EIP-AGRI Focus Group
Protecting agricultural soils from contamination

STARTING PAPER
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1. Introduction

The role of soil in providing endless functions and services to mankind, biodiversity and livelihoods is well known. Despite this, the EU Thematic Strategy for Soil Protection (EC, 2006)[1] identified a set of problems throughout the EU. Soil contamination is one of them, since the number of polluted sites is alarming and the figures are far too high and demand attention (Panagos et al., 2013). Altogether, over 137,000 km^2 (6.24% of all agricultural soils in Europe) need remediation activities (Toth et al., 2016).
Soil contamination comes from different sources, which could be natural or human-induced. Naturally occurring chemical elements derive from specific parent materials from which the soil is formed or from volcanic eruptions. hHuman induced sources vary from industry to intensive agricultural practices. Very recent data from two EU-funded research projects (iSQAPER and RECARE) show that pesticide residues were found in more than 80% of European soils tested (Silva et al., 2019).

Data from the abovementioned projects showed that by analysing for residues of 76 different pesticides in 317 topsoil samples, residues of 43 of these pesticides were detected in soil samples. But the tested substances account for less than 20% of the approved pesticides in the EU. What happens with the rest is unknown. The most common higher concentrations relate to the controversial weed killer glyphosate and its metabolite aminomethylphosphonic acid (AMPA); despite this, data availability for assessment impacts of both is limited. Some contaminated soils are in areas highly susceptible to water and wind erosion, implying that degradation risks could be multiplied.
However, the concentration of pesticide residues tested remained below the threshold values for soil organisms outlined by the European Food Safety Authority (EFSA). The controversy here is that to receive approval for the use of a pesticide, its effect on only five soil animals and two bacteria groups are tested (Silva et al., 2019). When the soil hosts more that 1 million species, many of them still unknown, what is tested accounts for less than 1% of the soils' microbial diversity.

Certainly, not only agriculture is to be blamed for soil contamination as according to the European Environment Agency (EEA) the industrial activities contribute significantly to soil pollution, mostly through the production sector followed by the service sectors, while mining activities are important sources of soil contamination in certain European countries. In the production sector, metal industries are reported as most polluting such as the ILVA steel factory in Taranto, Italy, the biggest in Europe, whereas the textile, leather, wood and paper industries are minor contributors to local soil contamination. For service sector, gasoline stations are the most frequently reported sources (EEA, 2014). The most common contaminants are mineral oils and heavy metals (Alloway, 2013).

Figure 1. Contamination of soils in the area Terra dei Fuochi, in Campania Region, Italy

The other issue of concern is the illegal urban, industrial trash and rubbish dumping as identified in the area of Terra dei Fuochi in Campania Region of Italy (Fig. 1)[2] that have contaminated an overall area of about 3,000 ha making farming practically impossible due to the high concentration of contaminants.
Soil contamination remains an issue of major concern in the EU, and the vast majority of the EU-28 Member States lack comprehensive inventories (Brombal et al., 2015).

[1] Erosion, organic matter decline, salinization, compaction, contamination, sealing, landslides and biodiversity decline
[2] https://nst.sky.it/content/dam/static/contentimages/original/sezioni/tg24/cronaca/2013/11/12/terra_dei_fuochi_corpo_forestale.jpg

However, soil contamination is not dealt with in the same way throughout Europe and care should be taken as the criteria for definition of a contaminated site are not the same. For instance, in Belgium (Flanders), Luxembourg, the Netherlands, and France potentially contaminated sites (PCS) are mapped based on potentially polluting activities while in Austria, Hungary and Norway on real evidence as being contaminated.

Scattered data are available for types of contaminants, and the main ones are mineral oils and heavy metals (Fig. 2). Mineral oils are particularly dominant in Belgium (Flanders) and Lithuania, while Austria is paying particular attention to heavy metals (EEA, 2014). Phenols and cyanides make a distinct contribution to the overall contamination load. Data for 2011 showed an increase in groundwater contamination with chlorinated hydrocarbons compared with 2006.

Soil contamination is a global problem and as such global efforts are underway to draw attention to its perils and define actions needed to prevent and remediate it. For instance, the USA Environmental Protection Agency (EPA) reports more than 25,000 oil spills a year throughout America. **The Global Soil Partnership** (GSP) that brings together hundreds of soil scientists and environmental NGOs supported by the national governments and the Food and Agriculture Organisation (FAO) of the United Nations, on the occasion of the celebrations of the World Soil Day on 5 December 2018, organised numerous events on many countries under the significant theme “Be the Solution to Soil Pollution”.

