Soils and ecosystem services: policy narratives and instruments for soil health in the EU

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Abstract:
European soils and their status is a matter of concern that has entered the policy arena and the objective to restore soil health is part of the Soil strategy to 2030. The aim of this study is to explore the integration of the concept of soil health and the provision of soil ecosystem services by conducting i) a content analysis of EU policies and ii) a scoping review on policy instruments for soil governance. Results show a focus on soil fertility, mainly soil organic matter, while services such as conservation of biodiversity or cultural heritage still appear underrepresented. The findings are reinforced by a gap in literature, which provides little evidence of policy instruments contributing to soil health. A more coordinated effort among policy sectors is required to prioritize soil health in the EU; invesitgating the role of market-based instruments could complement the gaps in public policies.

1. Introduction

Soil is a non-renewable and multi-functional resource which contributes significantly to global food security, hosting one of the greatest concentrations of biodiversity on the planet and providing further Ecosystem Services (ES) that include air and water purification, climate regulation and conservation of cultural heritage (FAO and ITPS, 2015). However, soils are under great pressure derived from both bio-physical processes and human-driven processes, such as erosion, floods and landslides, loss of soil organic matter, salinisation, contamination, compaction, sealing, and loss of soil biodiversity (Turpin et al., 2017; IPBES, 2018). When those processes impact soils' status, their ability to provide ES is reduced or lost, with an estimated cost of around 50 billion euros yearly in the EU (COM 2021/699). Therefore, maintaining and enhancing the capacity of soils to provide ES can bring economic benefits and is critical to sustain ES and ensure human well-being (MEA, 2005).
Acknowledging the interconnectedness between soil, plant, animal (humans included) and ecosystem health as framed by the "One Health" concept (van Bruggen et al., 2019), soil health can be understood as "the ability of the soil to sustain the productivity, diversity, and environmental services of terrestrial ecosystems"[1]. Primarily drawing from soil quality, the adoption of soil health in scientific literature started in the 1990s and developed by recognizing the role of biological processes in soil formation and functioning, identifying soils as ecosystems, mapping soils' biodiversity and assigning to it an

[1] As defined by the Intergovernmental technical panel on soils, available at: Towards a definition of soil health (fao.org), accessed July 3rd 2024

international scale (Lehmann et al., 2020). Soil health can be a useful metaphor that relates ecosystem functioning to human well-being, but its understanding and interpretation highly depends on the actors, issues, and values at stake in a given context (Janzen et al., 2021).

Recently, the soil health concept has entered the EU policy arena (Panagos et al., 2022) as testified by the Soil Strategy for 2030, included in the European Green Deal proposal to reach carbon neutrality by 2050. The strategy defines healthy soils as in good chemical, biological and physical condition, and thus able to continuously provide as much ES as possible; it also aims at restoring 60 to 70% of European soils, currently considered unhealthy (COM 2021/699). There is increasing evidence of the connection between decreasing soil health and loss of ES (Lehmann et al., 2020; IPBES, 2018); for instance, freshwater availability is affected by a reduction of soil organic matter in agricultural and forest soils (Keesstra et al., 2021); soil sealing in urban areas impacts human physical and mental well-being by hindering access to green areas (McElwee, 2021). However, investigating ES when applied to soil requires a deep understanding of chemical, physical and biological soil properties, additionally recognising benefits derived from soil components at different spatial scales (i.e., plot, field, landscape, regional area, countries, global). Comprehensive studies on valuation of soil ES are rare to be found often addressing methodological limitations derived from need of suitable and comparable indicators (Vysna et al., 2022; Baveye et al., 2016; Dominati et al., 2014).

If the current EU Soil Strategy (COM 2021/699) adopts a definition of soil health that is closely related to ES, it could be useful to understand the extent to which this definition is integrated into actual soil governance. By soil governance we mean the mix of different policies and set of instruments available for regulating, incentivizing, and informing about the management of soils (Heuser, 2022; Rogge and Reichardt, 2016; Juerges and Hansjürgens, 2018). Recent reviews have investigated available policy instruments to soil governance worldwide (Juerges and Hansjürgens, 2018) and within EU Member States (Ronchi et al., 2019); however, they have not addressed the connection to soil ES.

This study aims to explore the extent to which the concepts of soil health and the provision of soil ecosystem services (ES) are integrated into current EU policy instruments by conducting a content analysis of relevant policy documents. To the best of our knowledge, limited research has been conducted at the EU level on this topic. Additionally, we seek to identify evidence of the effective implementation of policy instruments that promote soil health and contribute to the delivery of ecosystem services.

The topic of soil health is gaining increasing interest in both the scientific and policy communities, particularly in light of the upcoming EU Soil Monitoring Law. If implemented, the law will constitute the first binding instrument for soil regulation at the EU level. It will require Member States to achieve responsive agri-environmental interventions within their national public policies. Addressing governance gaps and policy needs could contribute in ensuring purposeful action towards soil health. In the next section, the policy narrative of soil health is framed in order to gain an overview of definitions that characterize soil health as well as policy instruments referring to sustainability transition. Following the methodology will be presented. Results and discussions are structured in two sections, to address both research aims.

2. Framing the soil health narrative

Understanding the concept of soil health requires some clarification: while the previously used attributes of soil fertility and soil quality refer to the local/regional level and focus on productivity, nutrients, and water cycles (Bünemann et al., 2018), soil health is told to encompass a larger range of ES. Lehman et al. (2022) include in the description of soil health “public” ES such as climate mitigation and control, access to recreational and spiritual places to improve human wellbeing and provision of habitat for above and below ground biodiversity. Janzen et al. (2021) refer to soil health as a metaphor for an organism in good conditions and suggest considering soil as a (complex) organism, defining its

