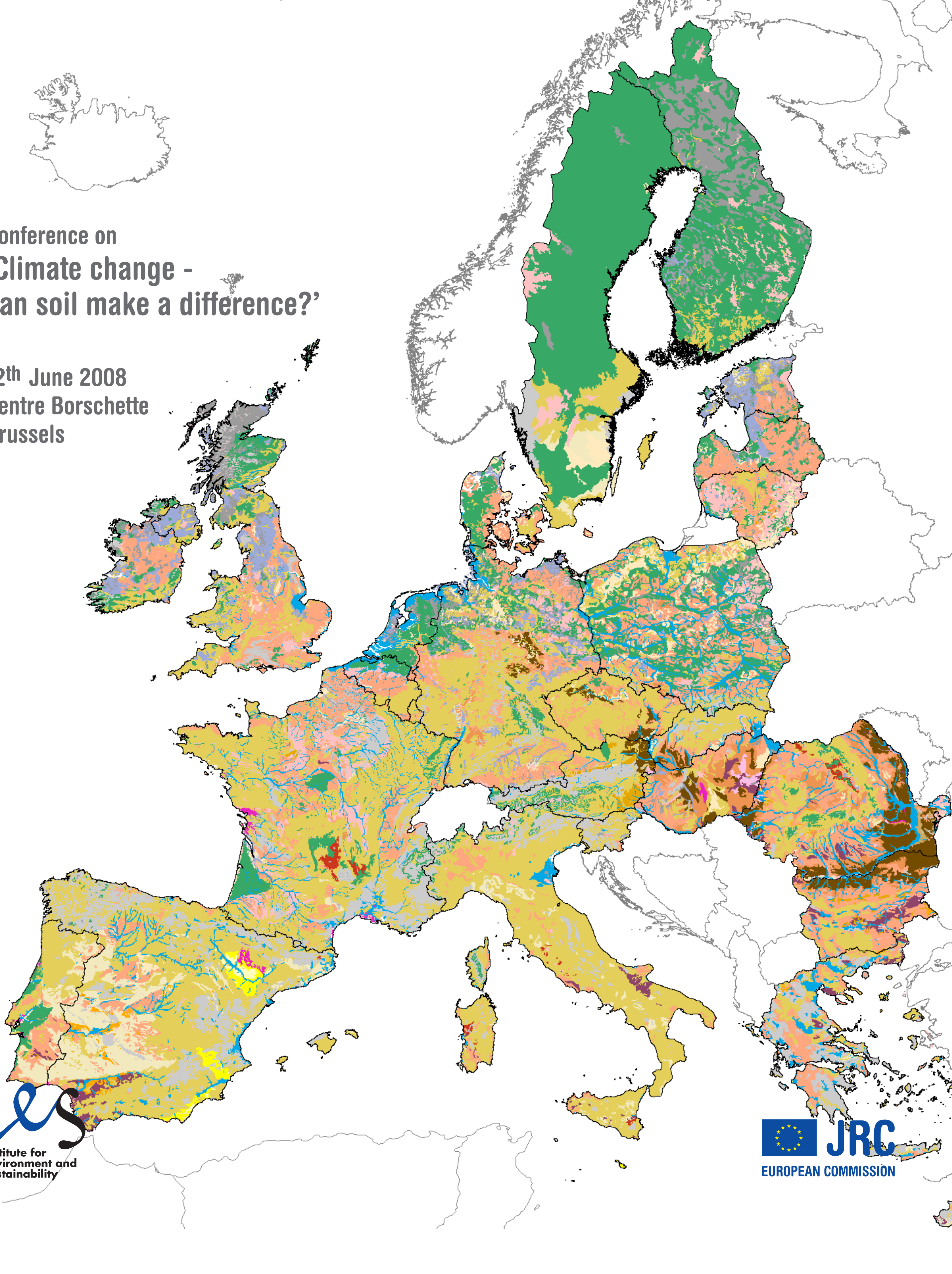
Climate change: soil *can* make a difference!



Conference on
‘Climate change - can soil make a difference?’