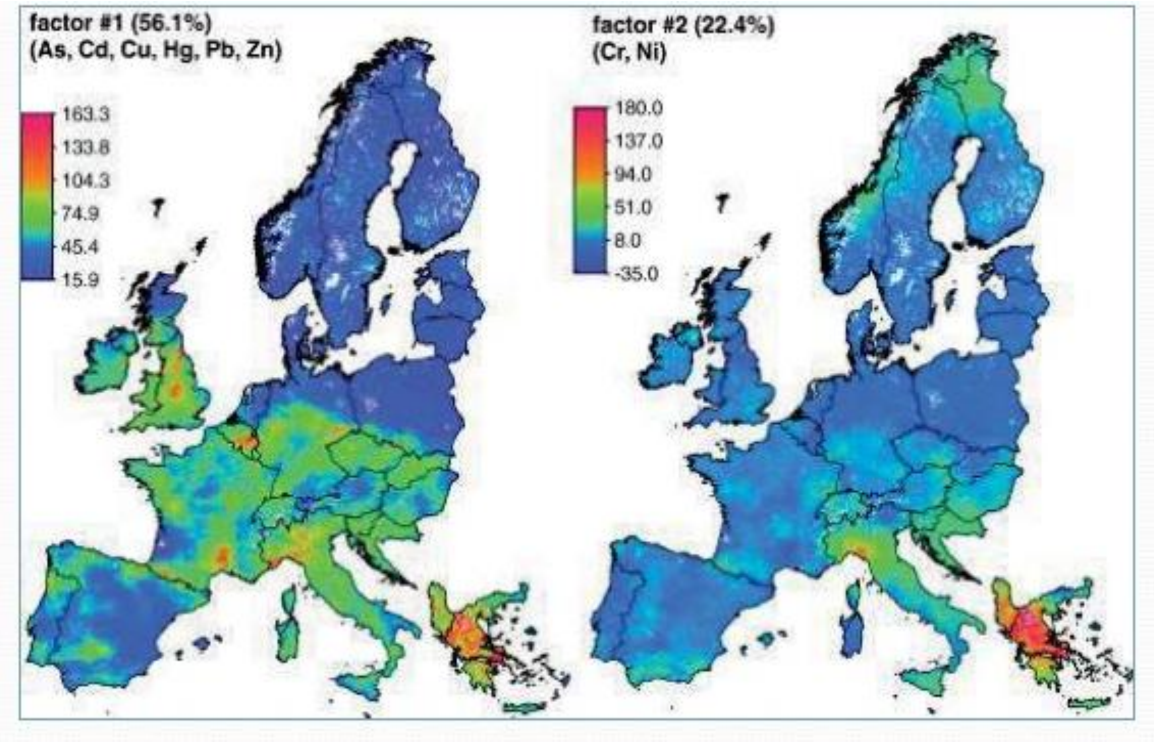

Fig. 2. Distribution of heavy metals in the EU-28 countries (Lado *et al.* 2008).

The EEA defines two main issues when dealing with soil contamination in Europe that are based on two topic questions: (i) how many relevant polluting activities (hence sites potentially polluted) and (ii) how many of these sites are in urgent need for remediation. Once these questions are answered, then planning of both labour and financial resources can be done. It should be noted that field ground surveys are needed to define the extent and intensity of contamination.
In other occasions, such as severe incidents like Chernobyl or what happened in Hungary in 2010 (Fig. 3) the effects of contamination are immediate and expand quickly in many bordering countries.

Figure 4 shows the main sources of contamination (left), with waste disposal and industrial/commercial activities playing a major role in pollution and the differences between potentially contaminated sites and contaminated sites in various European countries.

Fig. 3 Contamination of the Danube river. (From CBS news)