healthy conditions as "[…] the vitality of a soil in sustaining the socio-ecological functions of its enfolding land" (Janzen et al., 2021, p.2).
According to the authors, the concept of soil health helps to engage a broader range of stakeholders—not just farmers and landowners, but also local and national authorities. It underscores the fact that sustainable soil governance extends beyond the field level, making it a significant policy concern (Juerges and Hansjürgens, 2018).
The body of literature describes how emerging concepts and needs enter the policy agenda and subsequently progress through the policy cycle. Shanahan et al. (2011) claim that policy narratives are central to the policy cycle: being created by a broad set of actors, narratives are the device through which policy programs and the connected values and beliefs are communicated. The process of creating narratives is closely linked to agenda setting, which involves operationalizing certain issues at a decision-making level. These two phases occur continuously and alternately (Gonzalez Lago et al., 2019).
From a political point of view, as described by Montanarella and Alva (2015), even though soils are essential to sustainable development, they have never been the specific focus of a multilateral environmental agreement. Given the diversity of services that soils can provide, it is no surprise to find a set of policy domains competing for land use, including agriculture, forestry, protected areas, urbanization, and energy production (Löbmann et al., 2022).
Focusing on the EU, after the proposal, discussion, and withdrawal of a Thematic strategy for soil protection in 2014, Member States have found themselves lacking a comprehensive framework and have been relying on national regulations (Heuser, 2022).
Authors define policy instruments for environmental governance in various ways, with these instruments being tools or mechanisms used to achieve environmental objectives. They range from public to market-driven approaches and from voluntary to binding measures, resulting in a broad spectrum of options (Vatn, 2018). For instance, Piñeiro et al. (2020) categorize incentives for sustainable agricultural practices into regulatory measures, market-based and non-market-based incentives, and cross-compliance between payments and standards. The FAO provides a framework to display the numerous instruments available for environmental protection and compensation, involving individuals, private and public sector, and considering their level of compulsoriness (Garrett and Neves, 2016). Ronchi et al. (2019) refer to *measures* for soil protection and identify: regulatory, economic, information, monitoring, and research and innovation. Juerges and Hansjürgens (2018) outline instruments for soil governance as: regulatory, planning, economic, informational, co-operative. For the purposes of this study, we adopt the approach of Rogge and Reichardt (2016), who analyzed sustainability transitions and defined policy instruments as tools used to achieve specific goals, categorizing them into three groups*:* regulations, incentives, and information. Given that the pursuit of soil health is currently high on the EU political agenda, we found the approach of linking policy instruments to wider objectives, as outlined in policy strategies by Rogge and Reichardt (2016), to be well-suited to the purpose of this study. Hence, we define regulatory instruments as those applying restrictions, economic as those providing monetary resources and information as those producing and delivering knowledge. Table 1 provides an overview of the adopted definitions of policy instruments for soil governance.

Table 1 Definition of policy instruments for soil governance and related keywork search, adapted by the authors from Rogge and Reichardt (2016) and Garrett and Neves (2016)

Category	Typology	Defintion	Source	Keyword search
Regulation	Property/use rights	Privatization of natural resources. Owners can be individuals, private entities, communities, large entities e.g. the state	Bartkowkski et al., 2018	soil-health AND ecosystem-service* AND property OR property-use OR property-use-right

	Prohibition of use and mandatory farm set aside	Access to land is limited to certain land uses or partly given up for restoration and conservation	Bartkowkski et al., 2018	soil-health AND ecosystem-service* AND prohibition-of-use OR prohibition
	Taxes / charges	Applied to land use or management practices that are not compatible with agro-environmental principles, e.g. taxation on pesticides	Ronchi et al., 2019	soil-health AND ecosystem-service* AND tax OR taxe* OR charge*
	Conservation	Used to reduce or compensate the costs of conservation of portions of land, e.g. by nonprofit organizations like land trust	Vatn, 2018	soil-health AND ecosystem-service* AND conservation
	Permits and quotas	Quantified rights to use a natural resource and eventually trade the quotas, e.g. fishing quotas	Vatn, 2018	soil-health AND ecosystem-service* AND permit* OR quota* OR cap OR carbon-market
	Subsidies	Governments link compliance to agro-environmental standards with direct payments, e.g. GAEC	Runge et al., 2022	soil-health AND ecosystem-service* AND subsid*
	Offsets	Compensation for land development into (on/off)site environmental projects, e.g. planting forests	Vatn, 2018	soil-health AND ecosystem-service* AND offset* OR offset-program OR emission-offset*
Information		Raising awareness and delivering knowledge by means of research, extension services or certification schemes to farmers, advisers, consumers	Juerges and Hansjürgens, 2018; Bampa et al., 2019	soil-health AND ecosystem-service* AND research OR research-program* OR advisory OR advisory-service* OR extension-service* IR label* OR certific* OR standard*
Incentive	Payments for ES	Providers of specific ES are compensated for positive outcomes, e.g. farming practices respectful of water bodies	Vatn, 2018	soil-health AND ecosystem-service AND payment* OR pes
	Voluntary farm set aside	Landowners give up part of land for restoration and conservation purposes in exchange of payments, e.g. 4% of non-productive arable land	Runge et al., 2022	soil-health AND ecosystem-service* AND farm-set-aside OR set-aside
	Green Public procurement	Public authorities procure goods and services based on environmental requirements, e.g. ecolabel for school canteens	Neto et al., 2018	soil-health AND ecosystem-service* AND green-public-procurement OR public-procurement
	Corporate social responsibility	Declaration of business strategies to contribute in benefitting the environment, e.g. NGO assessing corporations' activities	Vatn, 2018	soil-health AND ecosystem-service AND corporate-social-responsibility OR CRS

3. Materials and Methods

The aim of this study is to analyze the integration of the soil health narrative into EU soil governance. To achieve this, a twofold approach was adopted. First, a content analysis was conducted to explore the conceptual integration of soil health-related keywords within various EU policies, assessing the explicit use of relevant terminology (Neill et al., 2022). Second, a narrative review of the literature was carried out to examine the available policy instruments that incentivize soil health and the provision of related ecosystem services, focusing on the existing evidence linking these instruments to ecosystem services (Grant et al., 2009). This methodology, which combines content analysis and a review of existing evidence, facilitated a comprehensive understanding of the topic of soil health and its framing within the current policy narrative (Gonzalez Lago et al., 2019).