12th June 2008
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Institute for Environment and Sustainability

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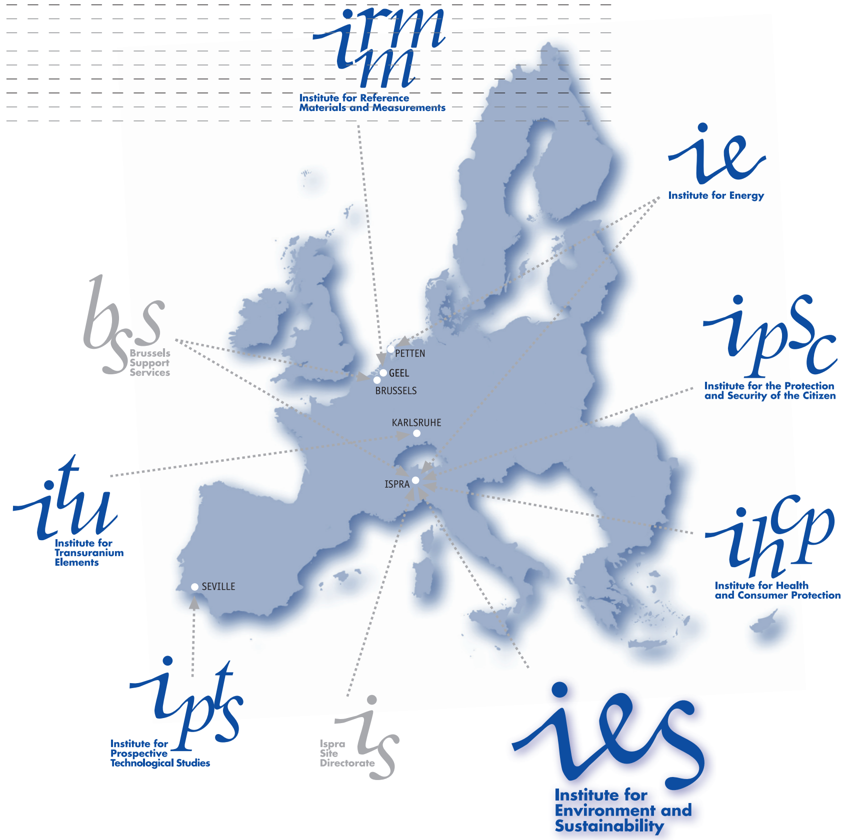

Cover Image

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Summary

Climate is a principle factor of soil development. Climate drives major soil-forming processes including transformation, accumulation and transport of substances that result in the diversity of soil types on the Earth. Soil is one of the key life support systems responsible for the performance of major ecological functions such as biomass production in agriculture and forestry, storing, filtering and transforming nutrients, substances and water, biodiversity (e.g. habitats, species and genes), physical and cultural environment for humans and human activities, source of raw materials, etc. The change of climate alters all processes in soil which may have serious consequences for the both environment and society. Therefore, climate-soil relationship is one of the priority topics in soil science.

The Soil Action of the Institute for Environment and Sustainability of Joint Research Centre of the European Commission focuses on policy-related research addressing climate-soil interactions. Recent climate change studies show a very complex picture where temperature increase in one region is accompanied by temperature decline in the other. The pattern of changes in precipitation is even more diverse and differs from that of temperature. Overlaying a variety of temperature-precipitation combinations with those of soil types shows that the diversity of climate response trajectories of soil evolution is difficult to predict. Therefore, an accurate and technologically sound inventory of soil resources in the EU is one of the fundamental tasks of the Soil Action.

This booklet presents an overview of the various activities which are being carried out by the Soil Action or to which the basic soil data were provided. In addition, new methods to verify the changes of the organic carbon and estimate the potentials of carbon change in the EU mineral soils are introduced. The overall goal of the document is to provide examples that clearly illustrate that soil is an important issue in climate change. Policies and strategies supporting the effective management of soil can really make a difference for the mitigation of climate change.

Soil and Greenhouse Gases

Soil is full of living organisms that generate biogenic greenhouse gases (CO2, CO4 and N2O), carbon soluble constituents and soil organic matter (e.g. humus).