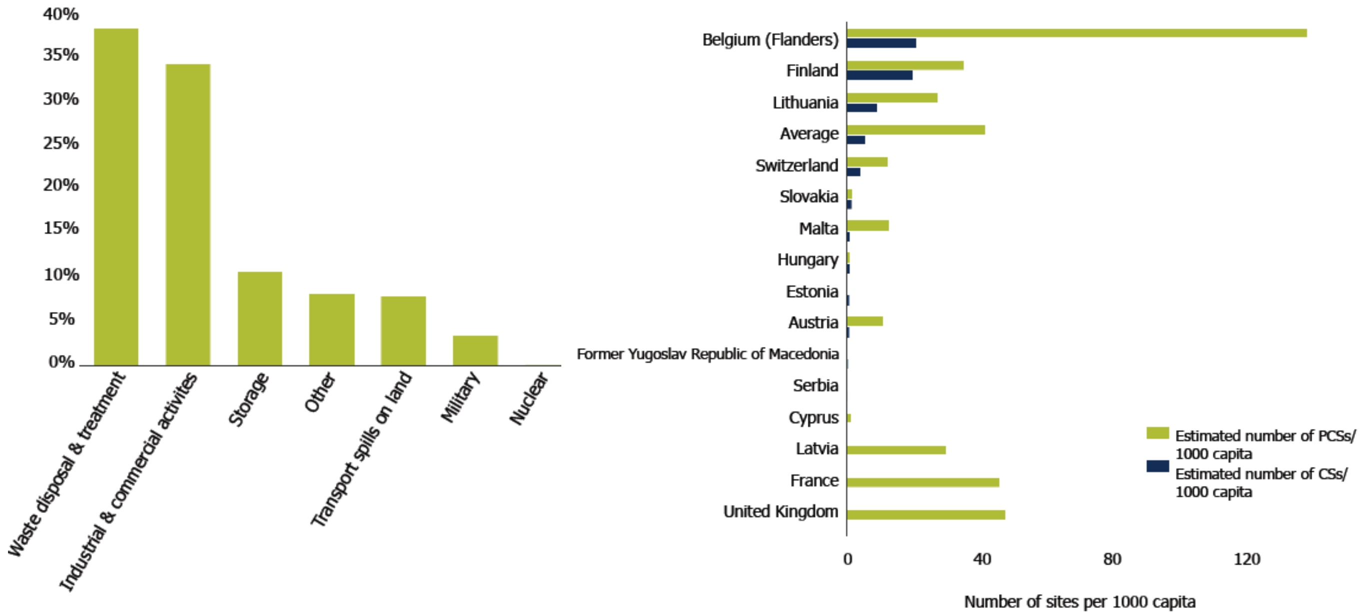

Fig. 4 Main sources of contamination and the rate between potentially contaminated sites (PCS) and contaminated sites (CS) for some European countries (European Environmental Agency, Progress in management of contaminated sites)

Efforts are being made at the EU level to also estimate the role of agriculture in soil contamination (see Fig. 5 for residues of pesticides in agricultural soils) and preliminary data mentioned in the introduction of this discussion paper show that little information is available but the problem does exist and it needs further examination.

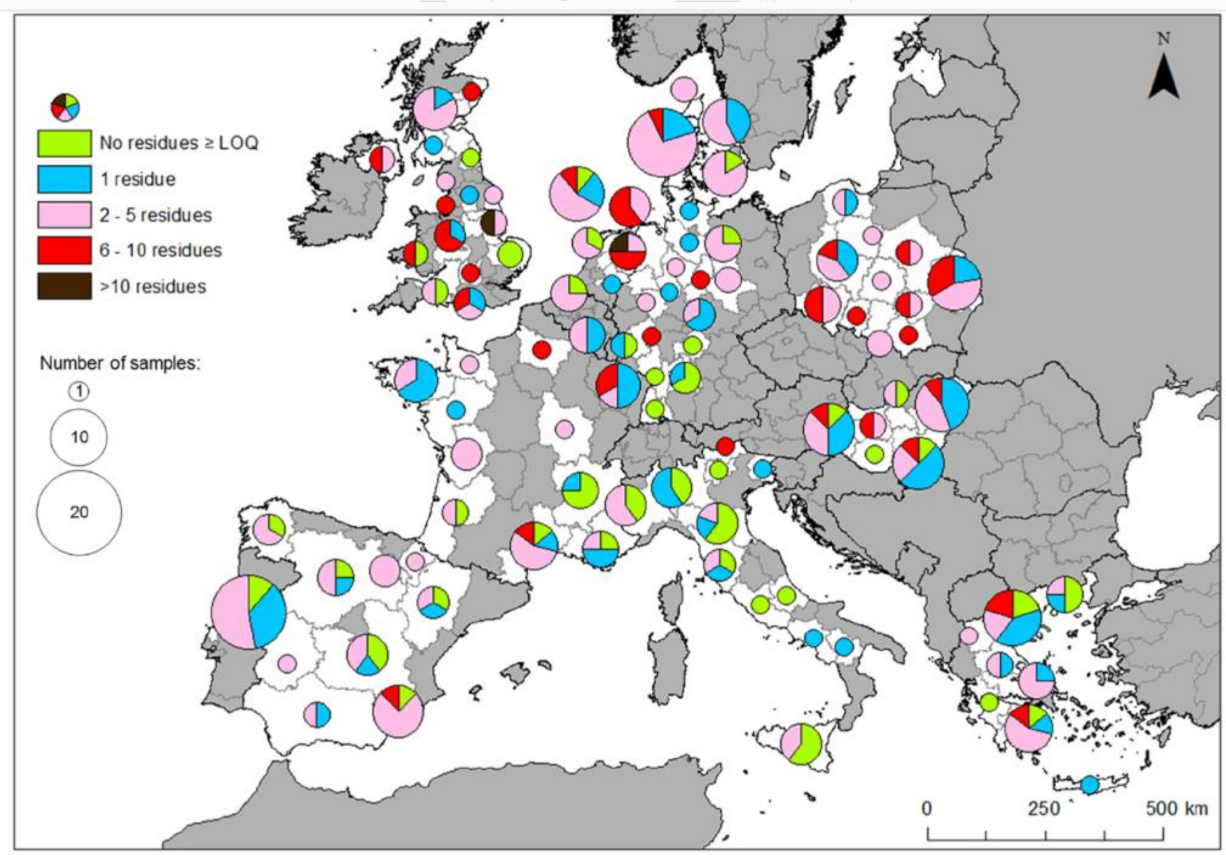

Fig. 5 Pesticide residues in agricultural soils based on topsoil samples collected from the LUCAS database

Plastic pollution has received increasing public awareness and attention by the EU, national governments and UN institutions. Nevertheless, while rightly so, the main focus has been on plastic ocean pollution, the role and impacts on soil pollution of plastics are greatly ignored and not sufficiently examined, including the biodegradable plastics, therefore additional research on this aspect must be done.

