microbes, fungi, plants, invertebrates and even a few vertebrates. The paradigm shift is reflected in the introduction of the concept of "soil health"[14], assessed on the basis of the dynamics of matter and energy flows, in place of "soil quality"defined by its chemical composition[15]. Soil is a living environment, just like the ocean. Yet

5 Source: CITEPA-SECTEN 2020 for emissions, and Humanité & Biodiversité assessment for fertiliser production.

6 http://www.fao.org/global-soil-partnership/en/

7 FAO & ITPS (2015). *Status of the World's Soil Resources.* Food and Agriculture Organization. Intergovernmental Technical Panel on Soils. FAO. http://www.fao.org/3/ca8943fr/CA8943FR.pdf

8 IPCC (2019). Special Report on Climate Change and Land. Intergovernmental Panel on Climate Change. Geneva: IPCC.

9 IPBES (2019). *Assessment Report on Land Degradation and Restoration. Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.* Bonn: IPBES.

10 Lal, R. et al (2021). Soils and Sustainable Development Goals of the United Nations: An intenational Union of soils sciences perspective. Geoderma Regional, 25 e00398, - https://doi.org/10.1016/j.geodrs.2021.e00398.

11 Fosse, J. (2019). Objectif Zéro artificialisation France Stratégie - European Parliament, Committee on the Environment, Public Health, Food Safety, Draft Motion for a resolution 2019-2024.

12 Article 192 of law no. 2021-1104 of 22/08/2021, known as the "Climate and Resilience" law, https://www.legifrance.gouv.fr/jorf/article_jo/JORFARTI000043957221

13 See the TerraGenome programme set up in 2009, modelled on the human genome project. https://www.terragenome.org/

14 Karlen, D.L et al (1997). Soil quality: Concept, definition, and framework for evaluation. Soil Science Society American Journal, 61, 4-7.

15 This semantic shift was brought to our attention by Alexis Thoumazeau, a researcher in agro-ecology and soil science at the ABSys joint research unit (Agrosystèmes biodiversifiés - Biodiverse Agrosystems).

this living environment is complex and poorly understood. Increasing our understanding of the behaviour of these invisible living organisms and their interdependence is fast becoming a major research objective.

3- From biodiversity to ecological services

The reconsideration of soils does not stop at highlighting this biodiversity but extends beyond the strict framework of agriculture. At the beginning of the 21st century, following the work of a number of agronomists and ecologists, town planners and geographers, the soil was seen primarily as an area to be protected or conserved because it performs multiple functions:

- regulation of water cycles: floods, droughts (also affect water quality);
- sediment storage;
- storage of organic carbon essential for fertility;
- climate regulation through sequestration (C and N sinks) and the mineralisation of organic carbon;
- biodiversity pool;
- storage of waste and pollution;
- waste recycling;
- filter function for biological and chemical contaminants;
- production of renewable energy;
- infrastructure support (housing, roads, etc.);
- source of materials;
- memory of humanity's past and religious or patriotic value.

These functions qualify soils as providers of "ecological services"[16], and more broadly as producers of cultural services in the sense that agriculture, infrastructure and religious burial practices are cultural. The various functions are therefore closely interdependent: alteration of any one of them by certain practices disrupts all the others. In this integrated system, the decomposition of organic matter at the lower trophic level dictates all the other processes on which the health of soil depends. Since soil functions are not independent of each other and can become conflictual, it is important to clearly define the conditions under which these functions are carried out, and to have a precise vision of the issues at stake and any potential conflicts. Finally, it is essential to call on the expertise of a wide range of specialists in order to provide informed and equitable solutions.

Soils are generally considered to be the basis for agricultural production. Their fertility depends on their ability to support the life of a host of organisms that help provide plants with the energy and materials they need to grow. And yet soil is more than just a support for biomass production, because it interacts with plants. "*There is not just soil and plants, but a soil-plant system*"[17].

Functional ecology considers soils to be the habitat of a host of highly diverse organisms that act as "soil engineers" [18]. Worms play a well-researched role as blenders of organic and mineral matter in soil formation, but little is known about the multiple functions of bacteria, archaea and fungi. They play such a fundamental role that the carbon and nitrogen cycles in soils are almost entirely dependent on these micro-organisms.

Soil plays a role in controlling greenhouse gases. In general, they act as a carbon sink, absorbing 2,400 GtC/year on a global scale, although in some cases they emit methane and nitrogen oxides. On average, carbon content peaks at 20 cm and then decreases exponentially with increasing depth. The "4 per thousand: soils for food security and climate" initiative launched by France in 2015 aimed to increase the carbon content of soils. Following the scientific controversies sparked by somewhat

[16] Ecological or ecosystem services refer to the benefits that humans can derive from ecosystems. They result from the natural processes by which ecosystems function and are maintained, without being confused with these functions (see below V.2)

[17] Abadie, L (2018). Soil fertility: quality through life. Annales des Mines, 91, 10.

[18] Blanchart, E. and Trap, J. (2020). Intensifying soil ecological functions to provide sustainable ecosystem services in agriculture. Special issue on soil functions and ecosystem services. Étude et Gestion des Sols, 27, 121-134 https://horizon.documentation.ird.fr/exl-doc/ pleins textes/ divers20-04/010077640.pdf.

simplistic initial calculations, more precise studies have been carried out on the storage potential of French soils[19]. But storage processes are not always well understood, and the sustainability of positive inflows after stabilisation of practices conducive to increasing carbon stock needs to be clarified.

In addition to carbon storage, waste is recycled. The micro-organisms that inhabit soils biodegrade organic matter and can produce nutrients for plants, notably by fixing nitrogen. Some even have the capacity to degrade or mobilise pollutants such as toxic metals in mining environments.

Soil also regulates the water cycle between seasons. This is vital for agricultural and forestry vegetation, which needs water in summer but not in winter. This is why soils that retain water, as opposed to stony or sandy soils that drain water, are said to be fertile.

This functionalist approach, which sees soil as a resource in terms of ecological and food services, underpins current research into soil management. Soils should be conserved, protected or rehabilitated when duly analysed and mapped.

4- From ecological services to social and symbolic functions

To this already long list of categories, we need to add other elements:

- *Land as an area to be developed.* In a context of spiralling urbanisation, land is seen as a surface that needs to be allocated according to the various uses to which it is put. This perspective goes hand in hand with the massive urbanisation of part of the planet's land surface, either as building land or as traffic zones.
- *The soil as a waste bin, out of sight, out of mind.* An undetermined space that makes invisible what we do not want to see. Whilst the disposal of excrement can help enrich the soil, the inclusion of industrial and household waste pollutes over time.
- *Soil as a source of materials, for use for example in construction*. Clay has been used for centuries to make bricks. Now that concrete is being used to build homes and for public works, sand - a form of soil rich in silicates - has become the world's second largest resource after oil.
- *Soil as heritage*. In many rural areas of sub-Saharan Africa, as well as in Europe, farmers consider that they owe the management of their soil not only to their family, their village and their community, but also to the ancestors who passed it on to them.
- *Soil as cultural heritage*. As most soils are anthropised, they constitute a palimpsest of diverse histories that are constantly being revealed by archaeological research undertaken during development projects. Soil bears the traces of past civilisations, wars and events affecting families, agriculture and industry. In this respect, soil assumes symbolic value. However, these signatures or stigmas of the past can interfere with, or even prevent, their current role.

III ■ Soil issues at a glance

From an instrumentalist perspective, the overall question is: how can the various functions of soil be reconciled and harmonised? For example, how can we guarantee food security and environmental protection? How can we reconcile housing or urban infrastructure with environmental conservation? Yet the reconciliation effort becomes more complicated when soil health is seen as an end in itself, because we have to reconsider the means, i.e., the uses to which the soil is put. The conflict between the two perspectives - instrumentalist or care ethics. This raises a number of specific questions.

Climate-related issues: How can agricultural practices be adapted to climate change, drought and soil fertility loss? How can we ensure that soils make the best possible contribution to mitigating climate change, through improved carbon storage? Banning or reducing chemical fertilisers is a first step, and

[19] Pellerin, S., Bamière, L., Savini, I., Réchaudière O. (coord.) (2021). *Stocker du carbone dans les sols français. Quel potentiel et à quel coût ?* Éditions Quæ.

trying to adapt plants (through selection or directed transgenesis, for example) is another, but if we consider the soil as a living environment that needs to be kept healthy, shouldn't we be working on the plant-soil system?

Questions of temporality: Soil is an active and dynamic living environment with its own timeframe. The process of carbon sequestration takes years, whereas the release of carbon into the atmosphere as a result of deforestation or certain agricultural practices is extremely rapid. How can soil regeneration cycles be reconciled with the pace of agricultural production?

Knowledge and understanding: Knowledge of soil health is as much a matter of fundamental science as it is of local folklore. This is borne out by the many Cirad publications that carry out a scientific assessment of the fertility indicators used by indigenous farmers and conclude that they are well-founded in the light of current scientific knowledge. The revaluation of local and common knowledge through the use of new techniques, raises questions about research policies. How can research programmes be directed to reconcile the expertise acquired in practice with the expertise of agronomic science? Should research programmes focus less on technical innovations and more on the study of traditional methods and past techniques? Which space-time context should be adopted? How can we take into account the great diversity of southern countries in terms of geography, ecology, climate, economics, culture and society?

Cultural considerations The health of soils calls into question the values of modernity from another angle. Soil health involves death, degradation and decay. In short, the impure, which leads us to change the way we look at microbes, long regarded as enemies that need to be fought or limited, whereas soil health leads us to recognise microbes as essential players because their action is also beneficial. Even if we are not referring to the same microbes, the image of humus and the practice of composting do not fit well with the common image of hygiene.