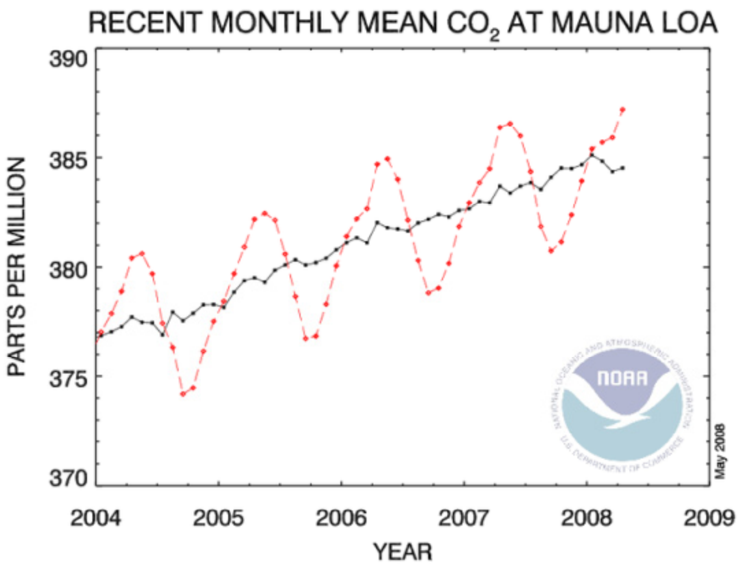
Image sources: Walter, Ehrmann, Ritz, Pawinski, Michel, Deacon, Hopkin, Calev
Montage produced by JRC-IES

Inappropriate land use practices and other soil threats change the structure and amount of live species. These changes lead to an imbalance of the processes that control the transformation of organic matter. This imbalance intensifies the emissions of greenhouse gases from soils, leads to the decline of soil organic carbon stock and an unwanted increase of the concentration of greenhouse gases in the atmosphere.

Are soil processes visible in the atmosphere?

The graph shows recent monthly mean carbon dioxide concentrations measured at the Mauna Loa Observatory, Hawaii. The red line represents the monthly mean values while the black line represents the same after correction for the average seasonal cycle.

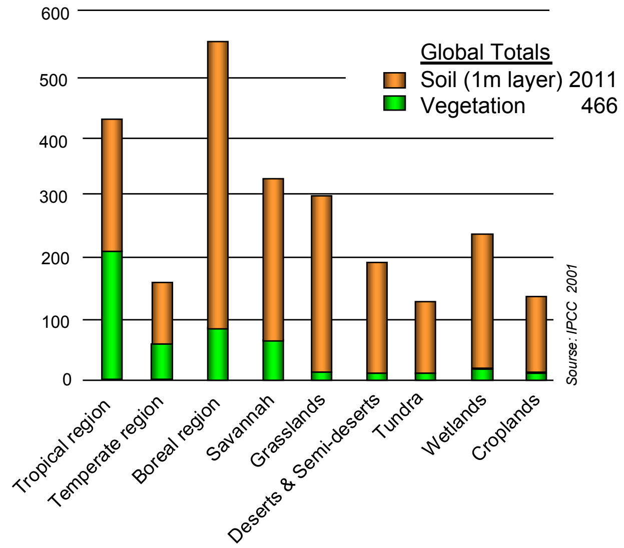
The seasonal dips are caused primarily by an uptake of CO_2 by plants during the summer that is controlled by soil fertility. The CO_2 rises due to heterotrophic soil respiration and decay of plant residues.



Peatlands and forest soils are perceived as major carbon sinks; also soil under permanent grassland to a lesser extent. Cropland soils are a major source of greenhouse gas emissions in the EU.

Global carbon stocks billion tons

Soil holds twice as much organic carbon as vegetation. Within a EU context, the role of soils in the temperate and boreal regions is critical.

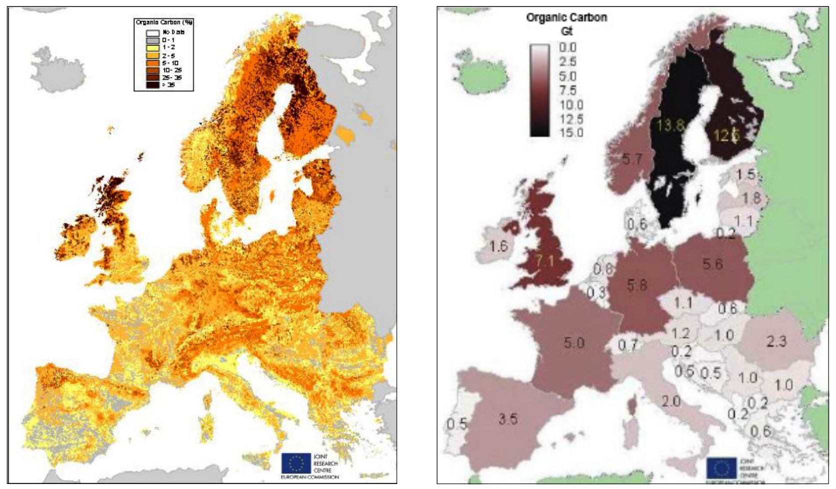


Organic carbon content in the soil of the EU

Soil in the EU contains about 71 GtC in the upper 0.3 m layer and 140 ±14 GtC to a depth of 1.0 m. This value is 7% of global total.