Issues of concern: identify contamination sources, increase testing of approved pesticides, increase testing of approved pesticides in a larger number of soil biota, define better criteria for contamination, examine soil's chemical, organic, physical and mineralogical characteristics and their interaction with contamination sources.

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1.1 The tasks of this Focus Group

EIP-AGRI Focus Groups are temporary groups of 20 selected experts focusing on a specific subject. Each group explores practical innovative solutions to problems or opportunities in the field, and draws on experience derived from related useful projects. Each EIP-AGRI Focus Group meets twice and produces a recommendations and outcomes report.
The EIP-AGRI Focus Groups also discuss and document research results, best practices and identify the implications for further research activities that will help to solve practical problems in the sector.
This discussion paper serves as background to prepare the first meeting of the EIP Focus Group on "soil contamination" which is taking place in June 2019. For this purpose, the document aims to:
Establish a common understanding about the purpose and scope of the Focus Group.
Identify some preliminary issues and key questions for discussion at the first Focus Group meeting.
Begin drawing together the available knowledge on protecting soils from contamination as a preliminary basis for the Focus Group final report.

Throughout the Focus Group process, a comprehensive review of research evidence and practical experiences in dealing with soil contamination will be made. The overarching QUESTION of the focus group is:

How to prevent agricultural soil contamination and how to address the problem of contaminated soils?

The main question will be addressed through these specific tasks:

- Identify the main soil pollutants in different regions and challenges each of them poses.
- Review existing knowledge about ways to measure soil contamination and share information.
- Identify innovative methods to prevent soil contamination in particular through improved management on farm.
- Identify a set of good practices to prevent agricultural soil contamination from various sources and to remedy agricultural soil contamination.
- Identify remaining research needs from practice and propose possible directions for further research on soil contamination.
- Propose priorities for innovative actions by suggesting ideas for Operational Groups to test solutions for the prevention of soil contamination or remediation of contaminated soils and other ways to exchange the practical knowledge gathered by the Focus Group.

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2. Public health consequences

Due to the complexity of the soil ecosystem and its interaction with the surrounding environment (Fig. 6) and the great diversity of contamination sources, it is not easy to make a direct link between the source and the health effect. However, the large body of existing scientific evidence has clearly shown that contaminated soils could harm human and animal health and they are integral part of the life cycle assessment. Once the contaminants have entered the food web from grazing animals to food produced for direct human consumption, these effects will become relevant, but probably not immediately as in the case of contaminated air or water.

Issues of concern: The fate of untested pesticides in soil, water, and plant systems and public health consequences, the fate of (unknown) plastic pollution in the soil and its interaction with food web system, the link between urban waste disposal and soil-food system, the impacts of bio stimulants in soil quality, ecosystem functioning and residue accumulation in the soil.

