SOILveR

Soil and land research funding platform for Europe

Project SOILval

Recognising SOil values in land use planning systems

Synthesis - SOILval project results

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SOILveR in brief

The SOILveR platform strongly believes in the need for integrated soil and land research and knowledge exchange in Europe. We acknowledge the added value of coordinating, co-funding and disseminating cross-border soil and land management research. SOILveR is a self-financed platform. The platform members have a common interest in sharing and implementing integrated multidisciplinary research. SOILveR builds on the experiences from other funding networks such as SNOWMAN and address knowledge needs identified by e.g. the Horizon 2020 project INSPIRATION and other initiatives as well as those proposed by the members of SOILveR.

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1 Introduction

Soil ecological functions provide multiple services to society, including regulation and support services (carbon storage, habitat for species, etc.), essential provisioning services (crops, timber, water,etc.), and cultural services (landscape, gardens, etc.). Urban development and soil sealing on natural, agricultural and forest land are continuing in Europe. However, land take is considerably damaging to biodiversity, to ecological soil functions and associated services (Born, 2010; France Stratégie, 2019).

European legislation on land use planning does not yet take into account soil quality in an integrated, systematic and ecologically coherent way, particularly when considering changes in land use (Born, 2010). In many countries, the soil is seen, from a legal point of view as building land only under planning process. In France and Wallonia, public policies organising regional planning/land use decisions are indeed based on regulations that are compartmentalised between different sectors (agriculture, forestry, environment, urban planning, biodiversity, etc.).

In order to reverse the phenomenon of land take, the European Commission has set a target of "zero net land take" by 2050 in its "Roadmap for a resource-efficient Europe" (European Commission, 2011). In France, this objective is part of the "Zero Net Artificialisation» (ZAN) objective initially introduced through the Biodiversity Plan (2018) and then by the recent "climate and resilience" law of 22 August 2021. In Wallonia, it is integrated into the framework of the Regional Policy Declaration (Declaration de Politique Régionale Wallone 2019-2024) [1]. In order to monitor and evaluate the achievement of French and Walloon objectives in terms of reducing land take and urban sprawl, it is essential to take into account soil quality in terms of ecological soil functions. Therefore, local authorities in both France and Wallonia need support and access to resources for a better understanding of soil quality with a view to recycling their land, particularly in the context of "de-artificialisation" actions. Since then, Europe has also launched at the end of 2021 a EU Soil Strategy for 2030, which promotes an integrated vision of soil management (European Commission, 2021).

Notes : To facilitate the reading of this document, the European objectives of "zero net land take "will hereafter be referred to as "ZAN objectives" in reference to the French Zero Net Artificialisation objective and/or Wallonia objectives of reducing land take and urban sprawl. Depending on the contributing authors, the concept of "land take" is sometimes referred to as "artificialisation" in the document. **"**De-artificialisation" or "renaturation" actions are operations to restore or improve the functionality of a soil, having the effect of transforming an artificial soil into a non-artificial soil (definition from the French Climate and Resilience Law 2021). The types of artificial sites that can benefit from these actions are brownfields, but also any artificial soils that have already been made impermeable and for which a new, more permeable land use with vegetation support is possible.

"Refunctionalisation" of an artificial or degraded soil is understood as actions implemented by man that allow the restoration of ecological processes in the soil, which are at the basis of the functions that the soil can provide (fertility, water infiltration, carbon storage, etc.) and that can lead to providing services to man (food production, flood regulation, climate regulation, etc.). Thus, refunctionalisation can include the enhancement, restoration or creation of the general functionality (several functions) or a specific function of the soil compartment, by acting on the expected soil ecological processes (adapted from Monfort and Limasset, 2019).

[1] https://www.wallonie.be/sites/default/files/2019-09/declaration_politique_regionale_2019-2024.pdf

2 SOILval overall objectives and program

The overall objective of the SOILval project is to enable better recognition of the value of soils - defined by SOILval as soil quality relying on soil functions and associated ecosystem services (ES) - in the context of land planning and development in France and Wallonia, and more particularly in the context of ZAN.

The SOILval project aimed specifically to evaluate over a period of one year (2020-2021) how the concept of soil value is recognised and or integrated in France and Wallonia in legal instruments and planning decision-making processes. The project also investigated how operational solutions for soil refunctionalisation could contribute to a better consideration of soil quality. Decision support tools and supporting soil quality knowledge bases that can support the planning and implementation of refonctionnalisation are reviewed in parallel. This work was carried out through literature review, legal analysis and consultions of relevant stakeholdres in both France and Wallonia. This work was planned to result in drafting recommendations for better integrating soil values into land use planning, in particular in the context of European ZAN implementation, through a series of “technical fact sheets”, an “R&D note” and two “public policy brief notes.

The technical and scientific work programme of SOILval was organised in five tasks and was carried out by the SOILval partners from December 2020 to November 2021. A series of report and deliverables were produced during the project. They are all available from the Soilver website, and from the ADEME and SPW online libraries.

3 Consideration of « soil quality » in French law

A legal analysis of the consideration of soil quality in French law was carried within SOILval (Limasset et al., 2021). The analysis of the legal sources related to the consideration of soil quality in French law began with setting up a methodological framework, in particular to enable possible comparisons between France and Wallonia (3.1). This was followed by an analysis of the texts identified as taking the best account of soil quality in its various meanings (3.2). From the analysis, some conclusions can be drawn (3.3.).

The results from this analysis have been summarised in a SOILval policy brief. It presents the current situation and the prospects for the development of soil quality in French law in a planning context (Desrousseaux, 2021).

3.1 Methodological framework

In view of the scope of the SOILval project, this legal state of the art selectively integrates the texts of French law, both legislative and regulatory, that are used in connection with changes in land use or occupation and with land management. Administrative jurisprudence, which is prolific in this vast field, could be an element to be analysed in the perspective of pursuing the research questions posed by SOILval. In addition, the elements of international law and European Union law can be analysed at a later stage with regard to any convergences identified with Walloon law. However, the small number of binding European texts on the issue suggests few common points and invites us to consider this scale of action as relevant. The recent resolution of the European Parliament on soil protection (Parlement Européen, 2021) is an interesting path to explore. Finally, institutional documents presenting public policies, such as the one relating to the remediation of polluted sites and soils, as well as legal doctrine analysing all the above-mentioned sources, are

included in this state of the art in the sense that they shed essential light on the application of the law.

More precisely, the branches of law analysed are the following: environmental law, rural law, forestry law, and more anecdotally, urban planning law, public health law, and local government law. This choice stems on the one hand from the problematic of the project and the actors it mobilizes, and on the other hand, from the attention given to the research projects already carried out on the consideration of soils in urban planning.

3.2 Identification of legal fields where soil quality is best taken into account

The legal provisions having an impact on soil are very numerous, on the one hand because of the almost ubiquitous presence of soil in the territory, and on the other hand because it is both a support and/or a resource for a very wide range of activities. Therefore, to pretend to be an exhaustive research would not bring any particular enlightenment in the framework of this study. On the contrary, the inventory proposed in this study highlights certain fields whose approach deserves to be taken as a model.

The notion of soil quality exists in French law under various meanings, but the first observation is that the pedological notion of soil quality is found neither in international law, nor in European law, nor in domestic law. It is essentially a quality of use: the vocabulary of agriculture or construction defines in its own terms what differentiates a good soil from a bad one. This quality corresponds to a value that can be improved by human action. Soils are modulated for many reasons: for economic exploitation, but also for pleasure, and the law accompanies this search for use. Rural law, with regard to soils used for food production, and the law on polluted sites and soils, offer two examples of legislation that determine implicit and explicit soil quality thresholds respectively. The former focuses on research and increasing their productivity, while the latter mainly establishes thresholds of toxicity and dangerousness with respect to other elements of the environment and human health.

Moreover, the law on water and aquatic environments, and in particular the regime for the protection of wetlands, includes advanced pedological identification criteria that demonstrate the feasibility of deepening the legal approach to soils. The same is true for the delimitation of nitrates vulnerability zones or the drinking water catchments protection zones.

The notion of soil quality, reflecting its functionality and its capacity to provide ecosystem services, should also be highlighted in the context of the levers required to implement the national low-carbon strategy. The carbon storage role of soils could thus be integrated upstream of development decisions. This state of the art reveals that the environmental assessment mechanism is currently under-exploited in terms of knowledge of soils and their functions. This observation reveals in particular a need for awareness raising on the issue of soil quality, both for those involved in planning and for the control authorities (administrative and judicial). It also applies to the implementation of the Avoid-Reduce-Compensate (ERC) sequence, which focuses on damage to biodiversity. In this respect, “de-artificialisation” operations considered as synonymous with “renaturation” (Art. L. 101-2-1) will be used to compensate for soil artificialisation. For the time being, the text of the so-called "climate and resilience" law (2021)[2] presents a broad definition whose simultaneous reference to the restoration and improvement of

[2] https://www.legifrance.gouv.fr/download/pdf?id=x7Gc7Ys-Z3hzgxO5KgI0zSu1fmt64dDetDQxhvJZNMc=

the functionality of a soil raises questions about its degree of requirement. Perhaps the implementing decree will clarify these points.