Social issues: Soil health also calls into question the modern trend to reduce human labour in order to increase leisure time. Indeed, "good practices" often require a lot of labour, more manual work than mechanical work, and fewer standardised technical interventions. Despite this, the farming population declined massively during the twentieth century as a result of a mass exodus from the countryside. Consequently, soil protection calls for a radical rethink of modern lifestyles (fixed working hours, division between working time and holiday time) modelled on those of urban populations.

Economic issues: The economic benefits of land capital can conflict with the necessity for care, which requires the protection of biodiversity or heritage. The report by the French Ministry for Ecological Transition on the objective of "zero artificialisation of land" estimates that an average of 30,000 hectares of land would be developed on each year in France between 2006 and 2016, excluding transport infrastructure[20]. On the whole, local authorities have an interest in attracting economic activity to their areas, and therefore in construction. Farmers, for their part, see urban sprawl as a way of increasing the value of their land in peri-urban areas by selling it for building or development. Soil denaturation not only leads to a loss of agricultural production, but also increases the risk of flooding and intensifies global warming. This tendency towards the disappearance of soil, in disregard of the services it provides, is on-going in spite of zero-denaturation policies.

Legal issues: Soil is generally considered to be an asset in its own right, owned by either individuals or local authorities. But soil degradation is a common problem of common interest. Soil is therefore an area of potential conflict between private interests and the wider public interest. Will soil protection and the adaptation of crops to the objectives of sustainable development revive the practice of the "commons"? This calls for legal measures and political arbitration. But by whom? By what means? Soil needs social innovation as much as, perhaps more than, technical innovation.

20 https://www.ecologie.gouv.fr/artificialisation-des-sols

IV ■ Points of conflict and controversy

In order to more clearly identify the players and issues at stake in the challenges to be faced, this section first examines the points of conflict in four soil categories: forest soils, agricultural soils, dry and wetlands and, finally, urban or peri-urban soils. It then addresses a key cross-cutting issue for ensuring soil health: the question of ownership and the commons.

1- Forest soils

Before tackling such highly topical issues as the role of forests in carbon storage or the adaptation of forests to climate change, we feel it would be useful to take a look back at how forest management has evolved, both to shed light on contemporary forestry methods and to provide an overview of the different legal frameworks that have prevailed, some of which may serve as inspiration for the future.

1.1. Forest activities, management systems and ownership rights

From the Middle Ages until the beginning of the 19th century, forest management was essentially limited to cutting timber (mainly for firewood, and to a lesser extent construction wood) but was also geared to granting a number of rights, which varied from place to place: grazing in the forest, "glandée" (gathering acorns, in particular to feed pigs), "soutrage" (gathering undergrowth), etc.

In regions where the feudal tradition remained strong until the French Revolution, these rights were granted to well-defined communities (villages, hamlets, groups of families, etc.), according to varied and inconsistently formalised practices, by the lord seen as the owner of the forests (sometimes the king, a monastery or any other nobleman).

In regions that had previously been freed from feudal control, particularly in the eastern half of France, in the densely wooded mid-mountain ranges (The Vosges, The Jura, pre-Alps, Le Massif Central), the collective use of forest harvesting was already organised as early as the late Middle Ages. Forests were already collective assets, managed as such before the official creation of the communes, which were really only formalised in the 19th century. Neighbouring communities sometimes had global agreements for trading services, for example grazing rights in mountain pastures, water rights in canals to irrigate crops and firewood rights in forests, over the territory covering all their lands.

Whatever the nature of ownership, forests have been an important source of raw material for building, shipbuilding (particularly around the Mediterranean) and domestic and industrial heating since ancient times. The very high demand for firewood led to the ill-considered development of the coppice system[21], which had a disastrous impact: in some areas, such as the Morvan, which supplied Paris, clump shoots and complete root suckering every 7 or 8 years, led to soil impoverishment.

From the early 19th century[22] onwards, the State forestry administration embarked on two distinct but parallel developments.

- The first was technical. From the outset, the new forestry doctrine[23] aimed to ensure the "conversion" of coppice forests, where renewal took place through stump sprouting[24], into mature forests that were much more protective of soil quality. Complete regeneration of the stock only took place once every century or so, and very often by gradual felling of natural regeneration, thus not exposing the soil, using silvicultural techniques developed at the end of the 18th century in the wake of the agronomic thinking of the physiocrats. Their main aim was to limit soil impoverishment caused by coppicing and to increase timber production, a strategy that proved highly successful.
- The second is a political-administrative one: after the nationalisation of the property owned by the nobility and the clergy during the French Revolution, the newly state-owned forests underwent a "confinement of rights of use", which consisted of purging all existing rights in exchange for part

[21] This system consists of assessing the age at which stump sprouts (for species that sprout well: oak, hornbeam, etc.) are sufficiently abundant to allow firewood to be harvested, dividing a forest into a number of plots equal to this age, and cutting one of these each year, before resuming the rotation.

[22] In the 1820s: creation of the Nancy forestry school in 1824, and promulgation of the Forestry Code in 1827.

[23] Established at more or less the same time in France with the creation of the Nancy forestry school and in Germany at the beginning of the 19th century.

[24] This limits the number of species that can re-grow well to a few: hornbeam, oak, and produces mainly firewood, with re-growth growing too fast to make good construction timber.

of the forest being given in full ownership to the user community, which was almost always a commune[25]. Today's communal forests[26], whether they are the result of a cantonment of usage rights or of older collective ownership, continue to allow owner communes, who so wish, to distribute firewood directly in kind to residents who request it, provided that the distribution is egalitarian: this is the right of "affouage", which was given a legal framework by successive texts throughout the 19th century and up until the Communal Law of 1884, which did not as such exist before.

Although the confinement of rights of use and the transition from coppice to "high-tree forest" has certainly played a role in improving the quality of forest soils over the last century, it should be noted that the efforts of foresters have been greatly aided by the emergence of fossil fuels (coal followed by oil) to replace firewood for industry and private use, which has dramatically reduced the demand for firewood.

Today, we are witnessing a partial return to square one: the over-exploitation of certain intensive softwood plantations is leading to soil impoverishment comparable to that which existed at the beginning of the 19th century. What's more, in French Guiana for example, the sedentarisation of the population, linked to the creation of infrastructures (water supply, electrification, schools) has had an impact on the viability of the slash-and-burn agriculture traditionally practised, precisely because of the loss of soil fertility due to the short fallow periods in the forest.

In addition, the identification of a multiplicity of ecosystem services provided by forests, and in particular by their soils, raises the question of the relevance of an approach based on the commons, inspired, among other things, by the old methods of collective management of forests or pastures: irrespective of the identity of the landowner, should we not introduce forms of governance of these areas that allow management by the groups concerned with a view to preserving these ecosystem services? We will return to this question below.

1.2. Carbon storage

In the forestry sector, questions are being asked about the role of carbon storage in offsetting emissions by 2050, which is essential if we are to achieve "carbon neutrality": hence the "4 per 1,000" initiative in agriculture, or the prospect of (roughly) doubling carbon sequestration by the forest or in extracted wood by 2050. These estimates are highly controversial, and poorly documented, on a number of points, including the capacity of forest soils to store more carbon or less carbon, depending on the type of silvicultural treatment applied. In temperate climates, carbon storage in forest soils is much greater than in above-ground vegetation, so the link between carbon flows in soils and in trees as a function of more or less "dynamic" silviculture is essential.

For forests, as for agricultural soils, the expected gains in storage between now and 2050 are temporary catch-ups, not permanent flows: the day the recommended good practices are applied everywhere, we enter a system of zero net flux and stable stock, which no longer offsets any greenhouse gas emissions. How fast should we move towards maximum storage?

Moreover, the best management methods from the point of view of carbon sequestration are not always optimal for other production objectives (food production, harvesting wood for building with wood rather than concrete, etc.) or for preserving biodiversity. Hence the controversy in forestry circles over the compensation system. Thinking that we can offset air travel or other emissions by planting trees inevitably leads to very intensive planting methods to optimise the volume of wood produced in the short term (too often considered the only criterion for assessing the scheme) compared with the cost of planting. Hence the contradiction between the desire to preserve soil health (i.e., biodiversity or water resources) and the desire to store carbon.

25 With rare exceptions, such as the rights to use the Dabo state-owned forest in Moselle, which belong to a group of designated families on a hereditary basis.

26 Particularly in the Massif Central, sometimes sections of communes, in fact hamlets.

1.3. Conflicting strategies for adapting to climate change

Adapting to climate change or preventing its effects is an essential condition for ensuring soil health. There are two opposing strategies for achieving this. The first, referred to as free evolution, is based on the principle of leaving as much of the forest as possible untouched by human intervention, on the basis that the natural capacity of forest ecosystems will adapt to changing ecological conditions, even rapid ones such as those currently prevailing. In fact, it is likely that after major diebacks of current forest stocks following climatic changes, a new forest landscape will be re-established within a few decades with pioneering species (depending on the site, birch, scots pine, willow, etc.). This strategy favours the spontaneous evolution of forest under the effect of its own dynamics, without prejudging the consequences of the adaptation of forest ecosystems to climate change, including extreme climatic events such as droughts and heat waves. The other, is the interventionist strategy, which consists of encouraging the replacement of existing forest species with others better adapted to warmer, drier climates, using a variety of methods (full plantations or "blocks of future" intended to serve as support points for natural regeneration around them). As a curative measure, this strategy involves direct replacing of dying trees with species thought to be adapted to future conditions. The choice between these two strategies depends on a number of criteria: the biodiversity and resilience of existing forest plantations to climatic events, carbon storage in the soil (affected by the impact of felling and planting), in the aerial part of the forest (particularly with regard to the risk of fire, which is a source of significant carbon loss, including in the upper layers of the soil) and in processed products, the impact on local economic activity, the landscape, etc. The existence of easily accessible funding under recovery plans favours the interventionist plantation strategy, even though scientific and technical knowledge in favour of one or other of the strategies and the conditions for their implementation has not as yet been established.