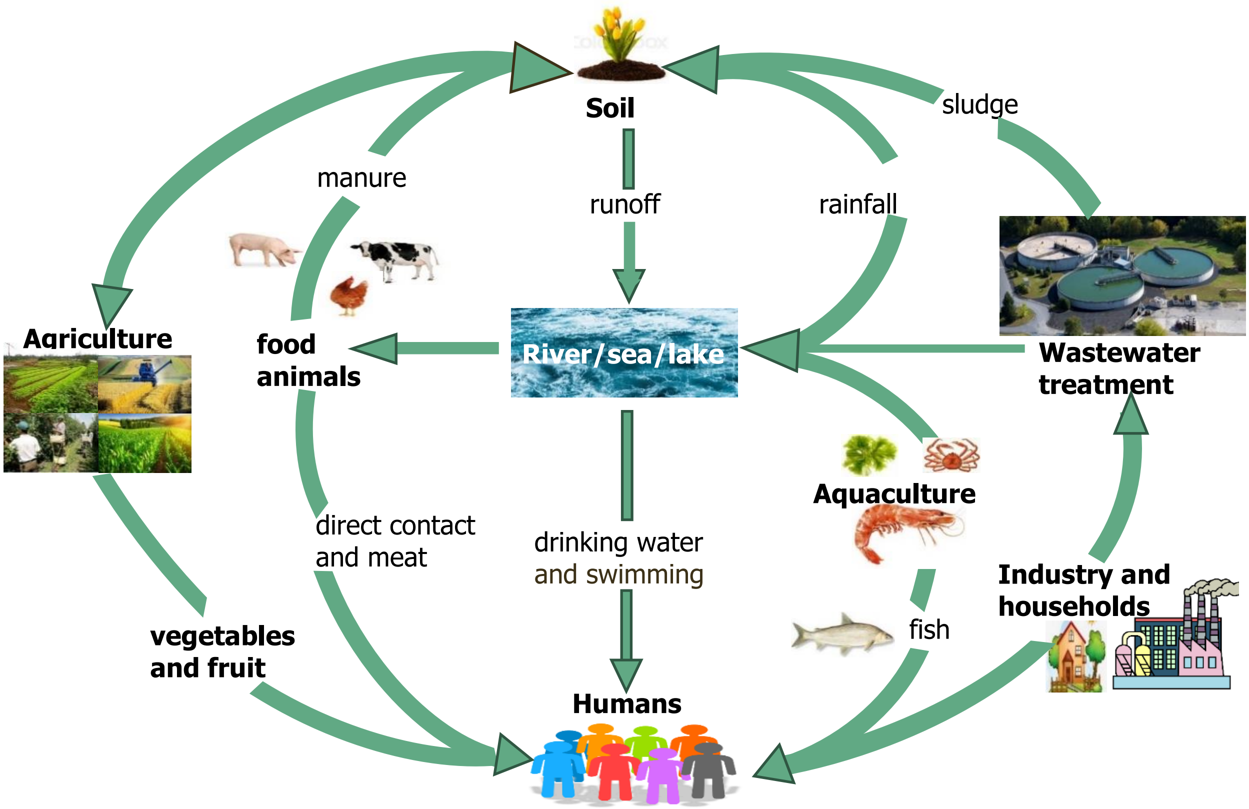

Fig. 6. Linkages between soil pollution, agriculture, industry and human health (Wanjaja et al., 2018)

Public awareness on soil contamination sources (Fig. 7) is increasing throughout the EU and many concerned citizens especially around polluted areas have raised their voice. Chances are that more Erin Brockovich's will join the fight and both the scientific community and policy/decision makers should offer solutions.

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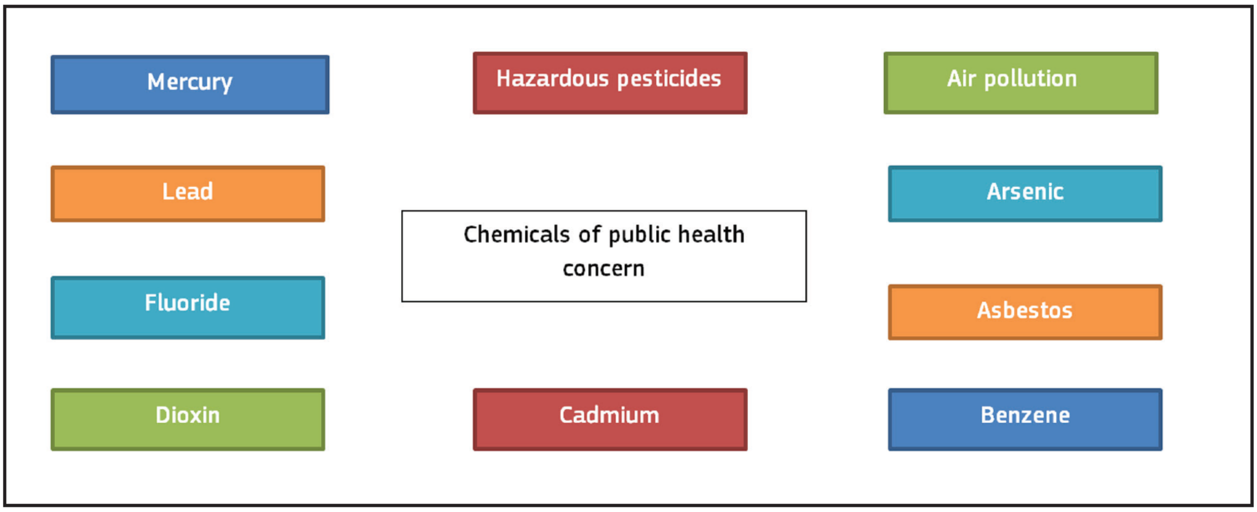

Fig. 7. Ten chemicals of major public health concern. (adapted from WHO)

3. Remedies and solutions to soil contamination

Contaminated soils are most commonly managed using "traditional" methods such as excavation and off - site disposal. Altogether, these methods account for one third of management practices. In-situ and ex-situ techniques are implemented almost equally (EEA, 2014).
The most important strategies for remediation include:

- BIOREMEDIATION

For this treatment process naturally occurring microorganisms are used (yeast, fungi or bacteria) to break down, or *degrade*, hazardous substances into less toxic or nontoxic ones. There are specific types of microorganisms that can digest organic substances such as fuels or solvents that are hazardous to humans, breaking them down to carbon dioxide and water.

- ENGINEERING REMEDIATION TECHNIQUES

The most effective engineering remediation technique is the removal of polluted surface soil, which is replaced by non-contaminated soil. After removal, the contaminated soil is washed with some chemical extraction or chelating reagent. This process is both effective and relatively low-cost.

- EXCAVATION AND AERATION OF SOILS

The most common decontamination method for polluted soils is to excavate and remove it to a disposal site where human or sensitive ecosystem contact will not be possible, or will be much less likely, to incinerate it or to accelerate soil aeration. These methods, however, often exchange one problem for another; land filling merely confines the polluted soil while doing little to decontaminate it, and incineration removes toxic organic chemicals from the soil, but subsequently releases them into the air, thus causing air pollution.