3.3 First conclusions from the French legal review

The law grants several types of value to land, but not all of them are synonymous with protection, quite the contrary. This state of the art, based on legal sources, institutional documents and legal literature published at the national level, identifies situations where the law relies, directly or indirectly, on one or more soil values to attach legal consequences in terms of change of occupation or use. Previous research work (Norma-sol - GESSOL 3)[3] had led to the conclusion that is now reflected in the recent European Parliament resolution on soil quality (Parlement Européen, 2021), which considers that "*soil protection in Europe is currently derived from the protection of other environmental resources and is partial and fragmented between many existing instruments that lack coordination and are often non-binding, both at EU, Member State and regional levels"*.

The question raised by the SOILval project, in the context of land development projects and planning, is to what extent the value of a piece of land would call make one questionning the decision to develop it or not. In the perspective of contributing to the definition of the objective of the French ZAN, but without being limited to it, the references identified below converge towards the primary need for the law to adopt a definition of soil that integrates its multifunctionality (Desrousseaux, 2021).. This definition would then correspond to the notion of "soil quality", the recognition of which by law would constitute a practical and conceptual advance, which will not come from either international law or European Union law. This progress has just been partially initiated by the adoption of the "climate and resilience" law. By introducing a new regime for soil artificialisation, it renews the definition of soil by focusing on some of the functions it performs. Moreover, by providing for the renaturation of artificial soils to compensate for the artificialisation of new soils, the law introduces new perspectives for soil restoration, including urban soils, which will necessarily question the practices of developers, particularly in terms of the reversibility of structures they develop. We will now have to wait for the application decrees to measure the effectiveness of this system and its proximity to the notion of soil quality.

4 Review of soil quality in land management Walloon law

As for France, a legal review was carried for Wallonia that highlights the way in which soil is dealt with in Walloon law (Limasset et al., 2021). The CoDT (Code du Développement Territorial), which governs Walloon land use planning and urban development, is the main item being reviewed within SOILval. Its analysis follows a preliminary examination of soil protection in Walloon law and more specifically the Soil Decree. The methodological approach that was chosen is the one classically used in law, based on the relevant legislation, jurisprudence and doctrine. In Belgium, although soil protection policy is a largely regionalised competence, the legal regime of soil is nonetheless scattered and its status is multiple.

Soil is first an asset that is owned when considering the Civil Code; its owner freely disposes of it and decides on its degree of protection subject to the limits established by the law. Soil is also an element of the common heritage of the inhabitants of the Walloon Region (Articles D.1 of the Environment Code and 1§1 of the Soil Decree). This notion refers the idea of conservation and transmission without alteration for future generations. Soil, taken as an element of the environment, is therefore understood as a natural element, and not just a support for land uses.

[3] 10/2010-04/2015 Projet Norma-sol - GESSOL 3 « Recherches sur la protection juridique des fonctions et services du sol »

The results from this analysis have been summarised in a SOILval policy brief. It summarises the integration of soil qualities in spatial planning law, reminding the context, the results of WP2 and recommendations for better integration of soil quality (Hucq, 2021).

4.1 « Soil » in Walloon law

There are many texts relating to soil. The decree of 1 March 2018 on soil management and remediation (known as the Soil Decree), which defines soil as "the surface layer of the earth's crust, including groundwater within the meaning from Book II of the Environment Code containing the Water Code, and the other elements and organisms present therein" (art. 2, 1° of the Soil Decree), does not regulate all soil-related issues. Provisions relating to soil can be found in many other Walloon laws. Without claiming to be exhaustive, texts such as the law on nature conservation, the Forestry Code, the Walloon Agriculture Code, the Decree of 11 May 1999 on environmental permits, the Decree of 27 June 1996 on waste, the Decree of 10 July 2013 on the use of pesticides, the decree of 12 January 1995 regulating the use of sewage sludge or sludge from septic tank sludge treatment centres on or in the soil, and the law of 12 August on the conservation of the beauty of landscapes are all texts that are more or less directly relevant to the soil.

4.2 « Soil » in land management Walloon law

As for the Code of Territorial Development (CoDT), its purpose is to cover the use of the land and to multiply the different perspectives on the land, which is sometimes considered as a support for anthropic uses and sometimes as a natural element, whether directly targeted or not. The CoDT mediates this multifunctionality of the soil. This mediation may be internal to the CoDT or may be carried out by importing rationalities external to the CoDT, which integrates them within it.
Book II of the CoDT on regulatory and strategic planning offers this range of different perspectives on soil. Soil is first and foremost a resource to be managed sparingly.

The plans (“Schémas” in Wallonia) define the territorial strategy at their respective levels. It includes objectives for territorial development and land use planning which aim, in particular, to combat urban sprawl and to make rational use of land and resources. In the “Schéma de développement Territorial” (SDT), a number of regional objectives relate to the land and alternate the designs projected on the latter. Above all, the SDT intends to support resource-efficient urbanisation by reducing the consumption of undeveloped land to six km2/year by 2030. By 2050, the SDT aims to completely stop the consumption of new land.

The “Schéma de Développement communal (SDC)” at municipal level and the Schéma d’Orientation Local (SOL) at local level are important levers for preserving, protecting and restoring soil biodiversity and the ecological functionality of the territories, but in practice they have certain limitations which put in second place considerations relating to soil quality and its functions (indicative value, expected added value, expectations in terms of the quality of the living environment, compliance with higher-level tools and the sectoral plan). Only the biological functions of the soil to ensure its role as a support for biodiversity are guaranteed to be respected, mainly with regard to the Nature Conservation Act and the CoDT, i.e. the protected sites and elements identified in the plans.

The “plan de secteur (sector plan), which determines the prescriptions of the different zones, perfectly illustrates the recognition of the multifunctionality of the soil. The soil is first considered only as a substrate for human uses, with the only exception, in certain zones, being the obligation

to have public green spaces. Soil can then be protected within certain areas through the mediation of several concepts that carry a certain soil quality such as the natural environment. Only the extraction (dependency) zones finally explicitly mention the soil, which is to be protected and used rationally.

The “guide régional d’urbanisme (GRU) (Regional Planning Guide)” and the “guide communal d’urbanisme (GCU) (Municipal Planning Guide)” allow soil to be taken into account by means of indications on soil preservation. The legislation on planning permission requires administrative authorisation for a series of acts and works that directly affect the soil (construction, deconstruction, significant modification of the ground surface, etc.). This authorisation is granted subject to the assessment of the competent authority and thus makes it possible to control the use of the land. It should also be noted that the CoDT has established links with other administrative policies. Thus, an orientation study within the meaning of the Soil Decree is required when applying for planning permission in certain cases. This makes it possible to determine whether obligations are owed with regard to this decree. The CoDT then integrates the Soil Decree's view of soil quality. It is determined by threshold values for the concentration of pollutants in the soil, depending on the legal use of the land or factual use of the land. This orientation study verifies that the quality of the soil is compatible with the planned uses.

The environmental assessment of Walloon plans, “Schémas” and projects must be able to establish the impacts on the land and be taken into account by the competent authority.

Operational urban planning, which constitutes Book V of the CoDT, is relevant to the studied problem, in that these tools aim in particular to recycle land and thus to combat urban sprawl. The integration of soil issues is based, on the one hand, on this recycling objective, and on the other hand, by the remediation work that will be carried out, if necessary, to aim for soil quality as provided for by the Soil Decree.

4.3 First conclusions from the legal Walloon review

The rapid overview of Walloon provisions relating to soil reveals some interesting provisions that could be mobilised, and without links with spatial planning law being made clear or effective: the possibility of establishing a sectoral action programme for soil quality (Art. D.46, 3° CDE), the Government's power to prohibit damage to the soil causing prolonged alteration of the soil (Art. 46 Forestry Code). The Soil Decree opens up a series of interesting powers to preserve and restore soil quality (Article 4 Soil Decree). Thus, the Walloon Government can, for example, take measures to regulate and organise "the management of works likely to affect soil quality" (Art. 4, para. 1, 3° Soil Decree) or to "impose reporting and data transmission obligations and set up an authentic database" (Art. 4, para. 2, 4° Soil Decree). As far as Walloon spatial planning law is concerned, although tools can be mobilised to preserve soil quality, the CoDT remains insufficient overall to take account of soil quality in a systemic and systematic way in spatial planning law. It can also be concluded that better consideration of soil quality in spatial development plans and projects will require better information on soil quality which could, if necessary, provide a framework for the decision-making power of the competent spatial development authorities (Hucq, 2021).

5 French and Walloon stakeholders' point of view on soil quality

5.1 Methodology

Consultations with stakeholders who play an active role in planning and land development have been carried out within SOILval in order to understand better how they consider soil quality (Merly et al., 2021). The specific objectives of the consultations were to apprehend how the stakeholders, take into account soil quality in their missions, which solutions or modalities they implement to encompass soil quality and which barriers and drivers they have to take into account soil quality. The consultation relied first on a web-survey conducted from May to June 2021 and was then followed by a virtual web-café (workshop) held in July 2021.

The web survey consisted in evaluating stakeholders' level of awareness and knowledge on soil quality, in assessing how urban planning and technical solutions considering soil quality were implemented (including locks and drivers) and in identifying stakeholders' needs. The web-survey was supposed to complete the state of art that was already carried within SOILval (See following chapters 6, 7, and 8 presenting the results froma literure review on refuntionalisation solutions, soil quality knowledge and related decision support tools in France and Wallonia). The web survey was aimed at local authorities, land holders such as industries, ecological consultancies, contaminated land consultancies, landscape architects, developers, construction firms. Research community and national authorities such as ministries were not targeted in France, but were in Wallonia.