The historic example of the transition from coppice to high forest highlights the interrelation between silvicultural management and soil health. Soil is completely exposed during clear-cutting, which is why limiting this practice is essential as is also the case of ploughing, which is sometimes used (but fortunately less and less) to facilitate plantation work.

1.4. Conflict of time scales

Ecological conditions, and in particular climatic conditions, have changed significantly in the hundred or so centuries since the end of the last ice age. In both "free evolution" and highly interventionist silviculture strategies, these conditions up to now were considered stable over the time-frame of a century, which is roughly the natural or artificial renewal cycle of a forest ecosystem. However, this is no longer true: current temperature variations are about a hundred times faster than those seen since the end of the last ice age. Consequently, foresters are no longer able to predict the effects of either "free evolution" or highly interventionist silviculture.

1.5. Water management

In much of Western Europe, the IPCC reports suggest that, in addition to a rise in temperatures, rainfall patterns are likely to shift, becoming more abundant in winter and less in summer. Foresters throughout the vast north-east quarter of France are currently facing an exceptional wave of forest dieback, no doubt mainly due to summers that have been slightly drier than usual since 2018, which has led to ecological equilibrium thresholds being exceeded in many scenarios (including scenarios as common as the Vosges coniferous forests: contrary to what is sometimes said, the problem is not just limited to spruce plantations unwisely planted in recent decades, even if the damage is more spectacular). The forestry debate has focused on the means needed to replant after these trees have been harvested. What kind of enlightened attitude can we adopt in the face of an apparent short-term anomaly, which could be part of a much more serious trend? Moreover, what can we say to wood suppliers (local sawmills) who are now supplied with dry wood only, which has limited uses?

2- Agricultural land

2.1. Tensions over soil health assessment

While there are several criteria for assessing soil quality (texture, composition, etc.), the initial assessment of soil health is based essentially on the population density of its living organisms (microorganisms, fungi, microfauna, mesofauna and macrofauna). However, this does not mean that there is a consensus. It is generally accepted that a 30% reduction in the microbial diversity of a soil reduces its structural stability and agricultural productivity by 50%, because it increases the survival time of pathogens. Nevertheless, assessment practices are faced with a dilemma: should priority be given to quantitative or qualitative biodiversity?

The mapping of French soils carried out by INRAE Dijon, clearly shows that there are significant differences between the quantitative approach, which assesses the number of microbial species per gram, and the qualitative study of the networks of biotic interactions between bacteria ("The Facebook of bacteria")[27]. Bacterial diversity is on the increase in agricultural soils, but the network of interactions between microorganisms is less cohesive. Bacterial communities that are beneficial to soil health are less stable and less able to perform the functions expected of them. In other words, the use of biodiversity as an indicator of soil health needs to be qualified. The conflict between the results of the quantitative and qualitative approaches raises the question: in what way or for what purpose is biodiversity good? Does its value not depend on the type of functionality we want to test or develop? With this in mind, Cirad and IRD have proposed a set of multi-criteria tools for assessing soil health[28]: Biofunctool® for assessing carbon dynamics, nutrient cycling and soil structure maintenance. These indicators are based on an assessment of the overall biological activity of soils (functions) rather than on a characterisation of biodiversity.

2.2. Conflict between storage functions and mineralisation

Soil provides an essential ecological service through its capacity to store carbon in organic form from plants and micro-organisms. The objective of the 4 in 1,000 initiative is to increase the carbon stock of agricultural soils by 0.4% (or 4 per 1,000) each year in the top 30 centimetres of the soil through sustainable agricultural practices - in particular, by increasing biomass production. However, this objective does not specify in which state - mineral or organic - the carbon should be stored. Yet the process of mineralising carbon in soils is an important driver of agricultural productivity, as it releases mineral elements that can be assimilated by plants. A balance therefore needs to be struck between two phenomena: maintaining a certain amount of organic matter in the soil to retain water or store carbon, and decomposing or mineralising this organic matter to improve soil fertility[29].

Which farming practices optimise carbon storage whilst maintaining agricultural productivity? All agricultural practices deemed to be sustainable -for example, organic farming and conservation agriculture - are certainly aimed at preserving soil biodiversity, using a variety of techniques such as mechanical or thermal weeding and cover crops. But not all of these techniques are equally conducive to agricultural productivity and soil storage, so for each agrosystem we need to find the best compromise between yield and soil health. To reach such a compromise, we have to recognise that the debate is not just a technical one. Calculations of the tonnes of CO_2 saved provide valuable indicators, and the prospect of compact robots capable of selective targeting and destroying weeds is attractive. But we need more than calculations and artificial intelligence. Finding the right compromise between the functions of storage and agricultural productivity involves choices of priorities, a hierarchy of values that is a matter of ethical choice and democratic debate.

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[27] See Lionel Ranjard's presentation to the UNESCO World Food Chair, https://vimeo.com/323201748

[28] See Brauman, A., Thoumazeau, A. (2020). Biofunctool® : un outil de terrain pour évaluer la santé des sols, basé sur la mesure de fonctions issues de l'activité des organismes du sol. *Étude et Gestion des sols*, 27, 289-303.

[29] See Pellerin, S., Bamière, L., Savini, I., Réchaudière, O. (coord.) (2021). *Stocker du carbone dans les sols français. Quel potentiel et à quel coût ?* Éditions Quæ.

2.3. How can the "4 per thousand objective" be envisaged over the long term?

For year 1, it is relatively easy to calculate the tonnes of CO_2 saved by switching to agro-ecological practices in a given area[30]. But how can annual emissions be offset every year? Let's assume that between now and 2050, the widespread adoption of these practices will make it possible to increase carbon storage capacity in the soil to offset annual CO_2 emissions from other activities such as transport, housing and industry. But beyond 2050, and once we have reached maximum storage capacity thanks to the implementation of the most beneficial agroecological and forestry practices, we will have to continue offsetting emissions, because they will not go from 90 Mt CO_2 eq to 0. Hence the need to drastically reduce GHG emissions and not be content with compensation markets. To maintain a balance in flows (maximum storage) in agriculture and forestry, we will have to find other means of sequestration, and above all not give up on agricultural and forestry husbandry on the basis that emissions have fallen.

3- - Drylands and wetlands

Despite their highly contrasting characteristics, drylands and wetlands have one feature in common: they are under threat from climate change, degradation and urbanisation due to rapid population growth.

Drylands make up around 41% of the Earth's land surface and support a population of around 2 billion people[31]. Twelve million hectares are degraded every year by erosion, intensive agricultural practices, particularly overgrazing, or poor irrigation practices[32]. In addition, many agricultural areas are threatened by burgeoning urbanisation in Africa. In recent years, a wide range of effective measures have been put in place by various bodies to curb this process. For example, the land degradation neutrality (LND) mechanism, comparable to the carbon neutrality principle, as part of the 2008-2018 ten-year plan of the United Nations Convention to Combat Desertification[33] (UNCCD). The aim of this tool, which is available to decision-makers, is to maintain and increase the amount of land used for food production in relation to a reference state: no net loss is to be recorded unless it is offset by an equivalent gain in land. On a different note, the PPZS system that Cirad has set up for pastoralism in West Africa brings together the multidisciplinary skills of national and international institutions and develops scientific partnerships to adapt pastoral practices[34] to changes in climate and soil. We should also mention the remarkable role played by Bruno Devresse's Association for the Promotion of Fertile Trees, which has developed agroforestry in Togo[35].

Unlike drylands, wetlands situated between land and water are among the most productive ecosystems in the world[36]. They offer a wide range of ecosystem functions[37]: reservoirs of biodiversity, carbon sequestration, climate regulation, water regulation, hydrogeology, protection against erosion, waste purification, etc. These are privileged environments in which human activities have flourished over the course of history. Egyptian and Roman civilisations developed around estuaries, deltas and rivers. Since the 19th century, however, wetlands have suffered massive destruction, either as a result of sanitation policies or under the pressure of urbanisation and intensive agriculture. Numerous protection and rehabilitation measures, similar to those for drylands, have been put in place[38].

3.1. Conflict between development and conservation

For contemporary Western societies, wetlands have become places for recreation, gatherings and leisure, and represent a rich landscape heritage. Policies to develop coastal areas for tourism have wreaked ecological havoc, some of it irreversible. Additionally, they must be adapted to accommodate climate change, since sea levels are predicted to rise significantly. What management measures could contribute to the development of responsible tourism and leisure activities in these fragile areas?

30 According to the 163rd Council of the FAO, agroecology includes organic farming, agroforestry, permaculture, the complementary relationship between livestock and crops, permanent soil cover, etc.: http://www.fao.org/agroecology/overview/overview10elements/en/

31 https://www.ipcc.ch/srccl/download/

32 Barbut, M. (2018). Rehabilitation of degraded land in drylands. Annales des Mines, 91, 51-55

33 https://www.un.org/fr/events/desertification_decade/convention.shtml

34 https://www.cirad.fr/dans-le-monde/dispositifs-en-partenariat/ppzs

35 http://ong-apaf.org

36 The Ramsar Convention - an international treaty adopted in 1971, which came into force in 1975 - defines wetlands as "*areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres*". The French Environment Code offers a more restrictive definition, limiting them to "*land, whether or not it is used, that is usually permanently or temporarily flooded or filled with fresh, salt or brackish water*" (art. L. 211-1).

37 Mitsch W. J., Gosselink J. G. (2000). The value of wetlands: Importance of scale and landscape setting. *Ecological Economics*, 35, 25-33 (…); Barbier, E. B., Acreman, M. C., Knowler, D. (1997). *Évaluation économique des zones humides : Guide à l'usage des décideurs et planificateurs*. Bureau de la Convention de Ramsar. – Costanza, R., et al. (1997). The value of the world's ecosystem services and natural capital. Nature, 387, 253-60.