- CHEMICAL REMEDIATION TECHNIQUES

This method involves adding chemical materials to polluted soils, in order to reduce the concentrations of heavy metals like cadmium and lead dissolved in the soil solution. The chemicals added include lime, organic manure or compost to increase the soil pH and to reduce the solubility of trace elements. Another approach is called the stabilizing method; this is used to transform certain heavy metals by adding chemicals to the soil that cause the formation of minerals which still contain heavy metals, but in a form that is not easily absorbed by plants, animals or people, thus much less harmful.

- PHYTOREMEDIATION TECHNIQUES

Phytoremediation (Fig. 8) refers to the use of plants to rehabilitate contaminated sites without having to excavate the contaminant material and dispose of it elsewhere. The use of plants capable of taking up high amounts of metals and reduce their concentration in the soil, has proven to be effective in the rehabilitation of heavy metal-contaminated soils. Plants are grown for a certain period of time and are then harvested and subjected to composting, compaction, incineration, ashing, pyrolysis, direct disposal, liquid extraction or in some cases by the metallurgical industry as source of prime minerals.

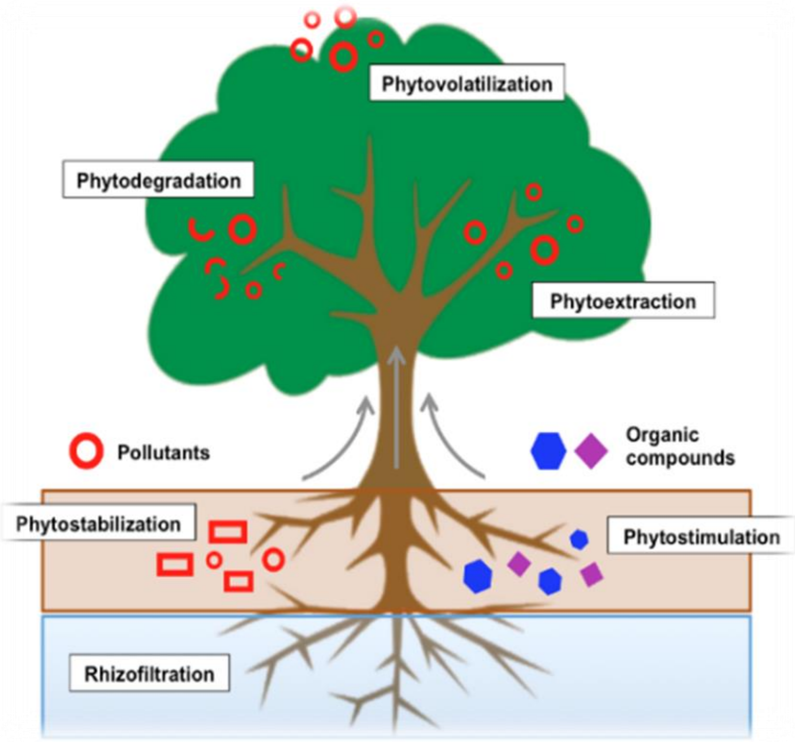

Figure 8. Phytoremediation process (Kvesitadze et al., 2006)

- USE OF MICROBES TO REMOVE HEAVY METALS FROM SOILS

Over the last decade, research progress has been made largely on leaching of chemicals (nitrogen, phosphorus, pesticides) from soils and to lesser extent on microbes, from application of a range of farm effluents and wastes. However, the mechanisms of contaminant transport differ between chemicals and microbes. Both are subject to dilution and adsorption, but unlike chemicals, microbes are subject to die-off/growth, filtration, predation, and pore-size exclusion effect. Bacterial leaching is the extraction of metals from their ores using microorganisms. Microbial technology offers an economic alternative for the mining industry, at a time when high-grade mineral resources are being depleted (Huang *et al.,* 2008).

- USING PYROLYSIS PROCESS TO REMEDIATE SOILS CONTAMINATED BY HYDROCARBON SPILLS

The pyrolysis method (Fig. 9) involves heating contaminated soils in the absence of oxygen, similar to the process of biochar creation. This approach is much better for the environmental quality than standard incineration techniques used for fast remediation (Vidonish et al., 2016, We Song et al., 2019). Research at Rice University (Vidonish et al., 2016) in the US, has found that pyrolyzing contaminated soil for three hours not only reduced the amount of petroleum hydrocarbons left to well below regulatory standards (typically less than 0.1 percent by weight), but also enhanced the soil's fertility by turning the remaining carbon into beneficial char.