The virtual web-café gathered French and Walloon experts in soil quality and in urban development from various fields (legal, technical, urban, R&D, operational). It relied on three thematic groups (legal, technical, and R&D) which discussed how soil quality may be better took into account. Together, the web survey and virtual web-café results enabled to co-build legal, technical and R&D recommendations to enhance soil quality consideration into land development.

5.2 Results and analysis

Detailed results of the web-survey and the virtual web-café are described in the SOILval report called « consultations avec les parties prenantes » (Merly et al., 2021). The web survey was sent to over 1,100 stakeholders and to French and Walloon networks and associations. A total of 277 individuals answered partially or totally the questionnaire within the on line survey (among those 168 entirely completed questionnaires were received), equally distributed over France and Wallonia (with high contribution of Walloon municipalities and high contribution of French private operators such as consultants, architects and geometers). The web-café brought together 28 participants (19 French and 9 Walloon participants). Stakeholders were experts involved in soil quality and urban development, including local and national authorities, consultancies (ecology, planning and environment, contaminated land management, landscape), architects, industrial landowners, lawyers, and funders.

The main results of the consultation process can be summarised in four categories: "soil quality in land developement", "Regulatory context", "Methodological and technical solutions, database and tools" and "Research & Development perspectives".

5.2.1 Soil quality consideration in land development

The web-survey results showed that most of the respondents are aware of the Zero Net Landtake strategies. Generally, they take into account, mainly in part (and in some case totally) soil quality in land development and planning. Soil quality is driven by compliance with human health and environmental risk management in France and human health risk management and agricultural performance for Wallonia. Main soil functions considered into the urban development process include for both countries “providing habitat for biodiversity”, “water regulation (through infiltration and storage)”, “buffering, filtering and the transformation of potentially pollutants”, “soil fertility and carbon storage”. Half of the respondents stressed that taking into account soil quality (in full) could lead to the choice of not redeveloping the land.

Most of the French and the Walloon respondents are involved into the “Avoid, Reduce and Compensate” sequence (Eviter – Réduire – Compenser (ERC)) to mitigate landtake, in which soil quality plays a part. The redevelopment of brownfield sites is common in France, but less implemented in Wallonia. Brownfield redevelopment lead more often to densification project, including or not renaturation actions.

5.2.2 Regulatory context

Soil and soil quality are already included into emerging initiatives encouraging virtuous soil management, such laws on soil protection of private land, on protection of the agronomic value of soil or a sober and sustainable soil management. However, there is no specific legal framework for soil.

The web-survey showed that the absence of soil legal framework and/or the absence of national or local soil policies is a barrier for taking into account soil quality into the Avoid-Reduce-Compensate sequence to mitigate landtake. Despite some legal evolutions (art. L.110-1, 6° CU in France/Décret Sol in Wallonia), practices on soil quality have hardly changed. The absence of legal framework is also seen as a major barrier for the implementation of the technical solutions (of refunctionalisation) which promote soil quality. Most respondents believe that regulation is a strong driver for practices evolution and are in favour of an overall soil regulatory framework, such as the water framework directive.

For the virtual web-café, discussions were launched by the presentation of legal French and Walloon mechanisms (*la publicité foncière et la documentation cadastrale* for France and *le permis d’urbanisme* pour for Wallonia). The main points raised included management of environmental and human health risk associated to land redevelopment, traceability of historical land use, numerous and dispersed sources from where to collect the information. The means to achieved the Zero Net Landtake were questioned and notably the trade-off between urban densification, ensuring societal wellbeing and protecting natural and agricultural land. The stakeholders proposed recommendations as follows: i) necessity to include soil quality information in property documents, while paying attention to potential drawbacks (such as project delay, land value increase, etc.) and ii) to information opposability.

5.2.3 Methodological and technical solutions, data and tools

Methodological guidelines, technical solutions (of soil refunctionalisation), database and evaluation tools on soil quality exist.

The web-survey showed that the technical and methodological solutions were implemented in a very heterogeneous way depending on their type. Less than half of the French respondents and a third of the Walloon respondents knew the methodological guidelines and the financial mechanisms which encourage brownfield development. According to the responses, the technical solutions which are the most implemented are biological and phytomanagement technologies for France and de-sealing technologies for Wallonia. Technologies dealing with soil reconstruction are globally not developed for both countries. Most respondents use national and local soil quality database, but hardly any are aware of evaluation tool which enable to assess soil functions.

From the web-survey, the main barriers identified for not implementing technical solutions (of soil refunctionnalisation) were: absence of legal or strategic framework, high cost of implementation and lack of expertise. For those who did not use existing database, it was either because they did not know them or because these soil repositories did not meet their needs. The virtual web-café confirmed the lack of tool to take into account soil multi-functionality and the lack of financial resources dedicated to soil quality from the decision makers.

The results of the web-survey and the virtual café indicated that one of the main drivers for a better consideration of soil quality in urban development of planning was the evolution of legal framework. A better assessment of societal, environmental and economic benefits associated with soil quality and the needs for practitioner soil quality awareness raising and training were also common drivers of both consultation steps.

Additional drivers stressed in the web survey, by order of importance were: including soil quality in requirements specification document, implementation of national or local policy, increase of financial means dedicated to soil quality, increase of excavated soil management and promotion of greening redevelopment options. In complement, participants of the virtual web-café stress the need to manage soil quality and landtake according to local land specificity (urban or rural). Numerous recommendation were suggested for a better use of soil repositories and database and evaluation tool such as: including biological quality, geochemical background levels, agronomic quality, carbon storage in soil data; compiling existing database in one simple access soil data platform; establish a link between soil quality and ecosystem services; adapt current evaluation tool to stakeholders' demands.

5.2.4 Research & Development perspectives

The participants of the web-survey and the virtual café identified four categories of R&D actions in order to promote soil quality intake in planning and urban development "Development of soil quality data", "Systemic approach of soil quality and urban development", "Tools and methods", "Knowledge transfer".

The need for an easily accessible and useable soil quality data platform, which could be transposed in property document was stressed by the stakeholders. This data repository may be designed by both the land and soil practitioners and experts in order to make sure that it meets users' demands and contain all relevant technical information such as biological quality, geochemical background levels, agronomic quality, carbon storage, geotechnical characteristics etc. The soil data repository may combined existing database and shall be coupled with a geographical interface representing various working scales.

In order to develop systemic vision of urban development including soil and sub-surface system, it was deemed important to develop multi-disciplinary R&D project and to promote education in geoscience and practitioners' training. It was considered important to develop assessment and evaluation tool encouraging the practical implementation of ecosystem services, including soil functions and ecosystem services and enabling to assess the suitability of land use options and soil functions. Soil multi-functionality and soil (as a resource and capital) need to be considered from the initial urban development steps onwards.

Guidelines or methodology on ecological rehabilitation shall be developed in order to encourage its implementation. Development of tools to evaluate land use options taking into account soil functions, land use value, exchange values was proposed. Eventually, it was recommended to adapt existing tools to meet end-users' needs.

In order to overcome the lack of stakeholders' awareness or knowledge on soil quality, it was recommended to develop efficient communication and training strategies and actions to transfer existing knowledge (or adapted knowledge).

Note : The web survey respondents, when questionned on descision suport tools , were given exemples of tools (MUSE, RECORD DESTISOL or NVE) (see chapter 8 for more details on these tools).

6 Refunctionalisation solutions applied on artificialised soil

6.1 Introduction

According to (Godart and Ruelle, 2019), the artificialisation process is, in practice, considered to be not easily reversible. However, we are hearing more and more about "de-artificialisation" or "renaturation" based on the restoration of soil quality or the refunctionalisation of artificialised soils combined with vegetation. "Artificialised sites" that can benefit from these actions are brownfield, but also any artificialised areas that have already been sealed off, and for which a new, more permeable soil occupation with a vegetation support is possible. Among the solutions for soil refunctionalisation, we find "desealing", soil engineering (construction and reconstitution of soil) or bioremediation techniques (biotreatments or phytoremediation).

The SOILval consortium carried out a review of these solutions (Limasset et al., 2021). The review was mainly based on French experience. For each of the solutions, the following has been reviewed as far as possible: the principles and definitions, a reminder of the regulatory context of implementation, how it takes into account soil functions and ecosystems services, its scales of application, its degrees of application or identified bottlenecks, and categories of stakeholders who can contribute to its implementation. Two SOILval Fact sheets have also been written to help disseminate the knowledge on refunctionalisation solutions towards land development stakeholders[4]. One covers the de-sealing solutions and the other one covers the soil engineering solutions (Quadu et al., 2021a, 2021b, 2021c) .

Note : In addition to these two Soilval Fact sheet, 3 other fact sheet are proposed that covers some planning tools SCoT for France, and SDC, SOL and environmental evaluation for Wallonia (Quadu et al., 2021d, 2021e, 2021f).