38 See https: //www.ctc-n.org/technologies/wetland-restoration-and-rehabilitation – https://www.wetlands.org/. Unesco is also very active: https://www.unesco.org/en/legal-affairs/convention-wetlands-international-importance-especially-waterfowl-habitat; https://www.unesco.org/en/articles/,

3.3. Conflict between ecosystem and productive functions

Wetlands are suitable to a wide variety of food production (livestock, fish farming, shellfish farming) as well as the production of energy resources (peat, wood) or raw materials (particularly rubber in tropical areas). Mangroves in tropical areas are particularly rich in a variety of resources. Exploitation of these resources may not affect ecosystem services when they are part of a local development approach.

However, intensive exploitation directly threatens the resilience of these fragile areas, giving rise to conflicts that are difficult to arbitrate. Many mangrove forests have been cleared over the last 40 years, to make place for aquaculture, particularly of shellfish such as shrimp, to supply a fast-growing world market. This is a key economic resource, ensuring food security for the local population and limiting rural exodus. However, it is a fragile resource, because it is highly sensitive to sea level, climatic variations (water temperature and salinity) and diseases that can lead to serious environmental disasters. In addition, discharges that are sources of pollution are leading to vast reservoirs becoming no longer useable, fragmenting the mangrove area. Finally, the primacy of monoculture in aquaculture pools and plantation areas is also having a serious impact on mangrove biodiversity. It has been estimated that 30 to 40% of the world's mangroves need to be réhabilitées[39].

4- Urban and peri-urban soils

The acceleration of urbanisation over the last few decades, with the creation of major conurbations, has led to a significant decline in agricultural land in peri-urban areas. Housing, commercial and small business zones, motorways, stations and airports have gradually taken the place of market gardens. This massive urbanisation has a number of direct consequences - atmospheric pollution, flooding - and indirect consequences - increased use of long-distance supply chains, food waste[40]. In short, town and country have become two distinct, separate entities, with populations living contrasting lifestyles. The problem is global and is mobilising international institutions[41]. There are two main opposing models: one in which towns and cities are concentrated in dense areas, leaving space for agricultural production with an option to protect biodiversity, or one in which human settlements are distributed across the territory along with farmland and wilderness.

4.1. Conurbation versus natural or cultivated land

The defence of farmland against urbanisation or infrastructure projects for city dwellers has often been seen as residents' opposition to a project of general interest (The NIMBY syndrome). But we have to recognise that the artificialisation of farmland, which amounts to between 30,000 and 50,000 hectares per year in France, is a global phenomenon that calls for urgent and legitimate responses[42]. In France, plans to build an airport, a multimodal station or other infrastructure on the outskirts of major cities, is often met by resistance which sometimes prevents the project from going ahead. The fight against the gradual erosion of agricultural land by urban sprawl remains much more challenging, despite the fact that it accounts for the bulk of the 30,000 to 50,000 hectares artificialised every year.

In the countries of the South, where sprawling conurbations are developing spontaneously, resistance movements are finding it harder to make themselves heard. *Isn't it the duty of researchers from the four organisations to take a stand on these issues?* If so, how should they intervene? While it may be tempting to intervene 'in the name of science' as an authority above reproach, it seems more ethical to us to highlight the values that drive researchers and their organisations and above all, do as much as possible to curb the artificialisation of land in tropical countries.

4.2. Tensions created by urban parks and urban agriculture

The development of urban parks and green corridors serves the dual purpose of improving the quality of life (by combating pollution) and preserving biodiversity. However, this virtuous practice clashes

39 See Brauman, A., Thoumazeau, A. (2020). Biofunctool® : un outil de terrain pour évaluer la santé des sols, basé sur la mesure de fonctions issues de l'activité des organismes du sol. *Étude et Gestion des sols*, 27, 289-303.

40 http://www.fao.org/food-loss-and-food-waste/flw-data

41 See the FAO's Green Cities initiative, http://www.fao.org/green-cities-initiative/fr/ and C40 Cities https://www.c40.org/

42 Report: Sols en danger : réduire l'artificialisation : *Annales des Mines*, n° 91, juillet 2018. http://annales.org/re/2018/re_91_juillet_2018.pdf

with the need to densify urban housing - particularly through the construction of social housing - to avoid commuting and urban sprawl, which is eating into the countryside. This is exactly the case for the La Courneuve park, in connection with the 2024 Olympic Games project. In the city, land is the focus of property speculation. In a context where land is scarce and expensive, the right to housing requires choices to be made; Access to low-income housing or urban ecology? - such is often the dilemma. We really need to rethink the way we build cities. What kind of expertise do local authorities need to implement a green space policy?

A similar dilemma is encountered with urban agriculture[43]. Public authorities (from the European Union to municipalities) are encouraging urban agriculture initiatives by awarding subsidies to promote the "sustainable city". Three pillars of sustainable development provide the supporting arguments:

- *Environmental:* cultivated areas in towns and cities reduce carbon footprint, regulate water cycles, reduce heat spots, scale down waste by encouraging composting of waste food, and promote biodiversity.
- *Economic:* kitchen gardens contribute to food self-sufficiency and supply quality food by reducing waste. They are also a source of employment.
- *Social:* allotments or shared gardens are a source of knowledge and know-how. They create neighbourhood solidarity and social interaction... and reduce the divide between farming and urban populations, linking nature and the city.

Urban agriculture has its annual 48-hour festival in May[44], organised by over 20 French towns plus Brussels and Geneva. It is gaining ground and new enthusiasts every year as part of the drive to eat well. It is being developed on rooftops (for example, the development of a 1,500 m^2 supermarket roof in Ixelles), between buildings, in green spaces, on wasteland and on industrial wasteland. Even if it is sometimes associated with a slightly Bohemian style, urban agriculture is reviving the philanthropic practices of the past. The "Ligue du coin de terre," founded in 1895 by middle-class citizens and ecclesiastics near Sedan, had as its slogan "*To each worker his own piece of land and his own unassailable home*". This holds true today, some 120 years later. Other associations are campaigning for its development.

However, the development of urban agriculture is creating a number of tensions. Social housing or vegetable gardens? In addition to the dilemma already mentioned in relation to urban parks, there is the question of the workforce responsible for maintaining these gardens. Often entrusted to unemployed people or volunteers, this work is poorly paid and considered unskilled. As a result, these initiatives are sometimes scrapped due to lack of manpower. Nevertheless, when urban or peri-urban agriculture is established on a sustainable basis, it becomes a locally sourced alternative to mass distribution channels and promotes cooperative associations and farmers' markets. It is sometimes an explicit challenge to the Common Agricultural Policy, which is accused of favouring large farms and mechanisation.

Finally, urban farming initiatives on land that has been polluted by industrial installations are giving rise to unusual confrontations between municipal authorities and farmers who are defying safety measures to bring soil back to life. Faced with bans on cultivating this land because of health risks, citizens farming on polluted soils appear to be claiming a right to be less protected, by taking risks to revive the soil and restore it to health[45].

4.3. Problems of remediating brownfield sites and restoring polluted land

The policy of zero soil artificialisation, which involves bringing abandoned sites back to life, *i.e.*, rehabilitating urban or industrial sites, presupposes recognition that the underlying soil is indeed

43 Advocated by a number of urban planners - including Rob Hopkins, founder of the Cities in Transition movement, and Carlos Moreno, an advocate of "living cities" - urban agriculture aims to overcome the divide between town and country. This does not include soil-less farming, such as aquaponics, but only urban vegetable gardens, which are concerned solely with soil management.

44 https://www.les48h.fr

45 See the account given in: Cahn, L., et al. (2017). *Terres des villes. Enquêtes potagères de Bruxelles aux premières saisons du 21e siècle*. Éditions de l'éclat.

polluted. ADEME's task is to identify the characteristics of the soil, render polluted areas safe and help with reconversion[46]. The aim is to restore 15,000 hectares of polluted land to agricultural use.

Two technical solutions are envisaged depending on the future use. For soil (unlike water), there is no pollution threshold. The threshold depends on the use of the land (stricter for housing, for example, than for shops). So, the first step in choosing a technical solution is to determine its future use:

- *either by reconstructing the soil after excavation and backfilling with materials suitable for well-controlled uses (no pollution or invasive species);*
- *or by ecological engineering to rectify degradation by adding micro-organisms and improving infiltration and revegetation capabilities.*

In both cases, ecological soil rehabilitation takes time: as much as several decades to bring the soil back to life.

4.4. Tension between soil quality and land value

There are two opposing approaches to soil. Soil as a living environment, which is the subject of research by the four organisations, must not blind us to the fact that it is also a property that has a price. Which measures can be envisaged to curb the tendency to overestimate the price of land in peri-urban areas in anticipation of urban expansion? How can soil quality assessments be incorporated into the valuation of peri-urban agricultural land? How can we reconcile the debate between the two views of land as a property value and as a set of functions or services? Can the habitat function be considered as an ecosystem service?

V ■ Cross-cutting issues

1- The question of the commons

The implementation of preservation or rehabilitation policies sometimes comes up against private, local or international interests. Designing or adapting legal tools to avoid or mitigate such conflicts is an integral part of research into efficient land management. What type of law can be put in place to bring about a collective interest in protecting or rehabilitating land?

The prevailing legal view attributes most of the prerogatives over land to the owner of the space defined by a boundary line on the surface of the land[47]. To what extent should land be considered a common good, given that its well-being is essential to the fulfilment of a number of functions that are part of fundamental human rights, such as food, clothing and access to quality water?