3.1. Content analysis of EU instruments

In the first phase, grey literature on EU regulatory instruments that tackle soil and land related issues was collected to compile a policy inventory. To do so we used as a reference the recent review by

Heuser (2022), double checking with laws and strategies related to soil and land as indicated on the EU website (https://environment.ec.europa.eu/topics/soil-and-land_en), and finally integrating further regulations with citation chaining. Three main typologies of regulatory instruments were found: i) laws, directives and regulations, ii) Environment Action Plans (EAP), that set out goals and legislative proposals for EU environment policy, and iii) horizontal strategies, that outline how to integrate SDG into EU policy priorities. A total of 28 regulatory instruments was finally included in the inventory.
Content analysis of the policy inventory was conducted using deductive coding (Saldaña, 2013) with the help of SketchEngine (Lexical Computing, 2003), a free software for text analysis that enables the analysis of keywords frequency across large text bodies. Adhering to the EU definition of soil health as the capacity to deliver as many ES as possible, we included three main keywords in the coding, namely 'soil', 'soil health' and 'ecosystem services'.Additionally, one more keyword, 'carbon', frequently appeared in association with soil (e.g. soil organic carbon) during the analysis, so it was finally added (a complete overview is provided in Appendix I, figure 2).

3.2. Review of policy instruments

In the second phase, a narrative review of the literature was conducted to explore the connection between the delivery of ES from healthy soils and the policy instruments designed to promote these practices. While systematic literature reviews hold a narraw scope and are used for investigating problems that have already been explored in the literature, narrative reviews are most frequently applied to explore a topic that has a rather broad coverage and that is evolving over time (Byrne, 2016). Even if systematic review apply a more rigorous methodology, the flexibility of narrative reviews was beetter suitable for addressing the large range of keywords of incentives to be linked to soil ES as well as the everchanging understanding of soil health. Peer reviewed papers were searched on the Scopus database, combining the keywords "soil-health" AND "ecosystem-services" AND policy instruments basing on the FAO indications over incentives for ES (Garrett and Neves, 2016); the complete overview of keywords' search is to be found earlier in Table 1. Searching criteria included search words in title, abstract and keywords, filtering was limited to papers and reviews published until 2023, accessibility and language were first criteria for exclusion . Secondly, relevance of the content was based on a first reading of methodologies and results, assessing whether ES had only been used as keyword in the abstract or also further addressed. Consequently, each type of soil ES was counted the first time it was mentioned in the texts, and examples of these services were identified and categorized. These examples were then divided into four categories—provisioning, regulating, cultural, and supporting ecosystem services—based on the classification provided by the Millennium Ecosystem Assessment (MEA, 2005).

4. Results

4.1. Content analysis: Integration of the soil health concept from a normative and narrative perspective

Soil in the EU began to be the subject of policy nearly 40 years ago, often implicitly integrated into various policy instruments over the past decades (Heuser et al., 2022; Ronchi et al., 2019). The timeline below (figure 1) shows the different type of policy instruments that concern soil governance at EU level. Soils are not mentioned in the timespan between 1992 and 2002. Therefore, for graphical purposes, this decade was represented as a striped rectangle. As can be observed, the integration of soils into various policy instruments increases in the latter part of the timeline, particularly with the introduction of the Green Deal. During 2021 and 2022, these policies delivered several strategies aimed at protecting, conserving, and enhancing the EU's natural capital, as well as safeguarding the health and well-being of citizens from environment-related risks and impacts. The Soil Health Strategy to 2030 (COM 2021/699) outlines objectives that address various policy sectors, including agriculture, forestry, and urbanization. These objectives include reducing nutrient losses and pesticide use, as well as lowering emissions from land use, land use change, and the forestry sector (LULUCF). Additionally, the strategy covers broader aspects of natural and environmental management, such as combating

desertification, restoring degraded carbon-rich ecosystems, improving water quality, and remediating contaminated sites.

In the upcoming paragraph some key findings on the conceptual integration of soil health across different policy sectors will be presented (for a complete graphical overview please see Appendix I).