[4] A fact Sheet « Qu'est ce que le phytomanagement » has been published by « ID Friche » in France. (https://www.idfriches-auvergnerhonealpes.fr/sites/default/files/20210419_fiche_phytomanangement.pdf)

6.2 De-sealing solutions

Soil sealing is the most damaging mechanism for any of the soil functions, whether biological, chemical or hydrological (Béchet et al., 2017). It can affect all ecosystem services as well. Considerable socio-economic impacts also arise from sealing, notably related to water management (CDC Biodiversité et Humanité Biodiversité, 2021).

There is no single definition of de-sealing, as it is a fairly emerging concept. It can be defined as an action or the result of an action that consists of uncovering totally or partially a soil covered by a pavement or a construction that disturbs the water cycle (CDC Biodiversité et Humanité Biodiversité, 2021). This involves "partially restoring the old soil profile by removing impervious layers such as asphalt or concrete, loosening the underlying soil, removing non natural matter and restructuring the profile. The aim is to re-establish an effective link with the subsoil". (Commission Européenne, 2012). Another definition, proposed by the Agence de l'Eau Rhône Alpes Méditerranée, also refers to the replacement of impermeable surfaces by more permeable ones, but in the perspective of new redevelopment projects and it is generally followed by the vegetation process of the area. In all cases, de-sealing objectives are to reduce rainwater runoff and the risk of flooding, to renature impervious areas in order to contribute to the improvement of biodiversity and to fight against climate change (Grand Est Agences d'Urbanisme, 2020).

Two types of solutions seem to emerge, i.e. nature based solutions (e.g. vegetation, infiltration ditches, etc.) or grey solutions (e.g; porous pavements, paving stones). The possible solutions can also be applied at two different scales. They may concern micro-interventions in very small areas or macro-interventions in large areas.

De-sealing of artificialised soils is indeed becoming one of the major concerns of metropolitan policies, such as the "permeable city" (ville permeable) project in Grand Lyon (Grand Lyon, 2017). In France, large-scale de-sealing operations have been launched by local authorities and the State[5]. De-sealing allows nature to return to the urban environment in parallel to the"permeable city" concept policies that have not been systematically applied in France or Wallonia. The cities are not seeking to recover the original habitat but to create habitats that provide solutions to heat islands, flood management, management of the small - scale water cycle, etc. In fact, depending on the context, desilting will generate positive impacts on the so-called hydro-geomorphological ecological functions (linked to the water cycle). Thus, the functions potentially favoured by de-sealing include the slowing down of runoff, soil stabilisation, retention of runoff, recharging of the water table or the support of low-groundwater levels.

Guidance that is suitable to local stakeholders are being developed to help on the subject of de-artificialisation/renaturation including de-sealing[6]. However, there are little indications on how to consider soil functions and services, particularly with regards to soil quality assessment prior to any ecological soil rehabilitation which may follow de-sealing, or in terms of monitoring the overall renaturation action in terms of effectiveness. It would also be necessary to stress the need to take into account constraints such as the management of the remobilisation of pollutants and the quality of the environment medium potentially concerned, depending on the degree of de-sealing that is targeted, but also depending of the envisaged new occupation and uses of the land.

[5] For example the project called 'Sauvons l'eau' of the French Agence de l'Eau RMC and the "OASIS cours d'école" project in Paris

[6] For example « Guide la nature dans nos villes et villages » (Grand Est Agences d'Urbanisme, 2020)

There is little feedback from the implementation of de-sealing solutions on artificialised soils in France or Wallonia. (France Stratégie, 2019) gives a range of average costs without considering deconstruction, decontamination or soil construction (60 to 270 Euros per m2 depending on the technique used). In addition, although the consequences of sealing on soil properties are known, very little work has been done to study the potential of de-sealing and its consequences on existing soil quality. Some R&D projects currently underway, such as Dessert[7], are attempting to meet these needs with laboratory experiments to optimise de-sealing processes and monitoring on pilot sites. The Désiville R&D project[8] also aims to develop decision-making tools for de-sealing of artificialised soils and propose a catalogue of solutions applicable in cities.

6.3 Soil engineering solutions: soil construction and soil reconstitution

For several years, the supply of topsoil to large urban areas in the context of redevelopment projects has become increasingly complicated. The areas where topsoil is extracted are further and further away from urban centres, which increases the economic and environmental costs of this topsoil. Thus, new sectors such as soil reconstitution or soil construction solutions are beginning to emerge in France and already applied in Wallonia.

These solutions, based on soil engineering techniques, consist of reconstituting or creating fertile soils from scratch from urban waste used as alternative materials (BRGM, 2020). Soil reconstitution occurs when existing soils do not have favourable agronomic properties for plant growth and development (Damas et al., 2016), whereas soil construction is based on the creation of a new soil profile ensuring a high level of functionality, but differing in structure and function from the original soil (Tagourdeau et al., 2020).

These solutions based on soil engineering techniques, consist of reconstituting or creating fertile soils from scratch from urban waste used as alternative materials (e.g. mineral waste produced by the construction industry such as excavated soils, aggregate washing sludge, paper sludge, dredging materials, etc.) (BRGM, 2020). Soil reconstitution occurs when the existing soils do not have favourable agronomic properties for plant growth and development (Damas et al., 2016) whereas soil construction is based on the creation of a new soil constructed with external materials ensuring a high level of functionality, but differing in structure and function from the original (Tagourdeau et al., 2020).

In Wallonia, reconstituted soils are defined and refered to in a series of thematic regulations such as "marketing of cultivation substrates[9]", "management of excavated soil[10]", "specifications for public road works[11]", or "recovery under waste status[12]". Also, there are currently no specific regulations governing these processes in France. Nevertheless, several technical aspects can be linked to the French rural and maritime fishing code or the environment code. In addition,

[7] DESSERT project2020-2024 https://www.plante-et-cite.fr/projet/fiche/101/desimpermeabilisation_des_sols_services_ecosystemiques_et_resilience_des_territoires_dessert/n:25

[8] https://aau.archi.fr/contrat-de-recherche/desiville-outils-daide-a-la-desimpermeabilisation-des-sols-artificialises-developpements-methodologiques-pour-levaluation-du-potentiel-de-desimpermeabilisation-et-catalogue-de-so/

[9] Arrêté royal du 28 janvier 2013 relatif à la mise sur le marché et à l'utilisation des engrais, des amendements du sol et des substrats de culture et ses annexes

[10] AGW du 5 juillet 2018 relatif à la gestion et à la traçabilité des terres

[11] CCT Qualiroutes – http://qc.spw.wallonie.be/fr/qualiroutes/index.html

[12] Arrêté du Gouvernement wallon du 14 juin 2001 favorisant la valorisation de certains déchets

compulsory standards govern the marketing of growing media (culture supports) and soil improvers.

In order to support professionals working in the development and management of green area, the SITERRE programme (2012-2015) has developed a soil engineering approach to help constructing soils with the desired agronomic fertility and bearing capacity. The programme also assessed social acceptance of off- site materials and proposed mix of materials used for soil construction (Plante&Cité et al., 2015).

At present, it seems that the implementation of soil reconstitution or construction solutions is mostly practised within private projects, mainly due to a lack of knowledge on the part of public stakeholders (especially technical services) and an attachment to the old (and current) practices of taking topsoil from agricultural areas.

There are currently no environmental guidelines for soil reconstruction or construction projects (Taugourdeau et al., 2020). However, various good practice guides exist in France, in relation to the reuse of materials (deconstruction materials from the construction industry, incineration slags and metallurgical slags (CEREMA, 2016)) or in relation to the recovery of excavated soil from non contaminated sites (Coussy and Dubrac, 2020). These guides propose threshold values for soil quality that should not be exceeded for chemical parameters (based in particular on health risk assessment principles). However, soil values in terms of the ecological functions or ecosystem services associated with soil biodiversity is not taken into account. A French national working group discussing off-site recovery of topsoil is meant to propose a specific methodology by the end of 2021.

The literature review shows that specific R&D-approaches exist for the reconstitution or construction of soils, which take into account soil functions. However, progress is still to be made and be better known by relevant stakeholders.

6.4 Phytoremediation solutions

Phytoremediation can be considered as a set of techniques that use in situ vegetation to immobilise or extract inorganic compounds or to degrade organic compounds present in the environment (Colombano et al., 2010). The definition of "phytoremediation" can vary according to the sources. For example, according to (ADEME, 2018), these are techniques that use vegetation to extract and transfer pollutants into the harvestable parts of plants (phytoextraction), extract and volatilise pollutants by transpiration (phytovolatilisation), contain pollutants (phytostabilisation) or degrade (phyto-rhizodegradation) pollutants.

Phytoremediation is relevant for large polluted sites, where more conventional remediation techniques (such as excavation) are not economically feasible (Morel, 2010). They are applicable to a wide variety of polluted soils, both in rural and urban areas, on shallow soils (down to the end of roots considered as 1 metre). The applicability of phytotechnologies must be acceptable according to the site constraints (e.g. topography, surface, volume of soil to be treated, etc.), soil characteristics (granulometry, permeability, organic matter rate, etc.), the nature of pollutants, etc. The study of climatic elements is also important (Colombano et al., 2010).

The main advantages of these techniques are their suitability for sustainable development and in particular for achieving ZAN objective, the possibility to bring more value to the land, and the

possibility they bring to manage soil quality in situ rather than off site compared to other conventional remediation techniques They can be integrated into a redevelopment project, for example to help with the landscaping aspects, the reinforcement of biodiversity, etc.[13].