On a global scale, the question of the commons has been raised since the Rio Conference (1992) concerning tropical forests. These reserves of biodiversity and carbon provide such essential ecosystem services, that it has been argued that they should be considered as a common heritage that would be subject to an international protection regime. In this way, tropical countries would become guardians of an asset belonging to humanity[48]. However, this proposal, which was put forward by the industrialised countries of the North, clashes with the countries of the South, such as Brazil, who see their forests as an economic resource (timber and land). The tension between ecosystem service and local or national resource is echoed at the legal level.

Moreover, in many countries of the South, two types of property rights coexist that are observed to a greater or lesser extent by the local population, depending on the circumstances. The so-called modern law, inherited from the colonial system and recognised by the public authorities, and the customary or traditional law rooted in culture and often observed by local people. This further complicates the measures taken in order to save the land.

46 See Cécile Grand, intervention au séminaire INRAE « Déconfiner les sols », 23 avril 2021.

47 Article 552 of the French Civil Code states that "Ownership of the land entails ownership of the land above and below it". There are some limitations to this right, for example with regard to mineral resources and archaeological remains.

48 Karsenty, A. Les forêts tropicales, des communs ? In Delmas, B., Le Roy E (coord.) (2019). *Les communs, aujourd'hui ! Enjeux planétaires d'une gestion locale des ressources renouvelables*. Karthala (ed.), pp. 123-133.

In 2006, Europe attempted to introduce a directive on this subject, with the aim of promoting sustainable soil use, an initiative that seemingly came up against the wall of agri-food lobbyists. In France, however, the status of tenant farming, which until now has been more favourable to the quest for productivity than to ecological functions, has been revised to ensure that soil health is maintained. Since the 2010s, a principle of economical land management has been introduced into the French Town Planning Code; the Territorial Coherence Scheme (SCOT) and the Local Town Planning Scheme (PLU) must include a consideration of how land is used - combating urban sprawl and preserving biodiversity are issues that can be broached[49]. Very recently, this assessment has been enshrined in the Climate and Resilience Act[50], which introduced a definition of artificialisation as "the lasting alteration of all or part of the ecological functions of a given land" and an undertaking to include goals for reducing the rate of artificialisation in SRADDET[51], SCOT and PLU Although progress has been made, it is still not enough to meet the challenges, namely compliance with the social and environmental objectives, especially as the indicators that would enable public authorities to characterise land and make informed decisions are largely inadequate.

Different approaches are being proposed to bridge the gap between the significance of soils and the shortcomings of the instruments used to govern them.

1.1. Converting farms into mission-oriented businesses?

The first approach is based on the unilateral commitment of those whose activity involves using the land. This consists, for example, considering a farm to be a company with a mission, as proposed by Bertrand Valiorgue[52]. This status, created by the Pact law on the growth and transformation of businesses, enables a company to clarify its raison d'être in addition to its economic objectives, by adding social and environmental objectives, such as maintaining or restoring soil quality, which the company agrees to pursue as an integral part of its activity[53]. A specific body, made up of representatives of stakeholders in the broadest sense, would be responsible for monitoring compliance with the social and environmental objectives. According to Valiorgue[54], this strategy is likely to have a cascading effect, generating enforceable commitments, creating more balanced relations with business partners, and possibly attracting specific funding. Here again, the difficulty lies in defining and monitoring soil quality.

1.2. Reinventing the commons?

The second approach calls for a radical overhaul of ownership, based on the notion of the commons. This approach is based on the work of Elinor Ostrom, who has shown, on the strength of an analysis of a number of real-life cases, that communities are capable of effectively managing the use, conservation and even development of a resource, without the intervention of a central authority or the market to allocate it[55]. The commons is therefore made up of both the resource and a set of rules and organisations that enable it to be managed by the community. The creation of the commons can be based on historical examples of former commons, of which there are still some remnants: for example, grazing rights at high altitudes, or "sectional forests" belonging to communes but with specific holder rights[56]; and other forms are appearing, such as allotments in urban areas[57].

Sarah Vanuxem points out that in this case, the question of property rights is both primary and secondary[58]. Secondary, because the commons can accommodate all forms of land ownership: the land on which the commons is built can be publicly or privately owned, individually or communally. Primary, because the commons presupposes a reshuffle of the concept of property rights: instead of an exclusive relationship between owner and possession, they establish a "bundle of rights"[59], to use Ostrom's expression, which connect a number of players to each other and to an environment/resource in different ways. These rights are defined by rules that Olivier Weinstein describes as follows[60]:

- operational rules defining rights of access to the resource, the ability to appropriate it and the practical and technical procedures for doing so;

49 This analysis is based on the work of Philippe Billet: Billet, P. (2018). Le statut juridique des sols face à l'artificialisation : État des lieux et perspectives. Annales des Mines - Responsabilité et environnement, 91(3), 24-28.

50 https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000043956924?r=d3tp66ZqI7, article 191 and following.

51 Regional plan for spatial planning, sustainable development and territorial equality.

52 Valiorgue, B. (2020). Le défi agricole de l'Anthropocène. *La Vie des idées*. https://laviedesidees.fr/IMG/pdf/20201006_valiorgue.pdf

53 Article 176 of rules and regulations, May 22 2019, https://www.economie.gouv.fr/cedef/societe-mission

54 Valiorgue, B. (2020). *Refonder l'agriculture à l'heure de l'anthropocène*. Le Bord de l'Eau editor.

55 Ostrom, E. (2010). Governing the Commons: *The Evolution of Institutions for Collective Action*. Cambridge University Press –French translation : Gouvernance des biens communs : Pour une nouvelle approche des ressources naturelles. De Boeck.

56 See la tribune du Monde du 28 août 2021 : Les communs fonciers peuvent servir de modèle pour relever les défis écologiques, https://www.lemonde.fr/idees/article/2021/08/28/les-communs-fonciers-peuvent-servir-de-modele-pour-relever-les-defis-ecologiques_6092597_3232.html

57 Donadieu, P., Rémy, E. & Girard, M.-C. (2016). Les sols peuvent-ils devenir des biens communs ? *Natures Sciences Sociétés*, 24(3), 261-9.

58 Sizaire, V. (2020). Protéger la diversité juridique pour préserver le projet politique des communs. Entretien avec Sarah Vanuxem. *Délibérée*, 10(2), 12-18.

59 *Bundle of rights*, in English.

60 Weinstein, O. (2013). Comment comprendre les « communs » : Elinor Ostrom, la propriété et la nouvelle économie institutionnelle. *Revue de la régulation. Capitalisme, institutions, pouvoirs*, 14.

- "collective choice" rules that define the right to intervene in the definition of access and usage rights;
- "constitutional choice" rules that define the rights to modify the rules of collective choice.

Dans From this perspective, land ownership in itself no longer defines the relationship between an individual and a particular thing, since it is enshrined, as it were, in a set of rights and obligations that define the relationships that a group of individuals have with each other and with that particular thing: the irrigation canals in the dry Alps, which were managed jointly by local farmers, are a good example of this "erasing" of land ownership. The right to benefit from water was accompanied by the obligation to take part in maintenance work, carried out together on specific days, without any reference to land ownership of the stretches of pipe. In Sarah Vanuxem's view, we would gain "*by conceiving ownership as the option for people to inhabit things, but to consider them as living places, environments or ecosystems. In this vision, people never really own things themselves, but only hold a right, i.e., a shared place in which the notion of community is retained*.[61]" In other words, the commons can have the effect of "*dissociating the absolute right of ownership of land from the rights of use of its exosystemic, social and cultural services, which would become inappropriate because they are produced by territorial governance of land*."[62]. This approach is particularly useful when it comes to recognising the multifunctionality of soils and preserving or restoring their health.

Since these uses and services are not necessarily compatible with each other, the aim is to avoid arbitration by an all-powerful sole owner who imposes his or her wishes. The commons approach recognises the potentially conflicting nature of the interests attached to these uses and services, and creates the conditions for debate between the parties concerned: the rules that define governance aim to "reconcile the interests of these distinct players who participate in the commons, on the basis that they are not necessarily identical"[63].

1.3. Inspirational initiatives

In practical terms, the authors who have examined the issue, propose different ways of building the commons of the future: Bernard Valiorgue imagines territorial chambers of agricultural and food commons that would steer change and manage funding; the aim being to bring farms away from their state of isolation, make them part of their territory and allow local stakeholders to participate in the organisation of farming, the question of soil being a subject among others[64]. Other authors see it as a fundamental tool for managing land in urban and peri-urban areas, particularly for combating soil artificialisation, and plan to bring together the State, local authorities, landowners, tenants, elected representatives, users, residents, etc.

Some initiatives are simply private[65]: "Terre de liens" is undoubtedly the most successful in France today. Founded in 2003, it brings together a network of local associations whose mission is to support land acquisition projects, mobilise civil society around land-related issues, raise awareness and support local authorities in promoting responsible land management. It is a socially responsible investment company open to the public, whose capital is used to buy farms that are then rented out to committed farmers; and a foundation authorised to receive legacies and donations of farms. By 2021, "Terre de liens" was the owner of a total of 250 farms and 7,000 hectares.

There are two conceivable approaches for tropical forests[66]. Either establish global commons from the top down, based on the Climate Convention. In this case, the countries of the North pledge to remunerate the forested countries of the South for preserving forests as ecosystem services. Or, build local commons from below - in African forests in particular - in the form of multi-use forest concessions (agricultural, economic, ecosystem) established in an inclusive manner with local and national stakeholders.

61 Protecting legal diversity to preserve the political project of the commons. Interview with Sarah Vanuxem, Interview written by Vincent Sizaire (2020). Délibérée, 10(2), :12-18.

62 Donadieu, P., Rémy, E., & Girard, M.-C. (2016). Les sols peuvent-ils devenir des biens communs ? *Natures Sciences Sociétés*, 24 (3), 261-9. Philippe Billet, in the article quoted above, draws a parallel with "*the legal regime applicable to historic monuments, under which the building belongs to its owner, but its historicity belongs to the community, thus justifying constraints on the use of the property*".