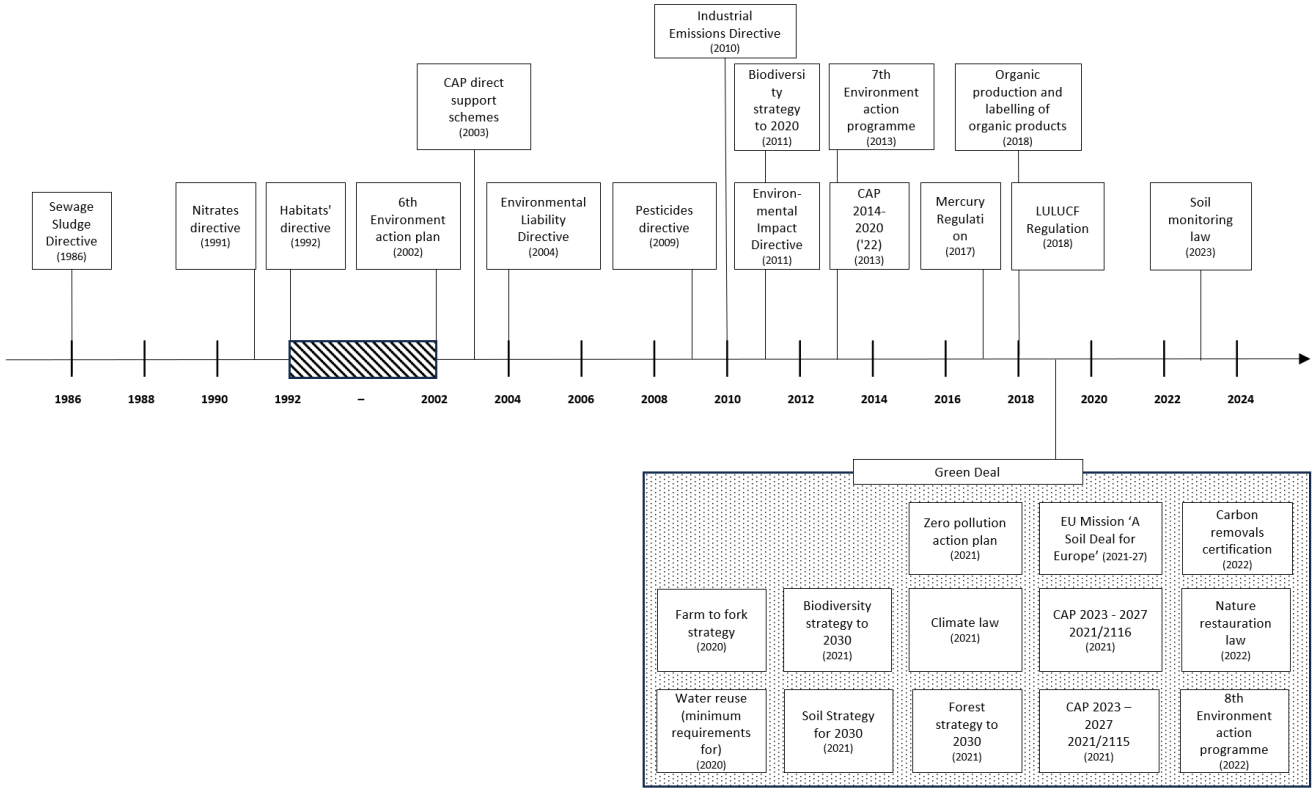

Figure 1 Overview of EU policy instruments relating to soils, source: authors' elaboration

a. Agricultural sector

Policy instruments have been historically focusing on agricultural soils with two specific objectives: i) to decrease pollution and ii) to protect from erosion and loss of organic matter by enhancing soil fertility. The first directives aimed at protecting human health by *preventing* and *controlling* soil pollution from sewage sludge (86/278), nitrates (91/676), pesticides (2009/128) and industrial waste (2010/75). The Common Agricultural Policy (CAP), the main instrument to support farmers, has primarily focused on soil fertility. The previous CAP (Regulation 2013/1306) outlined farming techniques aimed at enhancing good agricultural and environmental conditions (GAEC) for soils, such as reducing tillage, avoiding burning, and ensuring minimum soil cover. The current CAP (2021/2115) further included crop rotation among the GAEC to guarantee soil protection and quality, and protection of wetland and peatlands to ensure organic C storage. In the CAP, soils are never explicitly linked to ecosystem services (ES), with the exception of one specific objective aimed at enhancing ES. This objective identifies an increased share of agricultural land covered by landscape features as an impact indicator (Regulation 2021/2116). Additionally, the monitoring of soil conditions is required under the current CAP (Regulation 2021/2116).

The organic farming law (EU Reg. 848/2018) refers to enhancing soils' long-term fertility, stability, and biodiversity by reducing tillage and using only allowed fertilizers and conditioners, therefore improving soil ES. The Farm to Fork strategy (COM 2020/381) outlines reduction in use of pesticides and fertilizers and increase of organically farmed land but without listing any specific action connected to soil.

b. Forestry sector

The Forest strategy (COM 2021/572) refers to the contribution of forests to soil stabilization and explicitly relates healthy forest soils to the provision of ES, in particular to carbon sequestration, suggesting to-set up an ecosystem-based management approach and related payment schemes. Specific target to forests soils is also found in the LULUCF regulation (2018/841), addressing soil organic carbon as *sink* to mitigate GHG emissions, and in the current CAP (2021/2115) aiming to support forest protection and management of ES. The earlier Biodiversity Strategy (COM 2011/244) linked multifunctional forest management to payments for ES, although it did not specifically attribute the provision of these services to soils.

c. *Energy sector*

The revised version of the renewable energy directive (EU 2023/2413) contains reference to soils when it comes i) to harvesting forest products by maintaining soil quality (i.e. avoiding compaction) and biodiversity; and ii) to consider improvement of soil carbon and reduced green house gas emission (aka climate mitigation) by measuring or modeling changes in soil carbon amount.

d. Environmental regulations

The Habitat Directive (91/676/EEC) and the Environmental Liability Directive (2004/35/CE) marked the initial steps toward European natural environmental protection. However, soils are almost entirely absent from the text of these directives. Later on, the Environmental Action Plan (EAP), less binding instruments setting the ground for upcoming environmental policies, did target soils. The 6thEAP (Decision No 1600/2002/EC) aims at protecting soil from erosion and pollution and calls for a soil strategy, by also mentioning their role as carbon sinks. 7thEAP (Decision No 1396/2013/EC) lists water erosion, sealing and contamination to compromise soil ES, in particular biodiversity and water cycles, and addresses the need to increase knowledge and data collection on biodiversity to better value ES. The 8th Environmental Action Programme (Decision No 591/2022/EC) links the loss of unspecified ES to unsustainable land use management, soil sealing, pollution, and climate change. It also calls for the establishment of a soil health law by 2023.; it advocates for the full integration of the One Health approach across all policy levels. Both of these initiatives call for improved natural capital accounting tools and market-based instruments, such as payments for ecosystem services (ES).

The Zero Pollution action plan (cepPolicyBrief COM2021_400) aims at *reducing* soil pollution to levels that are no longer harmful to human health and natural ecosystems, underlining the need to prevent and restore from contamination and regularly assess for their status, specifically agricultural soils for pesticide and nutrient reduction. Yet in the same year, the Climate Law (Reg. EU 2021/1119), a more legally binding instrument, does not explicitly target soils. However, it extensively refers to the enhancement of carbon sinks by 2030. The recently approved Nature Restoration Law (Reg. EU 2022/195) introduces a time dimension that is particularly relevant to soil, requiring a long-term commitment to addressing soil degradation. Specific actions outlined in the law include increasing organic carbon stocks in cropland mineral soils and restoring and rewetting organic carbon in peatlands. Similarly, the Biodiversity Strategy to 2030 (COM 2020/380) highlights the need to restore soils and terrestrial ecosystems, linking human well-being to the provision of specific soil ecosystem services such as fertility, nutrient cycling, and climate regulation.