(Note: the EU occupies nearly 3% of the global soil area thus holding more than twice the carbon concentration than the global average);

Member States possess differences in soil carbon pools. This makes the regional diversification of policies on carbon management important.

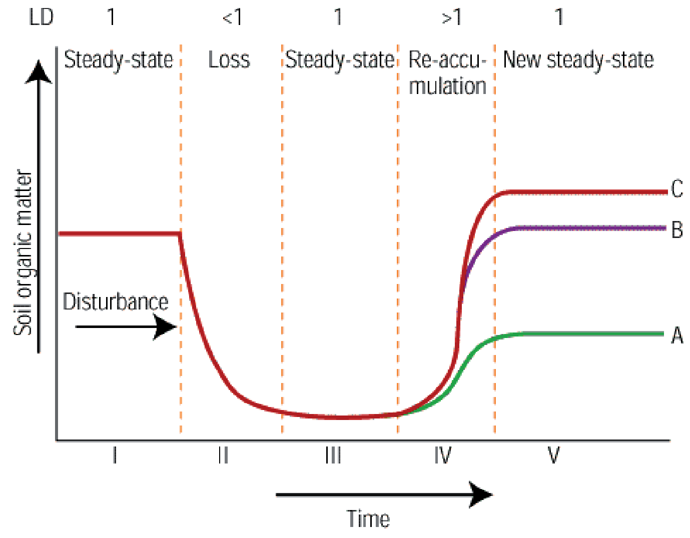


Source: Hiederer et al., 2004

The dynamics of soil organic matter

Conceptual model of soil organic matter decomposition and accumulation following disturbance.

At steady state (I), carbon (C) inputs from litter (L) equal C losses via decomposition (D) (i.e., L/D = 1). After a disturbance, D often exceeds L resulting in loss of C (II), until a new, lower steady state is reached (III). Adoption of new management, where L exceeds D results in a re-accumulation of C (IV) until a new, higher steady state is reached (V). The eventual steady state (A, B, or C) depends on the new management adopted.



(after Johnson, 1995; IPCC, 2000a).

Reducing soil threats to recover carbon balance

Karl Ritz

What can be done to maintain and improve soil carbon levels?

Increase organic matter content: Regular additions of organic matter improves soil structure, enhances water and nutrient holding capacity, protects soil from erosion and compaction and support a healthy community of soil organisms.

Reduce tillage: Less ploughing reduces the loss of organic matter and protects the soil surface with plant cover.

Limit agro-chemicals: Pesticides and chemical fertilizers have valuable benefits but can harm soil organisms. Even nutrients from organic sources can pollute when mis- or over-applied.

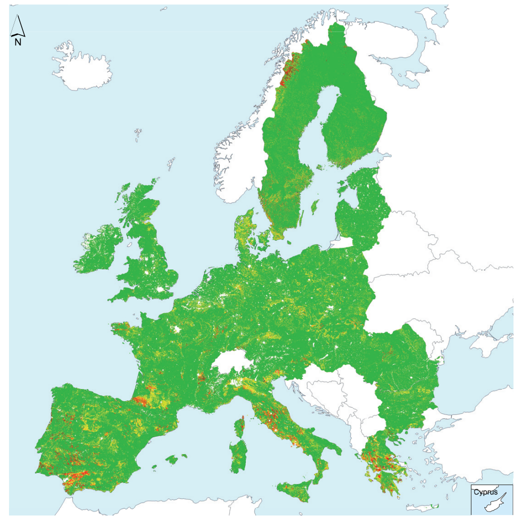
Prevent soil compaction: Compaction of the soil by repeated traffic, heavy machinery, or travelling on wet soil reduces the amount of air, water, and space available to roots and soil organisms. As remediation is difficult or impossible, prevention is essential.

Minimise the risk of erosion: Bare soil is susceptible to wind and water erosion, drying and crusting.