The use of “phytomanagement” concept has become increasingly common in recent years. The IDfriches working group defines it as "an approach to managing a degraded or abandoned site that allows its direct or indirect value to be progressively increased by using a set of phytotechnologies" (Bourgeois et al., 2020). According to IDfriches, it is based on the coupling of phytoremediation with renaturation approaches, notably as it considers the development of soil functions.

Several obstacles to the implementation of phytotechnologies have also been identified (ADEME, 2015; ID Friches, 2021). These include the lack of experience from the remediation sector, the need for short clean-up times, the often limited space available when dealing with concentrated pollution, and pollutants that have not yet been tested with phytotechnologies (BTEX, PCB, pesticides, chlorinated solvents).

Similarly, the implementation of these solutions requires to manage several constraints at the same time (soil quality, water management, length of time for treatment, long-term monitoring, etc.). Phytoremediation techniques are still little used, except for rhizodegradation (a process integrated into phytodegradation), which is beginning to emerge, particularly on soil polluted by hydrocarbons. Needs have indeed been identified to encourage further development of these techniques: evolution of the regulatory framework, development of decision-making tools, training of stakeholders, economic and societal levers, etc.

6.5 First conclusions from the review on soil refunctionalisation solutions

Some of the solutions previously mentioned are still under development, such as soil engineering, which are lead by a significant demand in topsoil in land developments. Others, such as the de-sealing solutions are based on techniques relying on the “permeable city” concept, which were known and widely used by local authorities. However, examples of concrete “de-sealing” actions on artificialised soils are still limited and their impacts on soil ecological functions and services have only recently been studied in France for example within research programmes.

Several obstacles to the development of the refunctionalisation techniques are therefore observed and research programmes are only very recently looking into these. One can name implementation constraints or lack of knowledge e.g. in the case of phytoremediation, cost constraints as identified for de-sealing techniques and whether we are looking into micro or macro scale interventions, regulations constraints in particular in France in the case of construction and reconstitution of soil etc. Furthermore, the review or the consultations process highlights that their implementation is generally not focusing on restoring soil ecological functions and services. These techniques are generally being chosen for a very specific purpose and not necessarily in a global holistic approach.

However, a global consideration of the value of soil is emerging. One example is phytomanagement. The emergence of such concepts reflects a desire from the stakeholders to change the perception of soil value, in particular by integrating its 'ecological' value. The review

[13] https://www.axelera.org/user_files/2021/04/Programme-JT-Phytomanagement.pdf

also highlighted the need for more feed feedback on refunctionalisation actions, particularly within projects.

Knowledge in Soil quality in France and Wallonia

7.1 Knowledge organisation

Soil Quality knowledge (i.e. data repositories such as database or geographic layers) in France and Wallonia is numerous and varied. Soil quality monitoring was first motivated to evaluate natural and anthropogenic impacts on soil or fertility for agricultural use. Thus, knowledge of French and Walloon soils is substantial, mainly for non-artificialised soils. The interest in gathering knowledge on artificialised soil quality is more recent and mainly concerns urban areas. It is particularly in connection with the management of contaminated land. For example, the Belgian soil map and its digital version, the CNSW, are reference tools, but they do not currently enable all urban soils to be characterised and mapped[14].

Various geo-information databases or data repositories have thus been developed in France to collect/store soil data at different scales, from the local authority level to the national territory. The data may be related to physical, chemical or even, more rarely, biological, soil characteristics, depending on the objectives of the data banking system. These data can contribute directly or indirectly to the characterisation of soil or ecosystem services. In Wallonia, as noted by (Stephenne et al., 2015) a policy has been adopted recently, making data available to the general public and to soil managers through the Walloon online geoportal (WalOnMap | Géoportail de la Wallonie)[15]. This access to information is confirmed by the Walloon Soil Decree, which establishes the availability of several geodata (BDES, background concentration map).

A review of Walloon and French knowledge or data repositories in soil quality was carried out within SOILval (Limasset et al., 2021). In France, these data are mostly organised within various databases. Not all of them are available in cartographic form. In Wallonia, all the data collected on soil quality is made available in cartographic form, under a single Walloon geoportal ((WalOnMap). The SOILval review was therefore carried out with the support of the GIS Sol (Groupement d'intérêt scientifique Sol) [16]. for the existing soil database, and, with the support of the SPW for the Walloon presentation of data accessible from the Walloon geoportal or from other websites that provide information on soil quality, in connection with the physical, chemical or biological parameters measured in the soil.

The review help to highlight, for each source of information, the different objectives targeted, what consideration is specially given to soil quality, the scale of application, the potential for knowledge transfer, etc. A SOILval Fact sheet also drafted to help disseminate the soil quality review both for France and Wallonia (Quadu et al., 2021d).

7.2 Soil Quality knowledge in France

The main programmes, projects or databases presented in this chapter are listed in Annex 1.

[14] Cette cartographie ayant été réalisée entre 1947 et 1991, les zones urbaines étaient moins étendues.

[15] https://geoportail.wallonie.be/home.html

[16] https://www.gissol.fr/donnees

There are several producers of soil data in France. One of the main ones is the GIS Sol. To date, the soils studied in these programmes are non-artificialised soils (field crops, vineyards, orchards, meadows, etc.) or forest soils. Four major data acquisition programmes coordinated by the GIS Sol can be cited: IGCS[17], RMQS[18], BDETM[19] and BDAT[20]. The IGCS aims to identify, define and locate the main soil types of a region or territory, and to characterise their physico-chemical properties of interest for agriculture and the environment. The data collected within IGCS programme are stored in the "DoneSol" tool[21]. The objective of the RMQS programme is to monitor soil quality over the long term and to assess the impacts of natural and anthropogenic factors on soil quality. Maps and statistics from the RMQS are available on the GIS Sol website, on the INRAe dataverse[22] and on the INRAe geoserver[23]. BDETM is based on several data collections since 1997 on soils within the monitoring program on wastewater treatment plant sludge spreading on agricultural soils. The data can be consulted on the GIS Sol website or on the INRAe geoserver. The BDAT includes the results of soil analyses (more than 2 million) carried out on French agricultural soil samples taken since 1994 throughout metropolitan France[24]. The GEOSOL[25] cartographic tool allows the visualisation of these data.

Other national information sources such as ASPITET[26], BDSolU[27]or the national mining inventory[28] complete the system. These data sources mainly list chemical, physical and agronomic data. Also, RENECOFOR (Réseau National de suivi à long terme des Ecosystèmes Forestiers) [29] banks soil data. Finally, the TypTerres database[30], currently being developed, is based on the "Référentiel Régional Pédologique[31]" (regional peologiocal database) aiming at defining simplified soil typologies for each region by associating reference physicochemical property values.

France also record specific zones called "Secteurs d'Information sur les Sols" (SIS), imposed by the ALUR law, where soil surveys and pollution management measures may be required in case of change of use for a specific site. The ALUR law also requires the State to publish a map of former industrial sites and service activities (known as CASIAS), which must contain, among other things, the information contained in various French databases related to former industrial activities (BASIAS, BASOL).

Data producers such as the ONB (Observatoire National de la Biodiversité) provide indicators on the abundance of earthworms, land use, threatened natural habitats, changes in soil bacterial biodiversity, etc. Europe, via the CORINE Land Cover database, inventories land use from a

[17] IGCS : Inventaire, Gestion et Conservation des sols (Inventory, Management and Conservation of Soils)
[18] RMQS : Réseau de Mesures sur la Qualité des Sols (Network of Soil Quality Measurements)
[19] BDETM : Base de Données sur les éléments en traces métalliques (Database on Trace Metals)
[20] BDAT : Base de Données d'Analyses de Terre
[21] https://www.gissol.fr/outils/donesol-web-336
[22] data.inrae.fr
[23] https://agroenvgeo.data.inra.fr/geonetwork/srv/fre/catalog.search#/home
[24] https://www.gissol.fr/le-gis/programmes/base-de-donnees-danalyses-des-terres-bdat-62
[25] https://webapps.gissol.fr/geosol/
[26] ASPITET : Apports d'une Stratification Pédologique pour l'Interprétation des Teneurs en Eléments Trace Cette base va être intégrée à la BDETM et sera consultable sur un outil à développer.
[27] BDSolU : Base de Données des analyses de sols urbains http://www.bdsolu.fr/
[28] Données disponibles via le SIG Infoterre (https://infoterre.brgm.fr/), avec la couche « ressources minérales » ou via le site http://sigminesfrance.brgm.fr/.
[29] http://www1.onf.fr/renecofor/@@index.html
[30] https://sols-et-territoires.org/produits-du-rmt/typterres
[31] https://www.gissol.fr/publications/fiche-referentiel-regional-pedologique-rrp-2192

biophysical point of view. Finally, we can mention the setting up of the French artificialisation observatory (CEREMA, IGN, INRAe) as requested by the government to establish effective operational guidelines to restrict artificialisation.