63 Benjamin Coriat (Éd.). Le retour des communs. *La crise de l'idéologie propriétaire*. Paris: Les liens qui libèrent, 2015.

64 Valiorgue, B (2020). *Refonder l'agriculture à l'heure de l'anthropocène*. Le Bord de l'Eau editor.

65 The report Des terres en commun ! Local strategies for access to land for peasant farming and agroecology lists a number of experiences in Europe (https://landportal.org/es/node/92454).

66 Karsenty, A. (2019). Les forêts tropicales, des communs ? op. cit. footnote 48.

As Ostrom has already pointed out, there is a wide variety of possible schemes, although in the end, they have not been sufficiently explored: one of the major questions that remains unanswered is how the participants at the different levels of governance should be determined. The examples we have, often concern small communities, and the shared 'benefits' are fairly circumscribed (irrigation, firewood, access to grazing land) and define certain categories of beneficiaries from the outset. Today we are faced with slightly different challenges, since we have to preserve resources that are much more dispersed, such as biodiversity or complex political and agricultural areas: for example, who are the local players who are entitled to participate in the territorial chambers of the agricultural and food commons imagined by Bernard Valiorgue? Lawyers, economists, sociologists, etc. would be well advised to develop research and support experiments on these subjects in relation to the issue of soil conservation.

For development, it is important to overcome the shortcomings of the law of the commons and to innovate with new forms of law negotiated with the parties involved. The Land and Development Technical Committee, set up in 2016, emphasises the ethical values of solidarity, justice and sustainability that underpin the law of the commons[67]. Insofar as it establishes human collectives in relation to other lifeforms, the law of the commons aims to establish resilient socio-ecosystems in a world where natural resources are limited. This is why we believe it is particularly appropriate for developing an ethic of care focused on soil health.

2- Advantages and limitations of the "ecosystem services" approach

The concept of ecosystem service, which has appeared in scientific publications since 1997, has been the subject of much interest since 2000[68]. It is recognised by all the institutions responsible for preserving biodiversity[69]. It offers a number of advantages. Firstly, by associating the scientific concept of ecosystem with the term "service", which is part of everyday language, this expression has the merit of making sense to the general public. Gretchen Daily's book Nature's Services (1997) analysed the socio-economic issues arising from biodiversity loss and sounded the alarm, drawing the attention of decision-makers and the general public to the need to protect biodiversity[70]. In addition, the concept of converting ecosystem functions into services or benefits for humans was highlighted in the case of agricultural ecosystems in the article by Robert Costanza et al (1997). The latter makes a second interpretation in economic terms and examines how the socio-economic importance of ecosystems can be quantified in terms of capital[71]. This article, which is widely quoted, has helped to disseminate the concept of ecosystem services, which was enshrined in the Millennium Ecosystem Assessment (2001-2005), which proposes scenarios for preserving ecosystems under the supervision of the United Nations. It is therefore clearly an interdisciplinary concept, between ecology and economics, but also hybrid, at the interface of science and politics. One of its merits is that it calls for action by highlighting the socio-economic challenges of soil health[72]. It has been used to inform decision-makers, for example, by quantifying for Great Britain the economic benefits of an agro-ecological scenario compared with a "conventional" scenario. Its promoters were also involved in the creation of the Intergovernmental Panel on Biodiversity and Ecosystem Services (IBPES), which operates on the IPCC model[73].

The application of this concept to the study of soils has played a very positive role in extending the scope of agronomic research, from plant improvement to the care of the plant-soil system. It has also enabled the quantification of various soil functions and the creation of instruments for action (taxation, compensation, etc.), with the aim of contributing to their preservation or regeneration. It has made it possible to create a decision-making tool, an international database on the evaluation of ecosystem services (ESVD), which provides duly validated, easily accessible information on the benefits of ecosystems or biodiversity, and the costs of their loss[74].

67 Aubert, S. & Karp, P. How can we envisage the rights of the commons created around the land and the resources it supports? In Delmas, B & Le Roy, E (dir.). (2019). *Les communs, aujourd'hui ! Enjeux planétaires d'une gestion locale des ressources renouvelables*. Karthala, 73-99.

68 Serpentié, G, Méral, P. & Bidaud, C. (2012). Des bienfaits de la nature aux services écosystémiques. *VertigO, la revue électronique des sciences de l'environnement*, 12 (3) https://doi.org/10.4000/vertigo.12924 – Devictor, V. (2021) *Gouverner la biodiversité ou comment réussir à échouer*. Éd. Quæ.

69 Notably the United Nations Environment Program (UNEP) in 2012, and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IBPES) in 2007.

70 Daily, G.C. (ed.). (1997) *Nature's Services: Societal Dependence on Natural Ecosystems*. Island Press.

71 Costanza, R., D'Arge, R., De Groot, R, Farber, S, Grasso, M., Hannon, B, Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P. & Van Den Belt, M. (1997). The value of the world's ecosystem services and natural capital, *Nature*, 387, 253-60.

72 Whether this can be put into practice in a pragmatic way to "save the planet" remains to be seen.

73 Bateman, I. *et al*. (2013). Bringing ecosystem services into economic decision-making: land use in the United Kingdom. *Science*, 341(6141), 45-50.

74 Ecosystem Services Valuation Database (ESVD : https://www.esvd.net/

Attempts to objectify the notion of ecosystem services in these databases should not, however, obscure the fact that it is only descriptive in appearance. It is a notion that is highly prescriptive, even moralising according to Daily et al, insofar as it postulates the intrinsic value of biodiversity. Moreover, when we manage to quantify local issues with precision (which proves very complex in practice), there is a performative dimension to the use of figures and graphs. According to some, it is a notion steeped in the values that dominated American ecological circles at the turn of the 21st century: a conservationist vision of nature embraced by the capitalist system, in which ecosystems and living organisms are seen as capital at the service of the human species. For others, it is simply a conversion system, to bring biodiversity issues into the political arena, which has to arbitrate between different socio-economic and ethical issues. Like all concepts, it is contextual. It could be seen as universal given its global approach to the Earth system and biodiversity, which would allow the functions of ecosystems to be dealt with in the abstract, independently of their position in a place, a landscape or a culture. Hence the problems that could arise from applying this concept to soil management in countries and cultures that share neither this vision nor these values.

Moreover, the economic conversion of the various functions of ecosystems makes it possible to put in place tangible mechanisms for action, such as the Care method[75]. One of the challenges for all environmental accounting is to accommodate the diversity of territories, to avoid a double process of abstraction, already initiated by the transfer of ecosystem functions from the biosphere to the datasphere of databases. The difficulty is that, in order to deploy such accounting, heterogeneous and disparate ecosystem functions need to be converted into socio-economic terms. In particular, if we were to overlook the fact that living species are constantly interacting and evolving when drawing up an inventory of biodiversity, we would be reducing the diversity and complexity of ecosystems in order to make everything commensurable, capable of being aligned on a single scale of values. This danger is highlighted by Daily et al (1997). In two successive chapters, the authors show that the notion of ecosystem service would not be deployed in the same way in territories occupied by indigenous peoples in India and by Caucasian populations in the United States, because the issues at stake are very different. All environmental accounting - particularly when it comes to introducing green finance - presupposes a certain number of trade-offs that should not be obscured; on the contrary, they should be made explicit and democratically arbitrated. The difficulties are considerable: How, for example, can we assess the ecological gain of an ecosystem over the long term? How can we quantify the heritage value of a soil or the value of a soil held sacred by a local culture? Should we put a figure on the cost of maintaining it? The danger is that, under the guise of objectivity, we try to make all services commensurable by monetising them, and that we then proceed to tacit trade-offs - for example by establishing an equivalence between the number of earthworms in 1 m^2 of soil and its landscape value - in order to set up a compensation mechanism. We must therefore question the limits of this approach to the objective of caring for soil health, when monetarisation establishes arbitrary coefficients of correspondence between ecosystem services or heritage values that are fundamentally incommensurable, because they come under heterogeneous value systems that are susceptible to coming into conflict.

The ecological-economic approach to soil services should therefore be the subject of debate. It is true that it promotes ecological awareness and raises awareness of the socio-economic issues involved in the harm caused by pollution in any society, particularly in neo-liberal economies where profit is the ultimate value[76]. Monetarisation without clarification or reflection would make the choices of ethical and political values implicit and invisible, and it is precisely these values that need to be made explicit so that they can be debated.

Is it legitimate to apply a financial logic to the management of natural capital? In the environmental ethics stemming from deep ecology, nature has an intrinsic value, it is an end in itself and therefore cannot have a monetary value[77].

75 https://blog.agiris.fr/des-chiffres-et-moi/le-role-de-la-comptabilite-au-service-de-environnement

76 Costanza, R. et al. (2013). Vivement 2050. *Programme for a sustainable and desirable economy*. Veblen Institute. In 2007, for example, the FAO estimated the economic value of pollinating insects at €150 billion to offset the profits from pesticides.

77 Marris, V. (2004). *Nature à vendre*. Edition Quæ.

The notion of ecosystem service was imagined to emphasise the interdependence of humans and other living things, and to prevent the predatory exploitation of natural resources and therefore, with the help of monetarisation, could become a tool for the administration of goods, exploiting ecosystems by invoking their benefits for the human race. Hence the urgent need to reflect critically on the uses of this concept, and to open a real debate on the tools that have been put in place, with a view to improving them[78].

3- Complementarity between local and global

The global approach proceeds from top to bottom, like the view from a satellite, making it possible to distinguish uniform masses and identify areas at risk. A local study requires a holistic approach that focuses on flows rather than stocks of carbon or other elements, because soil is a complex, multi-component, multi-functional medium that also involves a multiplicity of players. Quantitative methods such as Biofunctool® make it possible either to compare the health of forest soils with that of soils in various agrosystems at a given interval, or to measure changes in soil health over time. The local approach is essential because soils vary enormously from one place to another. However, this multi-criterion ecological approach to soil health does not lend itself easily to the introduction of scientific and technical standards to encourage farmers to change their practices. Hence the question: how can we simplify and invent practical tools that can be used by all those involved in the field?