Finally, two further regulations very relevant for soils are currently under discussion at EU level. On the one hand the Certification for Carbon Removals (2022) aims at improving soils' ES by increasing the stock of organic C in forest ecosystems and in cropland mineral soils in farming ecosystems. On the other hand, the Soil Monitoring Law (2023) defines soil as a vital, limited, non-renewable, and irreplaceable resource. It emphasizes the need for monitoring, sustainable management, restoration of soil health, and remediation of contaminated sites. However, it does not provide a definition or make any reference to connected ES.

e. *Urbanization*

No legally binding regulations exist at the EU level specifically addressing soil sealing, despite being recognized as one of the primary causes of soil degradation in past and current Environmental Action Programmes (EAPs). Minimizing soil sealing is also among the objectives outlined in both the Biodiversity Strategy (COM 2020/380) and the Soil Strategy (COM 2021/699) to 2030.

4.2 Availability of policy instruments' relating soil health to ES

The main findings are summarized below (Table 2). Keywords that yielded no results were not included in the table. These excluded keywords are: prohibition of use, farm set-asides (both compulsory and voluntary), any information instrument, green public procurement, and corporate social responsibility. The cells' color indicate a different amount of reference for each pair of ecosystem services and instrument typology. Overall, papers explicitly bridging soil ES to policy instruments for soil health were rather scarce, 23 articles were selected and can be found for a complete overview in Appendix II (since some of theme referered to more than one policy instrument the list comprises a total of 29 references with repetions marked). Most literature was published in the last five years, showing an increasing interest in the topic.

Table 2 Literature findings relating ES and soil health (number of counted ES in brackets, colours refer to: red lower than 1; orange between 2 and 6; yellow between 7 and 16; green higher than 15)

Instrument typology	Sub-typology	Examples and count of ES, divided according to MEA (2005)				
		Provisioning	**Regulatory**	**Cultural**	**Supporting**	**Total (# of ES) in instrument**
Regulation	Property rights and use rights	Food Fodder (mixed-grazing, rotational grazing and reforestation; grassland) Biofuel (3)	Water retention Erosion Carbon storage (7)	-	Microbial biodiversity Nutrients' cycles (6)	16
	Conservation (easements and concessions)	Crop-livestock systems Forest plantation Biofuel from pastures and cropland (9)	Flood protection Carbon sequestration Protection of peri-urban green areas (10)	Land stewardship for socio-cultural wellbeing Educational and recreational purposes Indigenous knowledge (5)	Nutrients' cycles Water filtration Biodiversity Wildlife (11)	35
	Permits and quotas	Carbon farming Pastures (2)	Carbon sequestration Erosion protection (2)	Rural livelihood (1)	Soil organic carbon Soil biodiversity (2)	7
	Subsidies	Crops Cover crops Biofuel (2)	Water retention Carbon sequestration (2)	Adaptive farmers and citizen support (1)	Native biodiversity Soil organic carbon (3)	8
	Offsets	Carbon farming (1)	Carbon sequestration Erosion protection Water retention (3)	-	Soil organic carbon Biodiversity quality (2)	6
Incentive	Payments for ES	Cover crops Pastures Biofuel (3)	Carbon sequestration Reduced emissions Water retention Erosion protection Flood protection (8)	Landscape heritage conservation (1)	Biodiversity Water filtration Phosphorous recycling Soil organic carbon (7)	19
Total (# of ES) per typology		**20**	**32**	**8**	**31**	**91**

Literature on property rights and land use rights primarily refers to ES provided by healthy soils (16) under various land use types, such as grassland, forest, and crops for food or fuel. It also explores differences in agricultural practices, such as conventional versus conservation approaches, and pasture management strategies, including mixed or rotational grazing. Additionally, there are instruments that highlight the role of regulating (7) and supporting (6) ecosystem services (ES), while also addressing the trade-offs associated with different land use types. Conservation instruments show the greatest contribution to all ES (35), examples include governmental programs, at regional or local scale, and often refer to landscape level, i.e. forest, grassland. The regulatory and often compulsory nature of conservation programs is rarely supported by incentive instruments that could complement these actions. Such incentives, whether provided by the government or private buyers of ES, could help compensate for the associated costs. Improvement in market for ES was mentioned as key outlook for conservation easements (Eastburn et al, 2017).

Both the literature on property rights and conservation instruments agree that weak definitions or poor enforcement of property rights in certain regions, such as South America or Africa, can lead to the overconsumption of common-pool resources. This issue is exacerbated by inequalities in the willingness to appropriate resources when new business opportunities, such as biofuels or carbon sequestration, arise, or among different types of farms, such as smallholders versus large properties. Thus, this literature emphasises the importance of improving social capital for enhancing cooperation and common actions (Targetti et al., in press), both horizontally among farmers and vertically among supply chain actors (D'alberto, in press) as well as call for new institutions or enhance the capacity of existing institutions to design rules, and conservation strategies for common-pool resources (Lant et al., 2008).

Other categories of regulation show a lower volume of literature exploring the interplay between these instruments and the provision of ecosystem services (ES). Examples of subsidies for soil health address regulating ES (2) and supporting ES (3) with the purpose of reducing erosion and increasing soil organic carbon. Tradeoffs emerged from provision of fuel instead of food (Gomiero, 2018) and from cover crops causing decreased production, having subsidies related to yield losses rather than to improved soil conditions (Deines et al, 2022). Offsets (6) and quotas (7) don't relate much to soil health but mostly to carbon farming, understood as a set of practices that increase soil organic carbon stored in farmland and should offset agricultural GHG emissions (Keenor et al, 2021).

Payments for ES reward farmers and landowners for improved regulating (8) and supporting (7) services, serving as compensatory mechanisms for investments, management practices and/or yield reduction. As for sources of financing, public sector is indicated as key funder, i.e., trough the form of direct payments but also private sector - e.g. ,industry was mentioned as source of finance, through compensation mechanisms (see for instance Lal et al, 2020).