In addition to national initiatives, local authorities have become aware of the need for better characterisation of their soils. They are therefore collecting data on the soils in their own areas, in order to respond to their local problems (pollution, de-sealing, biodiversity, etc.), via projects such as GeoBaPa, PHOEBUS or METOTRASS or databases such as RMQS Biodiversity. GeoBaPa aims to define a pedo-geochemical reference system for the lower Seine Valley and the Paris basin. PHOEBUS[32] (Depth of hydrogeological entities and evaluation of urban rainwater infiltration constraints on the territory of Rennes Métropole) provides, among other things, data on the types of soils encountered or the presence of wetlands and existing constraints (polluted sites, cemeteries, water catchments and catchment areas). METOTRASS aims to develop a geochemical background reference (including arsenic, lead, copper and zinc), for contaminated land management and spreading of sewage plant sludge. The RMQS Biodiversity[33] is specific to the Brittany region and proposes soil biodiversity measurements to be made available.

Finally, the SUPRA R&D project (Sols Urbains et Projets d'Aménagement) initiated in 2017, aims to evaluate the functions and ES provided by urban soils, from the soil profile to the urban area, via the development of a decision support tool. The data that should be generated will be stored in existing databases (chemical data in BDSolU, and agronomic data in DoneSol).

Regarding soil microbiology, the lack of data is identified in an ADEME report "Aménager avec la nature en ville" (ADEME, 2018). Thus, the national research programme (BIOindicators of Soil Quality) has been set up. Its objectives are to develop methods to measure biodiversity and soil functions, to use soil bioindicators to monitor soil quality and to identify relevant bioindicators for ecological risk assessment of soil contamination [34].

7.3 Soil Quality knowledge in Wallonia

All the Walloon programmes or data layers related to soil quality are listed in Appendix 1.

Various data layers are accessible on the Walloon geoportal and compile data on soil quality. These layers are the Carte numérique des sols de Wallonie (CNSW) [35], or Digital Soil Map of Wallonia, the Map of the main soil types of Wallonia[36] , Soil occupation (WALOUS 2018)[37], CARBIOSOL[38], ERRUISSOL, LIDAXES[39], the layer on “Contextes écologiques marginaux et sensibles” (Marginal and Sensitive Ecological Context)s, and the Banque de Données de l’Etat des Sols (BDES) [40].

The CNSW compiles all the information relating to the Digital Soil Map of Wallonia. The Map of the main soil types of Wallonia was derived from the Digital Soil Map of Wallonia. The WALOUS 2018

[32] https://infoterre.brgm.fr/rapports/RP-68599-FR.pdf
[33] https://ecobiosoil.univ-rennes1.fr/page/programme-rmqs-biodiv
[34] https://ecobiosoil.univ-rennes1.fr/ADEMEBioindicateur/
[35] Carte Numérique des Sols de Wallonie | Géoportail de la Wallonie
[36] Carte des Principaux Types de Sols de Wallonie à 1/250000 | Géoportail de la Wallonie
[37] Occupation du sol en Wallonie - WALOUS 2018 | Géoportail de la Wallonie
[38] Carbone, Bio, Sol : CARBIOSOL ! | Géoportail de la Wallonie
[39] La carte des axes de concentration du ruissellement LIDAXES | Géoportail de la Wallonie
[40] Banque de Données de l’État des Sols (BDES) | Géoportail de la Wallonie

data layer contains the land use mapping of the entire Walloon territory for the year 2018 (e.g. residential, industrial, commercial, agricultural, forestry, recreational). CARBIOSOL is a series of data layers that brings together all the information relating to the mapping of the content and stocks of total organic carbon (TOC) in Walloon agricultural soils. The project "Organic carbon, biomass and microbial activity of soils: towards an indicator of the quality of Walloon soils" (CARBIOSOL), which led to the creation of this data layer, is intended to develop indicators of the biological quality and organic carbon of the soil for the evaluation of the state of soils in Wallonia.

The ERRUISSOL mapping on "zones at risk of diffuse hydric erosion[41] , represents the critical slope length for 2 fixed soil loss thresholds (5 and 10t/ha.yr). The ERRUISSOL map on "zones at risk of diffuse runoff[42] ", represents the rate (coefficient) of potential runoff on the Walloon territory. The LIDAXES data layer - runoff concentration axis highlights areas at risk of flooding by runoff and/or mudflows resulting from the natural concentration of surface runoff. The layer « Contextes écologiques marginaux et sensibles[43] » (i.e. marginal and Sensitive Ecological Contexts) identifies soils where there are many issues in terms of biodiversity and associated ES. The BDES layer lists the cadastral parcels that are included in the inventory of polluted and potentially polluted land in the Walloon Region.

In addition to these data layers, Wallonia can provide important geological data on its territory (Geological Map of Wallonia, Basic Geological Data). Wallonia also offers access to the Inventaire Permanent des Ressources Forestières Wallon (IPRFW) and the REQUASUD network[44]. The REQUASUD Soil Database (ASBL REQUASUD) is a regional reference in terms of soil analyses allowing an assessment of Walloon agricultural soil quality. It provides status on land fertility in the Walloon region. These maps are available via the REQUASOL[45] application and in the REQUASUD brochures. The Permanent Inventory of Forest Resources in Wallonia (IPRFW) is a tool that organises the continuous characterisation of forest areas throughout the region relying on sampling process, and where information on pedology is provided.

Other ecological data layers are also accessible from the Walloon geoportal : the ecological data files on species obtained from forest observation stations, in particular providing information on the availability of water or mineral elements in the soils[46], the homogeneous ecological units[47] or the map of ecological links[48].

The Walloon geoportal also includes information related to the " Sites à Réaménager de droits " that is a register of zones identified as to be redeveloped. These zones are known as to be remediated, rehabilitated, renovated or rebuilt and benefiting from a redevelopment order (SAR by right)) [49]. Other information that can be found includes the DRIGM consultation zones (zones for which it is necessary to consult the Industrial, Geological and Mining Risks Directorate (DRIGM)

[41] ERRUISSOL | Géoportail de la Wallonie
[42] ERRUISSOL - Risque de ruissellement diffus | Géoportail de la Wallonie
[43] Contextes écologiques marginaux et sensibles | Géoportail de la Wallonie
[44] Base de données – Requasud
[45] https://requasol.requasud.be/
[46] Fichier Ecologique des Essences – Classes d'apport en eau (AE) | Géoportail de la Wallonie ; Fichier Ecologique des Essences – Niveau hydrique (NH) | Géoportail de la Wallonie ; Fichier Ecologique des Essences – Niveaux trophiques (NT) | Géoportail de la Wallonie
[47] LifeWatch - Ecotopes (v.2.9-2015) - Service de visualisation WMS | Géoportail de la Wallonie
[48] Liaisons écologiques – Article D.II.2, §2, alinéa 4 | Géoportail de la Wallonie
[49] Sites à réaménager de droit (SAR) | Géoportail de la Wallonie

[50]), the cartography of the main Walloon land use planning tools (sector plan, communal development plan, local orientation plan, Regional Stakeholder Zone, Communal Stakeholder Zone, regional town planning guide, etc.). The archaeological map is also available on the Walloon geoportal.

7.4 Conclusive remarks from the review on soil knowledge

Today, there is a need to carry on improving soil quality knowledge, as highlighted by a number of R&D projects that seek to meet the growing needs of many stakeholders. The following approaches rely indeed on soil quality data, e.g. soil quality assessment including the characterisation of ecological functions, management of excavated soils, ecological management plans, monitoring following rehabilitation/remediation, monitoring and control of soil artificialisation, etc. The French SUPRA R&D project tries to meet these expectations, particularly in terms of communication, dissemination, access to data, etc. Some data owners are still relecutant to dissemination of certain data (e.g. geographical coordinates of soil sampling points). In Wallonia, there is a need to develop further the Walloon soil map, which focuses on the suitability of soils for agriculture but also on resilient production in forests. It should be used more to support land use planning, and be expanded to cover more urban soils.

The evaluation of soil ecological functions still requires the acquisition of new knowledge, which results in France by more and more research programs covering this topic. Furthermore, data related to chemical, physical or biological quality in urban areas is still limited. In France, the availability, format and dissemination of these data are heterogeneous (depending on the producers and/or managers of these data). Heterogeneity makes it difficult to reuse data in a global and homogeneous manner throughout France. However, some French stakeholders are now more willing to migrate data collected in urban or rural areas to databases where data is georeferenced and interoperable. Web services using Open Geospatial Consortium (OGC) standards and meeting the requirements of the INSPIRE directive are tending towards data interoperability. In Wallonia, this interoperability of the various geographic databases exists and the availability of data on the Walloon geoportal makes it easy to use. However, an appropriation of these mechanisms by all stakeholders and their evolution, or even a better understanding of what information on soil quality is available in Wallonia, should be pursued. Despite significant recent developments in France, as in Wallonia, the measurement of biological parameters still requires to be more routine along, with improvement of interpretation reference systems for data quality (Blanchart et al., 2019).

8 Decision making tools that can support refunctionalisation of artificialised soils

8.1 Context

Decision support tools (DSTs) have emerged in recent years to help take better account of soil ecological functions (via indicators) for agricultural, forestry and urban ecosystems. These DSTs can support a soil refunctionalisation project targeting specific soil properties and encourage the strengthening, restoration or creation of the general or specific functionality of the soil ecosystem. Some of these DSTs invite users to follow a methodological approach, that is usually described in

[50] Zones de consultation de la DRIGM - Série | Géoportail de la Wallonie

a guidance that also highlights demonstrations with practical cases. Others DSTs also propose a complementary software to the approach to be implemented. Research projects aiming at developing such tools seem to be mainly proposing concepts to be applied at the agricultural plot and/or urban site level. Territorial approaches are less considered. According to (Drobnik et al., 2018), there are less soil quality assessment methods dedicated to urban planning compared to those proposed for agricultural ecosystems.