We consider these two levels of intervention to be complementary. They call on a multiplicity of disciplines and modes of intervention. Why and how should they be coordinated? At a local level, researchers diagnose soil health and make practical recommendations in line with the missions of the four research bodies. However, it is no less important for experts to advise the national or international public authorities responsible for regulations, in particular to break down the barriers between discussions on the relationship between food production and climate change. In this context, the participation of researchers from the four organisations in the work of international bodies such as the FAO and the IPCC is vital. This may be one way of overcoming the divide between global visions and local decisions[79]. Researchers can warn politicians of the limits of "good solutions" for the climate, such as agroecology or agroforestry. They encourage people to take into account the local impact on labour, farm size and market variations, as well as the sustainability of these solutions.

4- How can we interact with local players?

In addition to diagnosis, conservation and organic farming projects must involve local stakeholders and take into account the indicators identified by local players in order to build and evaluate scenarios. However, the researchers responsible for diagnosing and mapping the soil sometimes come up against the interests of local stakeholders who defend their own interests: some want to promote their region and develop rehabilitation policies by planting ill-adapted species (green washing). Others (industrial companies or NGOs) use the indicators developed by researchers to advance their own cause rather than that of the general interest.

This raises the question of how rehabilitation campaigns are monitored. Who is authorised to ensure long-term monitoring? Who has the authority to monitor endangered or rehabilitated land?

More generally, how can stakeholder participation be envisaged? Participatory science is actively promoted by the four organisations as the best way of involving local players in sustainable soil management. However, this consensus on the merits of participation does little to conceal a number of tensions over the role of the individual stakeholders.

As regards the role of farmers, some researchers speak of the co-production of knowledge. They emphasise that those working in the field have the capacity to question their hypotheses and research

78 Following on from the mission chaired by Bernard Chevassus-au-Louis, which proposed establishing an independent regulatory authority, Approche économique de la biodiversité et des services écosystémiques, Documentation française, 2009.

79 See the interview with Martial Bernoux, who describes his experience working with the FAO and the United Nations on the "Koronivia joint work on agriculture" to propose decisions that take into account both the impact of agriculture on the climate and agricultural production needs.

protocols, and that the abundance of their spontaneous innovation practices enables them to identify robust trends and thus increase the general validity of their recommendations. Other researchers, on the other hand, talk more in terms of raising awareness, or even training farmers, following a highly pedagogical, one-way model of their relationship with the players in the field.

Recommendations on the role of other stakeholders are equally divided. Some researchers stress that local players are essential for integrating the effects of the scenarios envisaged on farmers' incomes and, more broadly, on a region's economy. But others point out that their scenarios may be biased by certain local stakeholder representatives. How can we guarantee the independence of research results while we are at the same time listening to the various stakeholders? And how can the legitimacy of each stakeholder be assessed? For example, is the voice of the NGOs working in the field, in say Madagascar, more legitimate than that of farmers or local elected representatives? Finally, even though researchers believe that their findings are based on an impartial point of view, they run the risk of providing scientific backing for decisions or development projects that do not protect the health of soil.

5- How to interact with politicians?

The interaction of researchers with the political players who make the decisions is a source of problems. Researchers act as external experts before plans are drawn up on land use or rehabilitation. They are usually asked to give a scientific opinion on a problem posed by politicians rather than by themselves. Their response consists of assessing the state of the art and, in some cases, proposing strategies. However, experts are not called upon to participate in the decision-making process, or even in the drafting of regulatory texts. Hence the frustration of researchers who have devoted part of their time to these expert functions, who deplore the lack of effectiveness of their work. Nevertheless, it is clear that they cannot expect politicians to follow them in their entirety, unless they fall into the trap of scientism or technocracy.

This feeling of frustration prompts us to reflect on the values embedded in scientific expertise. There is no clear dividing line between experts and activists. While experts tend to consider that their opinion is neutral because it is based on solid, objective knowledge, validated by the scientific community, in the political arena their recommendation is rarely neutral, especially if it leads to concrete proposals and is not limited to general criteria or objectives. Their knowledge is effective, insofar as it is developed in response to certain issues that are associated with values such as soil health. Working for a manufacturer on the effects of using this or that input, is not the same as working for a group of farmers committed to agro-ecology on the effects of this or that practice. The experts' recommendations are determined by the framework of questions posed at the outset, and this framework is eminently political, in the sense that it is based on a certain analysis of today's world and the directions in which we can project ourselves for the world to come. It is therefore important to spell out the issues at stake and to highlight the values and interests involved, so that researchers can more clearly identify with them, and even redirect their research choices.

V ■ Recommendations

1- General recommendations

1. Engage researchers in reflecting on the issues using knowledge as the key, unbiased by vested interests. This involves taking into account the points of view of all parties concerned (stakeholders and principals), and by paying equal attention to all the non-quantifiable dimensions of the issue being addressed.
2. This reflection can focus on concepts such as ecosystem services, their relevance to soil health and the unintended effects of the mechanisms used to construct commensurability between these services (monetarisation, non-monetary indicators, etc.).
3. In order to facilitate reflection and encourage partnerships with local players, we recommend setting up meetings or workshops, to discuss research priorities and clarify the interests and values of each of the protagonists in total transparency.
4. Collaborate on a charter for relations with local players (elected representatives, local professional organisations, NGOs) for the four agencies. In the case of countries outside Europe, anticipate the impact of French organisations on the economy and politics of third world countries.
5. Researchers are expected to furnish publications, aimed at political decision-makers and the general public, in order to disseminate basic knowledge and best practices and also to alert the public to potential threats. The four organisations need to work together to specify the terms and conditions for exercising this obligation.
6. Researchers acting as experts in agricultural, food or climate policy bodies, should present an impartial overview of the current state of knowledge, clearly identifying the assumptions underlying the models or simulations of possible scenarios, the limits of knowledge and the areas of uncertainty.
7. This stance of expert engaged in service, cannot exempt researchers from clearly integrating the stakeholder approach when defending a cause (soil health) and values, rather than adopting an "expert above the fray" position, in order to promote democratic rather than technocratic management of problems.

2- More specific recommendations for soil research

1. Broaden the notion of soil health, by interpreting data from massive sequencing techniques, and using functional ecology to gain a better understanding of the «sociability» of microorganisms, their synergistic effects on plants, and the relationships between the biological and inorganic components of soils.
2. Continue to characterise the effects of different agricultural and forestry practices on soil composition and structure, analyse in greater depth the forms of biodiversity present in the soil, study their long-term evolution and provide farmers and foresters with guidelines for improving their practices.
3. Research further into the various timeframes involved in forestry and agriculture. This is essential in order to allow for soil regeneration within the systems put in place, and to clarify the place of agricultural and forest soils in the national low-carbon strategy, for the different deadlines 2030, 2050 and beyond.
4. Broaden the range of disciplines of research teams well beyond agronomy, biology and chemistry, by including geographers (for mapping tools), historians (to study the uses of

soil in past centuries), anthropologists, economists and sociologists (to identify the limits and undesirable effects of the monetisation of soil-related services).

5. Integrate local traditional knowledge into soil research and document it so that it can be taken into account in experiments and research aimed at improving practice.
6. Enhance the development of tools which enable the various players (developers, public authorities, local communities, NGOs, etc.) to characterise soils, their condition and function, according to a variety of criteria. These tools are invaluable in the fight against soil artificialisation and for informed public debate on land allocation choices.
7. Continue to develop soil management solutions in partnership with local stakeholders (farmers, elected representatives, associations, etc.), particularly in the case of wetlands.
8. Engage in a process of reflection on the various possible forms of land ownership, in particular the commons, and their ability to ensure an acceptable compromise between private interests and the general interest, as well as between short-term and long-term aspirations.

Appendix 1

BACKGROUND OF THE GUEST SPEAKERS:

THE MEETING OF 21 NOVEMBER 2020

Introductory presentation and discussions on the subject of "soils" at the plenary session of the Ethics Committee. Talks given by:

- Claire CHENU, AgroParisTech lecturer on secondment to INRAE, research director of the AgroParisTech-INRAE Ecology, Function and Ecotoxicology of Agroecosystems (ECOSYS) joint research unit at Thiverval-Grignon/ University of Paris-Saclay; Soil Science division. Special Ambassador for the International Year of Soils for the FAO in 2015. Member of the scientific and technical committee of the international "4 pour 1,000" initiative. INRA laureate in 2019 for excellence in agronomic research for her work: "Soils: a natural resource at the crossroads of a multitude of issues"

THE MEETING OF 1 FEBRUARY 2021

Talks given by:

- Tiphaine CHEVALLIER, soil scientist, researcher at the IRD, UMR Eco & Sols in Montpellier: "The impact of agroecology on soils in Madagascar";
- Martial BERNOUX, agropedologist, research director at the IRD, UMR Eco & Sols, in charge of natural resources at the FAO: "Soil as an object of territorial management".

THE MEETING OF 3 FEBRUARY 2021

Talks given by:

- Julien DEMENOIS, researcher in functional ecology, CIRAD, coordinator of a strategic thematic field entitled "Supporting all forms of agriculture in the Southern hemisphere in the face of climate change", in charge of the "4 pour 1,000" project for CIRAD's Directorate General for Research and Strategy;
- Lilian BLANC, researcher in the tropical forest ecology, CIRAD, Forests and Societies Research Unit (Montpellier). Research area: anthropisation of tropical forests, analysis in French Guiana and Brazil of the origin of disturbances and their consequences on ecosystem services;
- Alexis THOUMAZEAU, researcher in agroecology and soil science, CIRAD, UMRABSys (Biodiverse Agrosystems, Montpellier). Research area: soil health assessment indicators. Thesis topic: "How to assess the impact of land use on soil functioning" (defended in 2018).
- Hélène DESSARD, agronomy engineer and doctor of science, specialist in biometry, CIRAD, Forests and Societies research unit, head of the ForLand project (landscape restoration research and decision support in Amazonia). Research area: socio-ecosystem trajectories under different resource management modalities, including the restoration of tropical forest landscapes.