Cultural ES are the most neglected from research (8), with the exception of conservation programs that provided some valuable insights (5). A recent study highlights the contribution of relating result-based payments also to cultural ES, such as preserving socio-cultural heritage at landscape level (Helena Guimarães et al., 2023). Among supporting services (31), biodiversity is frequently mentioned, although authors often fail to specify whether it pertains to above-ground or below-ground biodiversity, with the latter being more relevant to soil health. Instruments related to information made no explicit reference to soil health as contributing to ES. Nevertheless, regarding certification schemes and marketing labels, while no literature was found explicitly linking certification to soil health, this may only be a matter of time. Interest in carbon certification schemes is growing (Keenor et al., 2021), and soil certification is anticipated under the Soil Monitoring Law.

5. **Discussion of results**

5.1. Defining the narrative

Looking at the current policy setting available for soils in the EU, the agricultural sector has paid much attention to preserve soil fertility, showing a shift in narrative from protection against desertification and erosion towards an increase of soil organic matter in the form of organic carbon. Policy interventions remain largely focused at the farm level, as evidenced by by the GAEC outlined in the CAP and in the individual labeling of organic farmers. These approaches lack the integration of coordinated efforts at the territorial level, which would be more consistent with the scale needed to effectively address soil health (Janzen et al, 2021, Lehmann et al, 2020). Considering the definition of soil health as encompassing a wide range of ES, few instruments integrate this concept with the related loss of ES in agriculture. For instance, the impact of practices such as ploughing or the excessive use of synthetic fertilizers on soil biodiversity is often overlooked (van Bruggen et al., 2019; Ingram et al., 2022). Moreover, the Farm to Fork strategy's attempt to strengthen linkages between food security and environmental sustainability—including soil health—at the food system level, by reducing nutrient losses and pesticide use, is facing significant resistance in its enforcement (Coderoni, 2023).

The forestry sector has shown greater linkages between sustainable forest management, increased soil ES – in the form of water retention, climate regulation and, most of all, carbon sequestration – and related incentives. Yet concentrating only on few ES, in particular provision of food and fibres or carbon sequestration, might result in insufficient targeting of other ES (Baveye et al., 2016) thus stepping out of the scale of action and scope of the soil health narrative (Lehmann et al., 2020). Improved forest management together with peatlands' maintenance and rewetting are depicted as carbon sinks in Forestry Strategy, Biodiversity Strategy, Climate Law, Nature Restauration Law. Those actions all focus prominently on carbon storage, but rarely further provide evidences to improvement of soil health to overall ecosystem health. While acknowledging the important role that carbon plays in key soils' functions, the risk of this narrow-scoped narrative is to only highlight the marketable and exchangeable value of carbon sequestration, while undermining the wider scope of the economic model for environmental preservation envisioned by ES, that greatly focused on biodiversity and habitat preservation in the beginning (Gómez-Baggethun et al, 2010). Instead of focusing on individual ecosystem services (ES), approaches that consider bundles of ES (Bartkowski et al., 2018; Piñeiro et al., 2020) or aim to maintain a minimum level of all ES (Bouma et al., 2022) could be more relevant from a soil health perspective. These comprehensive approaches better reflect the interconnected nature of soil health and its role in supporting multiple ecosystem functions simultaneously.

Our results confirm previous findings claiming that EU policies have kept a rather sectoral approach to soil, mainly focusing on productive sectors and rather neglecting instruments related to natural areas (Löbmann et al*.,* 2022; Ronchi et al, 2019). Moreover, a key finding is that while soil sealing is recognized as a significant cause of the loss of soil ecosystem services (ES) (Panagos et al., 2021) and its reduction is identified as a key objective in recent strategies (e.g., COM 2021/699), no binding instruments to directly address this issue are currently available. However, the Strategy for a Sustainable Built Environment is currently under discussion, which may potentially address this gap. A more coordinated approach along policy sectors could play a role in ensuring that soil health is pursued. Authors recently delving in the topic suggested that policy should focus on preserving and restoring actions, paying higher attention to soil *protection* in both regulatory (Heuser, 2022) and incentive instruments (Vysna et al*.*, 2021). This implies also a greater understanding of EU soils' status and improvement, as aimed by the Soil monitoring law proposed in 2023. Yet, establishing reasonable and flexible indicators for highly diverse soils remains challenging, for instance when it comes to soil biodiversity (Lehmann et al., 2020) or to soil temporal dynamics that can only be over long-time spans (Baveye et al, 2016), including effects of degradation and conservation.

Last but not least, references to cultural ES, were almost absent from the current policy instruments, showing that much needs to be done to integrate in the soil health narrative a social dimension that attaches societal valuations and preferences over mere land use and functions (Janzen et al., 2021). Authors from various subject fields have suggested that a new understanding of the relationship (and

reciprocity) between humans and soils could help tackle this issue. For instance, considering soils as natural cultural systems could help better recognize and value the cultural ecosystem services (ES) they provide (Costantini, 2023; Guimarães et al., 2023). Additionally, focusing on soil stewardship (Keith et al., 2016) and emphasizing the relational values held by farmers and land users (Friedrichsen et al., 2021) can further strengthen the connection between environmental and social well-being and the management of healthy soils.

5.2 Orienting the instruments

Given the limited results of this narrative review, we would first like to acknowledge the methodological limitations related to keyword selection and the choice of search databases. However, despite these constraints, the exploratory nature of this study contributes to expanding the body of knowledge on soil policy and offers key reflections that may be valuable from an EU perspective. Few findings also highlight the little evidence to be found in scientific literature between soil health and related ES. This reinforces our earlier finding that, although soil health has been part of the scientific discourse for some time (Lehmann et al., 2020), a significant gap exists when it comes to the development and implementation of policy instruments addressing this issue.