In an agricultural or forestry context, recent projects or tools tried to integrate soil ecological functions and associated ecosystem services (ES), in some cases proposing soil quality or ES indicators. In France, for example, the INSENSE[51], and PROSOL[52] projects have developed approaches and supporting DSTs to be applied in forest environments. The REVA[53], and AgroEcoSol[54], projects have been implemented in the agricultural sector. The "Soil Navigator DSS"[55] tool developed within the Landmark project makes it possible to evaluate and optimise soil functions in the context of agricultural practices at the plot level. In addition, the SOilSERV approach aims to consolidate soil related ES assessment methods by identifying the most suitable approaches according to the scale in question and the information available.

In Wallonia, there are very few tools specialised in taking into account of the ecological functions of soil as such. However, some web-based tools that allow decisions to be made on the suitability of soil use practices on the basis of its quality may be related to the topic to some extent. For forestry ecosystems, one example is the " le fichier écologique des essences (ecological tree file)"[56], which highlights the different ecological, economic and social functions of forests. In the context of gardening and urban agriculture, the SANISOL[57] web tool is available to all Walloon gardeners to provide them with specific recommendations soil quality depending on cultivation and the user's profile.

A non-exhaustive review of French and Walloon decision support tools for the refunctionalisation of artificial soils applicable at the parcel level was carried out within SOILval (Limasset et al., 2021). This review is common to France and Wallonia. A SOILval Fact sheet has also been produced to help disseminate the knowledge acquired on such DSTs encouraging better consideration of soil multi-functionality (Quadu et al., 2021d).

8.2 Review of Decision Support tools (DSTs) in France and Wallonia

The French and Walloon Decision Support Tools (DSTs) review with SOILval are listed in annex 2.

DSTs developed with supporting software are most often based on multi-criteria approaches, which can propose the cross-referencing of geographical data, monetisation, or even modelling. The raw results obtained can be in cartographic, graphic, digital or textual form. The data outputs

[51] Projet INSENSE : INdicateurs de SENSibilité des Ecosystèmes forestiers soumis à une récolte accrue de biomasse (http://www.ofme.org/documents/FiliereBois/Recolte/2018_Ademe_Insense_livret-indics-sensib-sols-recolteBE.pdf)

[52] Projet PROSOL : Pour une exploitation forestière respectueuse des sols et de la forêt « PROSOL » (https://www.ofme.org/documents/FiliereBois/Guide_FCBA-ONF-PROSOL.pdf)

[53] REVA : Réseau d'expérimentation et de veille à l'innovation agricole (https://www.ofsv.org/le-reva)

[54] AgroEcoSol : Développement d'une filière technique et économique sur le diagnostic et le conseil pour une gestion agroécologique des sols cultivés (https://www.aurea.eu/conseil-2/services-2/)

[55] https://landmark2020.eu/pillars/soil-navigator-pillar1/

[56] https://www.fichierecologique.be/resources/FO143-12-19.pdf

[57] http://sanisol.wallonie.be/

may be in cartographic, graphic, digital or textual form. A distinction can be made between tools that integrate soil quality with a "soil functions" approach combined with related ES assessment and those that focus solely on the ES approach. All the tools reviewed are mainly applicable to artificialised soils, and therefore to urban ecosystems.

The DESTISOL DST (Cherel et al., 2017; Séré et al., 2018[58]) proposes the calculation of soil function indicators that encourage to find land management solutions at site level that maximise the achievement of SE (Blanchart, 2018). The approach proposes a strong integration of soil properties, soil functions and related ES within urban development projects; aiming at the preservation of soils in general and of the soils most suitable for supporting specific activities. The Bio-TUBES approach (Tagourdeau et al., 2020[59]) proposes to evaluate soil functions and related ES in the context of ecological rehabilitations of degraded sites. It proposes indicators for several soil ecological functions that are related to regulatory ES. An economic evaluation method of ES is also proposed, taking into account the ES beneficiaries.

The “MEL fonctions du sol” approach (Monfort et al., 2020; Monfort and Limasset, 2019[60]) was developed to help urban planning officers within Lille metropole to identify, existing soil functions and related ES that or that could be gained in a redevelopment projet following desktop studies and site visits. The RECORD 1 DST (Baptist et al., 2018[61]), also known as "Biodiversity measurement and assessment of ES in restored environments", proposes a selection matrix to choose indicators from, in order to assess and monitor the impact of restoration measures implemented on degraded sites.. The RECORD 2 DST (RECORD, 2021[62]), also known as "Design and monitoring tool for the ecological rehabilitation of degraded sites integrating nature-based solutions", can guide users with a redevelopment project including ecological rehabilitation in implementing nature-based solutions. This tool proposes indicators for monitoring the functions and ES to measure the success of the ecological rehabilitation implemented on the site. The Bénéfriches DST (guidance and Excel file can be downloaded)[63] allows quantifying the net socio-economic and environmental benefits of a development project. This is to help local authorities and land development stakeholders to orientate their choices considering urban renewal and urban extension constraints.

The Walloon “Nature value explorer” tool that is partially transposed to Wallonia (NVE - Wallonia, accessible from a dedicated platform) [64], allows for a rapid assessment of the impact of a change in land use on the provision of SE (Liège Université, 2020). It proposes qualitative, quantitative and monetary evaluation of benefits of several ecological site conversion solutions using a series of cartographic databases of land occupation and use. It also encourages a practical approach for awareness raising. The “GAMMA” DST (Grille d'Analyse Multicritère pour les Méthodes d'Assainissement - Wallonie, methodological report and digital tool accessible from the SPW Soil and Waste Department website) [65] was developed for walloon accredited experts. GAMMA aims to link the notion of Best Available Technique (BAT) to the notion of intrinsically sustainable remediation. It proposes amongst some criteria, a criterion considering "restoration of soil

[58] Consultable sur le site de l’ADEME

[59] Consultable sur le site de l’ADEME

[60] Consultable sur le site du BRGM

[61] Consultable sur le site de l’association RECORD, https://record-net.org/

[62] Consultable sur le site de l’association RECORD, https://record-net.org/

[63] Bénéfriches : un outil pour accompagner l’aménagement - ADEME Infos

[64] https://www.natuurwaardeverkenner.be/

[65] https://sol.environnement.wallonie.be/home/sols/sols-pollues/code-wallon-de-bonnes-pratiques--cwbp-/projet-dassainissement.html

functionality" which is based on four factors (plant production, recycling of organic matter, biodiversity reserve and water storage and purification).

Note: the most advanced work of DSTs considering a territorial application and integrating ecological soil functions is associated with the French R&D projects MUSE and SolUC3ion[66]. They proposes methodology for determining a soil multifunctionality index based on a set of indicators to be integrated into the PLUi. This tool was not the subject of the SOILval review.

8.3 Conclusive remarks from the DSTs review

From the approaches and tools developed to date within various R&D projects, we can see that soil multifunctionality is studied at all territorial scales. Despite a strong similarity between the reviewed DSTs (i.e. philosophy of maximising environmental benefits in general), they have relatively different objectives. We can identify two categories of tools. On the one hand, some tools consider only the t final use envisaged for the site and propose an SE approach without taking direct account of the soil's specificities (Bénéfriches, Nature Value Explorer). These tools estimate the potential benefits in monetary units. The state of the soil and its functions is somehow "hidden" or integrated into the estimated costs of redeveloping sites.

On the other hand, tools such as DESTISOL, RECORD 1, RECORD 2 and “MEL fonctions du sol” and Gamma - Wallonia, although having different purposes and modalities, encourage different stakeholders involved in a project to interact. They also guide them to make choices on land uses and soil management that would be most favourable to soils functions and considering soil physical, chemical and biological characteristics.

However, the reviewed tools still have difficulty in general in making the link between soil functions, that is very much linked to inherent soil processes, and soil related ES (Tagourdeau et al., 2020).The ES are estimated according to the intended use of the site, while the functions are measured on the basis of in situ measurements. Consensus seem to emerged nonetheless on the ecological soil functions to consider most in the various approaches. Among these functions, some seem to be assessed more frequently, regardless of the soil use considered: water retention, circulation and infiltration, nutrient retention and supply, stable physical support for plants (Blanchart et al., 2019).

Given the tools developed to date, there is an obvious need to transfer effectively this knowledge (methods, conceptual approaches, protocols, indicators, etc.) to the relevant stakeholders involved in land management. The consultations carried out under SOILval highlighted that key stakeholders were not necessarily aware of what is already available. In addition, to date there is no feedback in France or Wallonia on the current or anticipated use of these tools. It is necessary to make the evaluation methods proposed by the DSTs known, to communicate better on the advantages to use them and to support end users on which tools or approach to use (e.g. by providing training, creation of a resource centre dedicated to sustainable soil management, etc.).