THE MEETING OF 3 MARCH 2021

"Soils and wetlands" session: mangroves and marshes. Talks given by:

- Christophe PROISY, physicist, IRD, UMR AMAP, Montpellier (botany and modelling of plant and vegetation architecture) and Hugues LEMONNIER, biologist, Ifremer, the Lagoons, ecosystems and sustainable aquaculture division in New Caledonia: "Aquaculture and mangroves: a shared future";
- Pierre POLSENAERE, biogeochemist and ecologist, Environment and resources in the Pertuis Charentais laboratory Ifremer in La Tremblade: "Coastal marshes and carbon budgets: role, processes and associated exchanges".

THE MEETING OF 17 MAY 2021

Meetings with researchers from the INRAE Bourgogne-Franche-Comté centre (Dijon). With the participation of Nathalie MUNIER-JOLAIN, president of the Centre and Bertrand SCHMITT, director of research at the Centre for rural economics and sociology applied to agriculture and rural areas (CESAER)-INRAE Dijon, coordinator of the Territorial Axes, environment and aliments, Bourgogne-Franche-Comté I-SITE.

Soil quality and agriculture, talks given by:

- Lionel RANJARD, INRAE, UMR Agroecology, "Soil microbiological quality for agricultural production";
- Jean-Sauveur AY, INRAE, UMR CESAER, "Soil quality and farmland prices".

Soil related services and the impact of agricultural activities on soils, talks given by:

- Philippe LEMANCEAU, INRAE, UMR, Agroecology, "Telluric biodiversity and biotic interactions: essential levers for agroecology";
- Fabrice MARTIN-LAURENT, INRAE, Agroecology, "Agriculture, soil biodiversity and disservices: assessment of the ecotoxicological impact of chemical inputs on agricultural soil microorganisms".

Soils and systems experimentation, talks given by:

- Stéphane CORDEAU, INRAE, UMR, Agroecology, "Ca-SYS: agroecology experimentation platform - Focus on conservation agriculture".

Members of the working group set up by the Ethics Committee to examine Guidance 14, which was debated in plenary sessions and finally adopted on 17 November 2022:

- Bernadette BENSAUDE-VINCENT (rapporteur),
- Pere PUIGDOMENECH (rapporteur),
- Michel BADRÉ,
- Hervé THÉRY.

Appendix 2

Composition of the INRAE-Cirad-Ifremer-IRD Committee (July 2022):

- Michel BADRÉ, Chairman of the Ethics Committee, Ingénieur général des ponts, des eaux et des forêts (École polytechnique, École nationale du génie rural, des eaux et des forêts), Vice-Chairman of the INRAE-Cirad-Ifremer-IRD Joint Consultative Ethics Committee since 2016; member of the Board of Directors of the Humanité et Biodiversité association; member of the Economic, Social and Environmental Council (CESE) from 2015 to 2021, vice-chairman from 2018 to 2021, as a member of the environmental associations group; member of the special commission for the public debate, then chairman since 2020 of the "orientations" commission of the Radioactive Materials and Waste Management Plan; former chairman of the Environmental Authority (2009-2014).
- Bernadette BENSAUDE-VINCENT, Vice-President of the Ethics Committee, Professor emeritus at the University of Paris 1 Panthéon-Sorbonne, attached to the Centre d'études des techniques des connaissances et des pratiques; agrégée in philosophy and Doctor of Letters and Humanities. Member of the INRAE-Cirad-Ifremer-IRD Joint Consultative Ethics Committee since 2016, and of Andra's Ethics and Society Committee since 2020. Member of the editorial board of the International Journal for the philosophy of Chemistry (Hyle). Member of the French National Committee for the History and Philosophy of Science. Member of the Académie des technologies.
- Madeleine AKRICH, research director at the École des Mines de Paris, (Centre for the Sociology of Innovation), an engineer from the École des Mines de Paris and a doctor in the socio-economics of innovation.
- Catherine BOYEN, director of Research at the CNRS, PhD in plant biology, Director of the Roscoff Biological Station (Centre for Research and Teaching in Marine Biology and Ecology, Sorbonne University-CNRS). Main scientific areas of interest: marine biology, algal biology, genomics, evolution, microbiome, marine biodiversity and marine biotechnology.
- Denis COUVET, professor at the Muséum National d'Histoire Naturelle, Chairman of the Fondation pour la recherche sur la biodiversité, associate professor at the University of Lausanne and Sciences Po Paris, agricultural engineer, doctor in evolutionary sciences and ecology.
- Mireille DOSSO, director of the Institut Pasteur de Côte-d'Ivoire, Professor of Microbiology.
- Mark HUNYADI, professor of social and political philosophy at the Catholic University of Louvain; associate professor at the Institut des mines-Télécom Paris and at EHESS; mines-Télécom Paris and EHESS; member of the Orange Ethics Committee; member of the Steering Committee and the Steering Committee of the Mobile Lives Forum.
- Youba SOKONA, professor, 40 years of experience in the field of water, energy, the environment and sustainable development in Africa. Involved in the work of the IPCC since 1990; elected Vice-Chairman in October 2015. Successively co-founder of ENDA-TM's energy programme, executive secretary of the Sahara and Sahel Observatory (OSS) and coordinator of the African Climate Policy Centre (ACPC). Until 2020, Senior Advisor for Sustainable Development at the South Centre. Member of the African Academy of Sciences.
- Marie-Geneviève PINSART, philosopher, professor at the Université Libre de Bruxelles, applied ethics research centre. Member of the IRD's Comité consultatif d'éthique pour la recherche en partenariat (CCERP.
- Pere PUIGDOMENECH, Research Professor at the CSIC (Spanish Higher Council for Scientific Research) at the Institute of Molecular Biology in Barcelona, specialising in the molecular biology of plants, PhD in Biological Sciences.

Former members of the INRAE-Cirad-Ifremer-IRD Committee who contributed to this guidance:

- Céline BOUDET, scientific coordinator at Ineris, specialising in risk analysis in the field of health and the environment (epidemiology, toxicology, biostatistics, etc.).
- Jean-Louis BRESSON, doctor, nutritionist, university professor, founder of the Necker-Cochin Clinical Investigation Centre.
- Françoise GAILL, CNRS research director, special advisor to the CNRS general management. Head of the Institute of Ecology and Environment (INEE). Biologist, specialist in deep sea ecosystems.

- Stéphanie LACOUR, CNRS research director, PhD in private law. Deputy director of the " Institut des sciences sociales du politique" (ENS Paris-Saclay). Director of the GDR standards, science and techniques at the CNRS.
- Lyne LÉTOURNEAU, Professor in the Department of Animal Science at Laval University in Quebec (Canada). She holds a doctorate in law and lectures on ethical issues in contemporary agri-food and research integrity and is also the Vice-Dean of Science and Technology Studies at the University.
- Louis-Étienne PIGEON, philosopher in environmental ethics, Doctor of Philosophy from the Faculty of Philosophy at Laval University (Quebec, Canada); lecturer at Laval University.
- Michel SAUQUET is a graduate of the "Institut d'études politiques" of Paris and holds a doctorate in applied economics. At present, lecturer specialising in intercultural issues.
- Hervé THÉRY, geographer, Associate Professor at the University of São Paulo (Brazil), Emeritus Research Director at the CNRS.

Appendix 3

Joint secretariat of the INRAE-Cirad-Ifremer-IRD ethics committee

The secretariat for the committee is provided jointly by the 4 organisations, with administrative support provided by INRAE.

- **INRAE**: Christine CHARLOT, General Secretary, and Claire LURIN, with the support of Nathalie HERMET
- **Cirad**: Philippe FELDMANN and Marie DE LATTRE-GASQUET
- **Ifremer**: Philippe GOULLETQUER and Marianne ALUNNO-BRUSCIA
- **IRD:** Chloé DESMOTS

Appendix 4

The principles and values of the INRAE-Cirad-Ifremer-IRD Ethics Committee

1 The Joint Ethics Committee considers the recognition of human dignity to be a fundamental value. In its recommendations, it will endeavour to give tangible form to this value, implementing the rights set out in the 1948 Universal Declaration of Human Rights.

2 More generally, the Committee considers that the values of the body of declarations and conventions established over several decades by the United Nations and specialised organisations, in particular UNESCO, form part of its reference framework, including the protection and promotion of cultural expressions and biodiversity. This body of work is implemented through international standard-setting agreements.

3 The environment in which future generations live must not be deteriorated, and the future must not be irreparably jeopardised, in particular by depleting natural resources or undermining the balance of nature. This principle of sustainable development requires the Committee to work in both the long and very long term, not just in the short term. However, the principle of total reversibility appears utopian and impractical.

4 The world is a system. Any action taken on one part of it has an impact on other parts: the analysis must therefore explore the secondary and knock-on effects of an action, and the dynamics and strategies that it may encourage or promote. Problems must therefore be tackled primarily on a global basis, while at the same time ensuring compatibility between global and local, and by taking account the realities on the ground.

5 The Committee considers that the robustness and flexibility of a system are positive elements. Thus, even in an open society, a degree of self-sufficiency in systems of production is desirable at both the national and the regional level.

6 Progress implies a society that is open to technical and social innovations, in the knowledge that we need to analyse and predict the impact of these innovations on lifestyles, their contribution to human development, and ensure that the benefits they can bring are shared equitably.

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