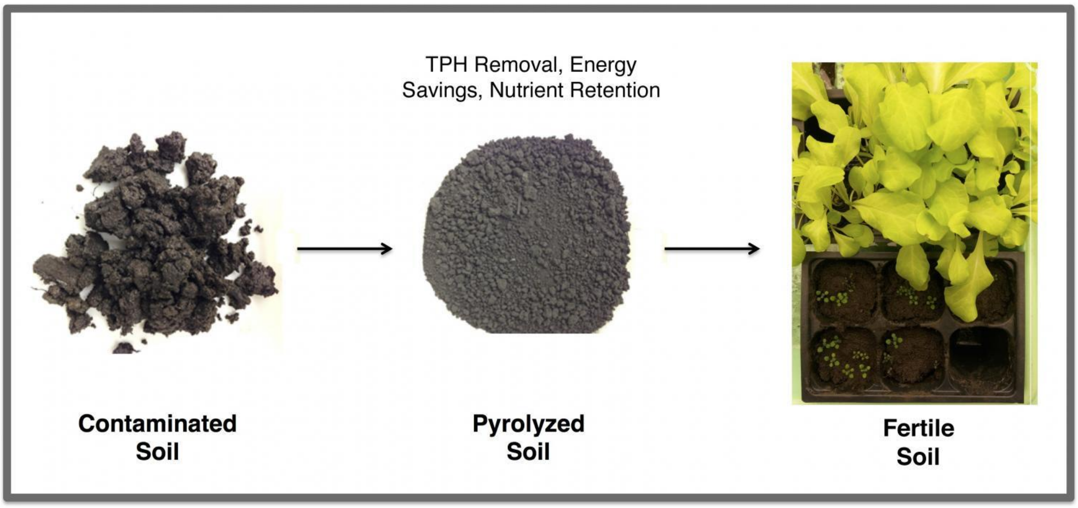

Figure 9. Schematic presentation of the pyrolysis process Source: (Wen Song et al., 2019)

Issues of concern: How feasible is it to implement these technologies, what are the costs, who should pay for them?

4. Sustainable intensification of agriculture vs agro-ecology, regenerating agriculture and organic farming

This section deals with the impacts of farming on soil quality and its eventual contamination under three different perspectives:

4.1. Soil contamination from the farmer's perspective:

For farmers, good yields and profits are very important. To reach this goal, there are several options, which are often contradictory and debated. The European Commission (see Call SFS-38-2018: Highly efficient management of soil quality and land resources) and other international organisations have recently embraced the term "sustainable intensification" which in other words means to sustainably increase food production to feed 10+billion people by 2050 with the existing land resources and without degrading them.

Furthermore, *precision agriculture* and artificial intelligence applied in farming systems is expected to increase the efficiency of chemical inputs such as fertilisers and plant protection products like pesticides and herbicides. These are the new frontiers of farming. It is expected that drones and robots will be able to spray chemicals in precise hotspots where weeds and pests are located. Certainly, this could have enormous benefits in terms of costs for the farmer and benefits for the environment in general and the soil in particular. But whether these become common practices is an open question as it will require technological updates, investments and farmer training.

On the other side, a more conservative type of agriculture is based on agro-ecological principles that encourage minimum or no-till, rotations, cover crops, use of organic manure and much less, or no chemical fertilisers, ban of pesticides and introduction of beneficial insects to eliminate the damaging pests. The Common Agriculture Policy (CAP) also supports these principles as there are mandatory measures (cross-compliance and greening), which include practices aiming to prevent damage to the soil and ensure its protection. Many of these principles are the base of organic farming that is increasingly playing a major role in Europe. Most importantly these practices have a very positive impact on soil quality, reduce the loss and leaching of nitrogen and phosphorus from the soil into surface and groundwater and increase soil organic matter that is the "elixir" of life for the soil.

Fig. 10. Good old days? Painting by Julien Dupré, La récolte des foins, 1881

Chances are that both sustainable intensification, modernisation of agriculture and more conservative farming systems will remain in Europe and will be complementary rather than competing with each other. Much will depend also on the consumers` choice; whether price or quality is a priority. One thing is sure: no one will be willing to buy a product that is grown in a contaminated soil, hence delineating these areas should be a priority for each MS.

Healthy soils produce healthy nutritious food and maintain a healthy environment

Last but not least, no farmer alone could bear the cost of remediation of contaminated soil, even if he was responsible for that due to adverse farming practices he implemented. Decontamination requires public support or private-public partnership with adequate financial resources.

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4.2 Soil contamination from the scientist's perspective:

Scientists by nature have an approach that is based on data and methods as explained above. There are already plenty of these data and methods and perhaps more need to be collected. The main issue though remains the implementation of the research results at wider scale and the narrowing of the science-policy-farmer gap.

4.3 Soil contamination from the policy/decision maker's perspective:

Policy measures should aim to effectively recover the environments exploited and impacted by human activities and they should establish an equilibrium between economic development and environmental protection. Policy implementation is another crucial issue because despite existing legislation in place, soil and groundwater contamination was not stopped as in the case of Nitrate directive (EEA, 2012, Colombo, 2015), while Phosphorous contamination of soil and waters, including eutrophication, is largely unknown (Schoumans et al., 2014).