Soil health is not effectively addressed by most of the identified instruments. Instead, the literature search reveals a stronger emphasis on soil fertility, as evidenced by the frequent mention of carbon sequestration and soil organic carbon among the regulating and supporting ES. This focus is apparent in both public and market-driven instruments. In the EU subsidies accessible through the CAP are currently the main instrument to incentivize farmers to fulfil environmental requirements, resulting in a hybrid form between regulation and incentive. As for soil they currently include i) direct payments for cross-compliance with GAEC concerning soil cover and organic matter, and ii) voluntary eco-schemes that include among areas of action additional "prevention of soil degradation, soil restoration, improvement of soil fertility and of nutrient management and soil biota" (2021/1115 p. 41). In addition, the second pillar, mainly through Agri-Environmental-Climate Schemes (AECS), addresses soil health either directly or indirectly (Mantino 2022; Eichhorn et al., 2024a). For example, several Rural Development Programmes (RDPs) include measures to increase organic matter in the soil, promote cover crops and conservative agriculture, or invest in reducing soil erosion through repairing or rebuild dry stone walls or other landscape elements. Conversely, AECS incentivize measures that indirectly affect soil health, such as organic production or the maintenance and reintroduction of grasslands in mountain areas (Vergamini et al., 2024).

The current EU Common Agricultural Policy (CAP) could serve to test some initial result-based payments in AECS (Eichhorn et al., 2024b) and contribute to developing indicators to target ecosystem services (Bartkowski, 2018). The combination of command-and-control instruments and market-based instruments in the CAP could significantly affect soil health and the delivery of ES by farmers.

Conservation instruments appear to be more aligned with the soil health narrative compared to the field-level approaches commonly associated with agricultural subsidies and regulations. For example, ecosystem services provided by forest soils, permanent grasslands, and rewetted peatlands could significantly contribute to promoting soil health.

Regarding payments for ES, landowners – most typically farmers – could bekeen on generating ES that are marketable, as the case for carbon credits, yet a recent review shows that hybrid incentive mechanisms combining result and action based payments are more likely to be interesting to farmers (Raina et al., 2024). Payments for ES then will need to consider also mechanisms for distribution of benefits and incentives, to reduce the risk of having large landowners as main beneficiaries, attracting land accumulation and lobbing in areas where the land prices are low, thereby excluding small holders (Baveye et al., 2016). This is also tightly connected to length and typology of different land tenure arrangements, that might distort the trade-off between profitability and ES, given that long-term land

tenure contract might also have the positive side effect of increasing commitment towards soil health and thus provisioning ES (Stevens, 2022).

Market regulation (i.e. carbon markets) are becoming the main solutions rather than compensation mechanisms parallel to emission reduction actions. Private financial institutions appear increasingly interested in mechanisms such as payments for ES or offsetting (Simspon et al., 2021), this on one hand can provide new source of income for supporting those ES that are currently neglected. On the other hand, the role of the public sector is crucial in ensuring that market-based solutions continue to address key objectives, such as the restoration of healthy soils in the EU by 2050 (Vatn, 2018). To address this issue, key scholars in soil science have suggested the option of subsidizing farmers based on maintaining a minimum level of all ecosystem services associated with soil health (Bouma et al., 2022). While the current level of detail on soil practices that contribute to soil health seems limited, the concept of bundles of ecosystem services could further enrich the discourse (Bartkowski et al., 2018). In addition, our results highlight the need for improvements in developing new empirical and theoretical models that enable understanding causal effects between decision-makers' actions and their impact on multiple dimensions aimed at targeting various ES. This would call the development of bioeconomic models to address both ex-ante and ex-post the complexity of interactions between economic behaviour and soil dynamics at different scales and spatial resolutions.

Finally, given the scarce results concerning information as a policy instruments, we would like to highlight the important role that this could play in the form of research and dissemination as well as extension services. A recent review by Arias-Navarro et al. (2023) has summarized key themes of past EU research over soils, primarily on regulating ES (erosion protection, soil contamination, soil and water, climate mitigation, carbon storage). Moreover soils are one of the five topics included in the EU *missions*, new instrument to support research and innovation in the period 2021 – 2027. "A soil deal for Europe" aims to reduce several soil degradation processes by addressing four operational objectives including: funding research and innovation; establishing living labs and lighthouses; develop a soil monitoring framework and raising people awareness[2]. This mission has allowed to finance a wide number on soil-related projects that are now running all over Europe, assessing their outcomes and contribuitions towards soil health might constitute a topic for future research. On the other hand, extension services mainly focus on soil fertility and show quite heterogenous approaches to advice, mostly lacking the holistic understanding of soil microbiology and chemistry embedded in the understanding of soil health (Ingram et al., 2022). Lack of information and evidence on which further ES might benefit from improved multi-functional soil management might prevent farmers from adopting practices that could benefit soil health, including accessing incentives and markets (Schröder et al., 2020).

There is a need to move the focus from a soil fertility and carbon-centered discourse to a landscape level understanding of soil uses, that embeds socio-cultural services provided to land users as well as the wider public (Guimarães et al., 2023; Friedrichsen et al., 2021).

6. **Conclusions**

This study contributes to the analysis of policy narratives, which are understood as the way an environmental problem becomes part of the policy discourse and agenda, by focusing on the topic of soil health. It provides an insight over the integration of the soil health concept, intended as the delivery of a broad set of ES, throughout current EU policy instruments and scientific literature. The findings of the narrative review suggest the need for further, more focused investigation. Future studies could apply mitigation measures such as narrowing keyword selection to policy incentives most

[2] For more details on the Soil mission objectives please refer to EU Mission: A Soil Deal for Europe (europa.eu) [accessed on July 3rd 2024]

relevant to soils, broadening the range of search engines used, and employing the PRISMA flow for a more systematic review process.

The agricultural sector enlists a set of incentives that promote a correct management of soils to guarantee greater fertility, well managed forest soils are found to improve soil structure and protect from erosion, yet soils are seen predominantly as carbon sinks. Overall, recognition of the value of ES related to soils in policy instruments was identified for primary production – food, fuel and fiber – and carbon storage, thus better fitting the scale of action of soil fertility and soil quality. Scientific literature also provided evidences of little availability of instruments explicitly tackling a range of ES that is understood for healthy soils. There is a need for integration of broader societal values connected to increased soil health, e.g., in the forms of safeguarded soil biodiversity or land users' wellbeing, including access and ownership to land.

The mix of policies and instruments currently available has so far not been able to tackle the issue of soil degradation, therefore a more coordinated effort among policy sectors is required to prioritize soil health. Given the prominent role of the private sector, future research could focus on the role of market instruments in pursuing soil health where more regulatory instruments have failed.