The question of being able to propose relevant indicators in terms of set objectives, costs and operationality is also raised. The Bio-TUBES and RECORD 1 & 2 projects have recently worked on this. RECORD 2 is the only project identified within the review that would propose a complete list

[66] https://www.cerema.fr/fr/actualites/quelle-prise-compte-sols-documents-urbanisme-premier-rapport

of soil ecological function and related ES indicators that can be used for the assessing and/or monitoring ecological restoration of artificialised degraded soils (RECORD, 2021).

9 Perspectives

One of the objectives of the SOILval project was to identify the R&D needs on the major topics that should be examined in the short, medium and long term to facilitate the consideration of soil quality in land use planning and development. A SOilval R&D note (Quadu et al., 2021e) has been drafted, expressing these needs, based on the work carried out as part of the legal review and state of the art and the consultations with stakeholders.

The R&D needs address four different areas: i) the need to strengthen knowledge on soil quality; ii) the need to encourage ta better operational consideration of soil ecological functions and associated environmental value in land development;iii) the need to develop a solid legisltation to encompass better integration of soil quality and iv) the need to support, train and raise awareness of stakeholders on the concept of soil quality and on existing tools and data. It would be important that the new European Strategy for Healthy Soil published at the end of 2021[67] could encourage effective and thorough research on these topics.

The specific R&D needs are summarised below.

The need to "strengthen knowledge on quality of artificial and natural soils in terms of ecological functions and associated environmental values and make it accessible to planning and development stakeholders" was identified. Four specific areas were identified:

- Defining data to be collected (soil parameters, etc.) that are needed for evaluating soil ecological functions and their associated environmental values,
- collecting soil quality data and access to this data so that they can be used in any land developement project,
- encouraging sharing existing knowledge and improve data interoperability,
- Defining the most suitable cartographic representations for integrating the ecological quality of soils and environmental values.

In parallel, there could be an aim to "strengthen the operationality of tools that support soil refunctionalisation projects in consideration with challenges of a given territory", and more particularly looking into:

- proposing ecological soil function indicators that can optimise the monitoring and evaluation of soil refunctionalisation projects with points of attention regarding the operationality of a parameter: (i) its capacity to represent at least one of the identified functions, (ii) its cost/benefit ratio (information contribution), (iii) the reliability of the method (sampling, measurement and analysis) and of the interpretation reference system, and (iv) its ease of implementation and interpretation;

[67] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12634-Des-sols-sains-nouvelle-strategie-de-l%E2%80%99UE-pour-la-protection-des-sols_fr

- the establishment of more databases and reference systems integrating data related to the characterisation of soil multifunctionality that are more easily usable and transposable in land and urban planning documents as well as in environmental impact studies

The need to "encourage and capitalise on technical, economic and social feedback on the implementation of actions to refunctionalise artificialised soils" was highlighted. Four areas to be strengthened were identified.

- a better knowledge of the costs associated with implementing soil refunctionalisation solutions,
- evaluation of the benefits associated with the ecosystem services provided by soils for a systemic vision of the territory,
- proposing a range of decision support tools to encourage the implementation of soil refunctionalisation projects
- better understanding of the potential of soil renaturation and society's view of these projects.

The need to "improve the dynamics and tools for land use, land use planning and urban planning that are useful for achieving ZAN and integrating soil quality" has been identified. It can be broken down into three areas:

- how an estimation of soil environmental value would affect the decision to develop land or not and how to measure and compare the effects of a future urban planning project on soil quality,
- How and over what period of time can urban land tools be adapted to better integrate soil quality and support models for reducing artificialization?
- How can we optimise the use of data on soil quality when issuing planning permission? Which data are the most relevant for promoting soil functions in an urban planning project?

Also, "How can the notion of "soil quality" be legally defined within the French Urban Planning Code and the Walloon Soil Decree in order to provide a better framework for development projects, and how can land information be improved" was identified as a need. It could be broken down into three areas:

- To what extent can property rights be a barrier to better consideration of soil quality, given that an ecological function must be recognised? What is the role and effect of compensation for loss of land value?
- How can soil knowledge be improved at site level in order to ensure the transfer of knowledge in the event of sale/rental and what role should land registration and cadastral documentation play in this transfer of knowledge and the integration of the notion of soil quality at site level?
- Can an annual evaluation of the regulations be envisaged on the basis of indicators relating to soil quality?

Finally, the need to "transfer acquired knowledge towards relevant stakeholders and support them towards a systemic vision of development integrating the quality and environmental value of soil" was identified. It could be broken down as follows

- identification of the most appropriate forms of awareness-raising and training that can help taking soil quality into account and soil refunctionalisation supporting solutions, tools and databases,
- supporting land development stakeholders towards a more systemic vision of the territory
- identification of needs and evolution of training offers and educational curricula on geosciences and multidisciplinary subjects

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Annex 1 – Summary of programs/ databases or geographi layers integrating soil quality data

Table 1. Programs/ database integrating soil quality concepts in France

		Types of soils being targetted		Initial objectives							
Program/database/project	Geographical cover	Agricultural/ natural soils	Urban soils	Evaluate the quality of artificialised soils	Evaluate the quality of non-artificialised soils	Evaluate fertility (physical and chemical characterisation) for an agricultural use	Evaluate natural impacts on soils	Evaluate anthropic impacts on soils	Reuse of excavated soils	Infiltrtation of rain fall in urban areas	Overall knowledge on soils
IGCS (DoneSol)	national	x			x	X					X
RMQS (DoneSol)	national	x	(x) (a few sitess)	(X)	x	X	x	x			X
BDETM	national	x			x			x			x
BDAT	national	x			x	X					X
BDSolU	national	x	x	x	x			x	x		
ASPITET	national	x			x		x	x			x
Inventaire minier national	national	x			x						
RENECOFOR	national	x			x		x	x			x
ORB	national	x	X		x	x	x	x			
GeoBaPa	territorial	x	x	x	x			x	x		
METOTRASS	Départementale (county)	x			x			x			
RMQS Biodiversité	regional	x			x	x	x	x			x
PHOEBUS (idem Tours, Lyon, Brest)	metropolis	x (within Rennes area)	x	x	x					x	
SUPRA	metropolis		x	x				x			

Tableau 2. Layers of geographical data that integrate soil quality concepts in Wallonia

				Types of soils being targetted							
Layers of data	Program/database/project	Geographical cover	Agricultural/natural soils	Urban soils	Evaluate the quality of artificialised soils	Evaluate the quality of non-artificialised soils	Evaluate fertility (physical and chemical characterisation) for an agricultural use	Evaluate natural impacts on soils	Evaluate anthropic impacts on soils	Reuse of excavated soils	Overall knowledge on soils
Carte numérique des sols de Wallonie (CNSW)	territorial	x	X[1]	x	x	x				x	x
Carte des principaux types de sols de Wallonie	territorial	x	x	x	x					x	x
WALOUS	territorial	x	x				x	x			x
IPRFW	territorial	x			x		x				x
REQUASUD	territorial	x			x	x		x			x
CARBIOSOL	territorial	x			x		x	x			x
ERRUISSOL (érosion et ruissellement)	territorial	x		x	x		x	x		x	
LIDAXES	territorial	x					x	x		x	
BDES	territorial[2]	x	x					x	x		

1 urban soils are not all mapped in Wallonia

2 sdepending on the inventory of contaminated or potentially contaminated sites and analysis opportunities

Annex 2 – Summary of decision making tools that can help consider ecological functions of artificialised soils and related ecostsem services

Tableau 3. Decision Supporting tools (DSTs) that were reviewed under SOilval that can help consider ecological soil functions and/or related ecosystem services (ES) at site level

DSTs	Main objective of the DST	Scale of application	Integration of soil functions	Integration of ES	Acces
DESTISOL (Fr)	To provide recommendations on the uses or destinations to be given to the available urban land (via soil function consideration) those involved in urban planning (developers, public institutions, local authorities, etc.), in the "upstream" design phases of development project	Site	x		Public report, articles
Bio-TUBES (Fr)	Assessing ecological soil functions aand related ES within refunctionalisation of degraded soils (within ecological rehabilitation of brownfields)	Site	x	x	Public report
MEL Fonctions du sol (Fr)	Identification and evaluation of soil functions and related ES - identification check list to support the land strategy department at city level	Site	x	x	Public report, articles
RECORD 1 (Fr)	Biodiversity measurement and ES assessment of restored environments. (provides soil functions, related ES and biodiversity indicators)	Site	x	x	Public report. Software (Excel file) only accessible to RECORD network
RECORD 2 (Fr)	Tool for designing and monitoring ecological rehabilitation of degraded sites integrating nature-based solutions (provides soil functions, related ES indicators)	Site	x	x	Public report. Software (Excel file) only accessible to RECORD network
Nature Value Explorer (NVE) Wallonie (Wal)	Evalution of a project impact on ES and well-being. Possibility to create its own secnrio (SE indicators and integrated database)	Site and territory		x	Software publicaly available on the web (web platform)
Outil GAMMA (Wal)	Multi-criteria analysis grid for sustainable remediation methods to be applied at contaminated sites taking into account concept of soil functions. Tool for soil experts approved under the Soil Decree.	Site	x		Public Report. Software can be downloaded on the internet
Bénéfriches (Fr)	Evaluate the socio-economic benefits of regenerating brownfields in the context of applying ZAN ibjectives (ES indicators)	Site		x	Public Report. Software (Excel file) can be downloaded on the internet

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