5. Long-term monitoring

Keeping soil contamination under control requires a well-functioning monitoring system that is based on a large-scale EU network. The best option for that is the Land Use Land Cover Survey (LUCAS) managed by the EUROSTAT in close cooperation with the Directorate General responsible for Agriculture and the technical support of the Joint Research Centre (JRC) of the Commission. More than 250,000 sample points spread throughout the EU are collected in a range of approximately 4 years to detect land use changes.
In 2009, the European Commission extended the LUCAS scheme to sample and analyse the main properties of topsoil in 23 EU Member States. This topsoil survey represents the first attempt to build a consistent spatial database of the soil cover across the EU based on standard sampling and analytical procedures, with the analysis of all soil samples being carried out in a single laboratory. Approximately 20,000 points were selected out of the main LUCAS grid for the collection of soil samples. A standardised sampling procedure is used to collect around 0.5 kg of topsoil (0-20 cm depth).
Published data based on LUCAS, as well as other studies recently estimated the content of copper in EU soils (Ballabio et al., 2018). This could be used to track other elements as well on a regular basis. But the monitoring should not be solely confined to LUCAS sampling points as they may not be placed on potentially or actually contaminated sites. Therefore, ad hoc sampling should be conducted in these other areas as well. Each MS has a list of elements that need to be analysed in the lab and compared with allowed threshold values. A comprehensive database should be built to track changes over time. This should be a continuous process and the public should be informed about its results.

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Annex 1: Legislative framework

In 2006 the EC launched the EU Thematic Strategy for Soil Protection (EC COM (2006) 231) that was based on four pillars, namely: raising awareness, research, integration, and legislation. But this effort failed to result in a new Soil Framework Directive and in 2015 the EU Commission withdrew the proposal. Currently, a legally binding legislative framework for land and soils is missing at the EU level.

In the framework of the COM (2006) 231 a separate approach was proposed for soil contamination, addressing the issue of contaminated sites, their inventory and successive restoration measures.

The Thematic Strategy (COM (2006) 231) defined the actions to address soil contamination by the MS as follows:

> *"On the basis of a common definition of contaminated sites (i.e. sites which pose significant risk to human health and the environment), its application by the Member States, and a common list of potentially polluting activities, Member States will be required to identify the contaminated sites on their territory and establish a national remediation strategy. This strategy will be based on sound and transparent prioritisation of the sites to be remediated, aiming at reducing soil contamination and the risk caused by it and including a mechanism to fund the remediation of orphan sites. This is complemented by the obligation for a seller or a prospective buyer to provide to the administration and to the other party in the transaction a soil status report for sites where a potentially contaminating activity has taken or is taking place. The Directive also addresses prevention of contamination via a requirement to limit the introduction of dangerous substances into the soil".*

Despite the failure to endorse the Soil Directive, the EU remains committed to protect its soils. The EU strategy adopts the principles of preventing further degradation and preserving soil functions by restoring degraded soils to a level of functionality consistent with the current and intended use. Efforts that are being made in the EU towards the soil protection indicate two important key issues: i) that soil degradation is not merely an issue of developing countries, and ii) that drafting, approving and implementing soil protection legislation is a complicated issue which also interferes with special economic interests. In 2011 the Commission released the communication Roadmap to a Resource Efficient Europe (COM(2011)571 and in 2012 adopted a report on "The implementation of the Soil Thematic Strategy and ongoing activities", COM(2012)46 that emphasise actions needed to implement sustainable soil management throughout the Union.

The 7th Environment Action Programme (EU 2013) restated the EU's commitment to *"reduce soil erosion, increase soil organic matter, limit the effects of man-made pressures on soil, manage land in a sustainable fashion, and **remedy sites with contaminated soils**"*. In November 2013, the EU adopted the General Union Environment Action Programme, to "ensure that by 2020 land is managed sustainably in the Union, soil is adequately protected and the ***remediation of contaminated sites is well underway***".

"Without a healthy planet, none of the Sustainable Development Goals can be achieved…..We need to protect, restore, and manage our natural capital, not just to survive, but to prosper. Achieving a circular economy means changing global mind-sets…..spreading an understanding that a healthy environment is a source of growth and jobs " Commissioner Karmenu Vella

In the context of the SDGs, a healthy planet is a major concern for the EU to ensure the well-being of European citizens and of all other countries for future generations. EU policies affect the long-term safeguard of life on our planet, including in developing countries (SWD(2019)20 final.
The EU has consequently stepped-up its efforts in protecting and restoring the environment as well as improving the sustainable management of natural resources including the protection and sustainable use of ecosystems, such as land and biodiversity (SDG 15.3 Life on Land: "protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forest, combat desertification, and ***halt and reverse land degradation*** and halt biodiversity loss").

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On 28 November 2018, the Commission presented its strategic long-term vision for a prosperous, modern, competitive and climate-neutral economy. Applying the principles of a competitive, inclusive, socially fair and multilateral European approach, a number of overriding priorities, fully consistent with the SDGs, should be guiding for the transition to a climate neutral Europe. Among other issues is the one below with relevance to this FG:

promote a sustainable bio-economy, ***safeguard our natural resources***;

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