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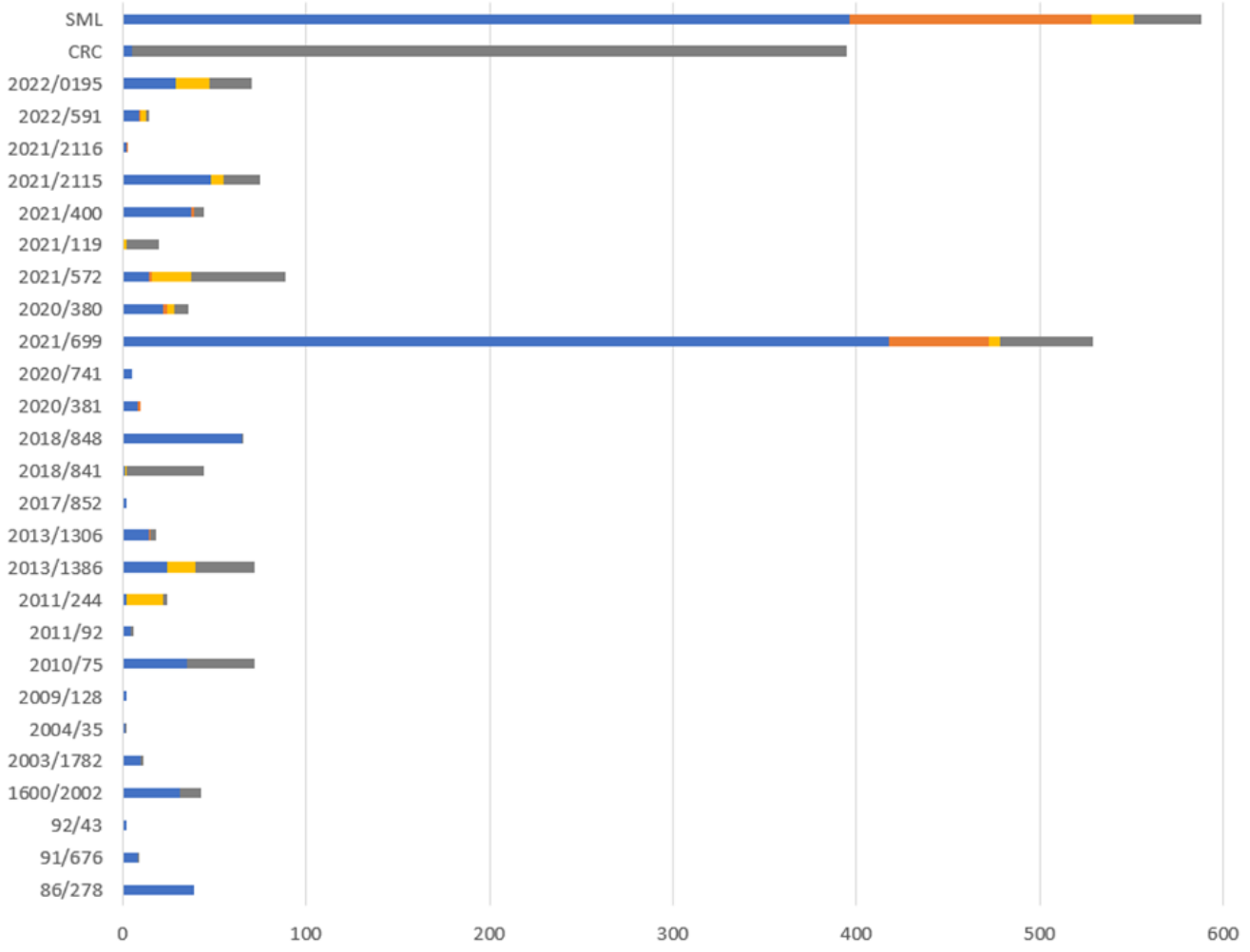
Appendix I – Content analysis



Year	Law	Code	SOIL	SH	ES	C
2023	Soil monitoring law	SML	396	132	23	37
2022	Carbon removals certification	CRC	5	0	0	390
2022	Nature restauration law	2022/0195	29	0	18	23
2022	8th Environment action programm	2022/591	9	1	3	1
2021	CAP 2023 - 2027	2021/2116	2	1	0	0
2021	CAP 2023 - 2027	2021/2115	48	0	7	20
2021	Zero pollution action plan	2021/400	37	2	0	5
2021	Climate law	2021/119	0	0	2	18
2021	Forest strategy to 2030	2021/572	14	>2	21	52
2021	Biodiversity strategy to 2030	2020/380	22	2	4	8
2021	Soil Strategy for 2030	2021/699	418	54	6	51
2020	Water reuse (minimum requirements for)	2020/741	5	0	0	0
2020	Farm to fork strategy	2020/381	8	2	0	0
2018	Organic production and labelling of organic products	2018/848	65	0	0	1
2018	LULUCF Regulation	2018/841	1	0	1	42
2017	Mercury Regulation	2017/852	2	0	0	0
2013	CAP 2014-2020 ('22)	2013/1306	14	1	0	3
2013	7th Environment action programm	2013/1386	24	0	16	32
2011	Biodiversity strategy to 2020	2011/244	2	0	20	2
2011	Environmental Impact Directive	2011/92	4	0	0	2
2010	Industrial Emissions Directive	2010/75	35	0	0	37
2009	Pesticides directive	2009/128	2	0	0	0
2004	Environmental Liability Directive	2004/35	1	0	0	1
2003	CAP direct support schemes	2003/1782	10	0	0	1
2002	6th Environment action plan	1600/2002	31	0	0	12
1992	Habitats' directive	92/43	2	0	0	0
1991	Nitrates directive	91/676	8	0	0	1
1986	Sewage Sludge Directive	86/278	39	0	0	0

Figure 2 Conceptual integration of soil, soil health (SH), ecosystem services (ES) and carbon (C) based on content analysis of 28 EU regulatory instruments.

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