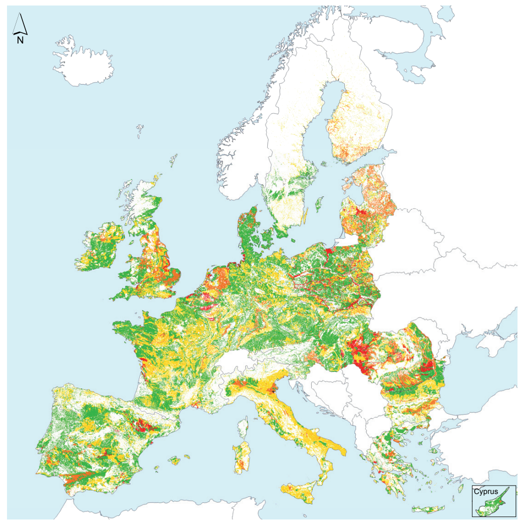
Soil threats in Europe

Climate is a key factor controlling major soil threats in Europe directly or indirectly. The temperature rise and decrease in precipitation cause an acceleration of wind erosion and salinisation. The associated decline in soil carbon will increase compaction and the release of pollutants (e.g., cadmium) due to the deterioration of soil absorption capacity (i.e. effect of a chemical time bomb).

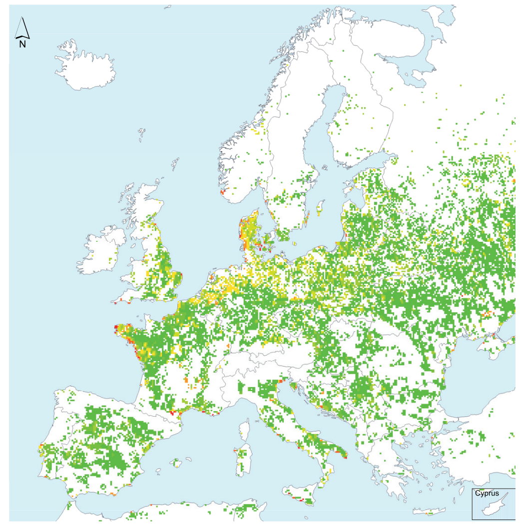
Water erosion risk assessment



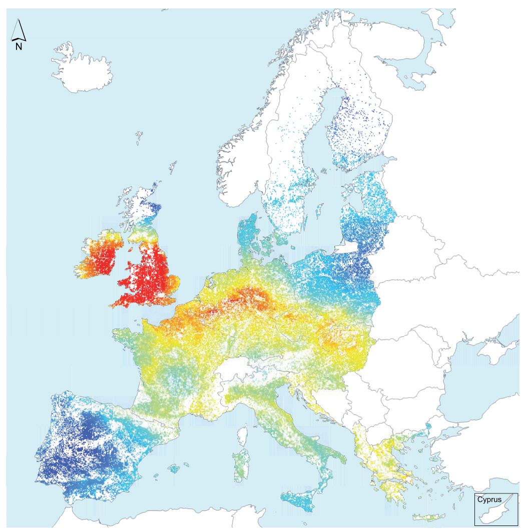
Natural susceptibility to compaction



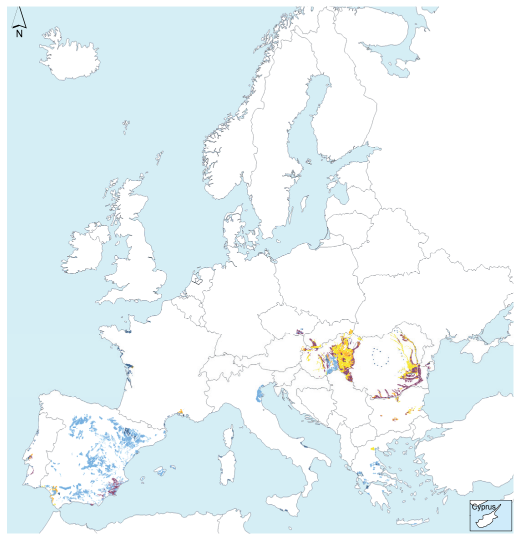
Wind erosion: number of erosive days



Estimated cadmium concentration



Saline and sodic soils



Articles 3.4 of the Kyoto Protocol

3.4 Prior to the first session of the Conference of the Parties serving as the meeting of the Parties to this Protocol, each Party included in Annex I shall provide, for consideration by the Subsidiary Body for Scientific and Technological Advice, data to establish its level of carbon stocks in 1990 and to enable an estimate to be made of its changes in carbon stocks in subsequent years. The Conference of the Parties serving as the meeting of the Parties to this.

Protocol shall, at its first session or as soon as practicable thereafter, decide upon modalities, rules and guidelines as to how, and which, additional human-induced activities related to...

*...changes in greenhouse gas emissions by sources and removals by sinks in the **agricultural soils** and the land-use change and forestry...*

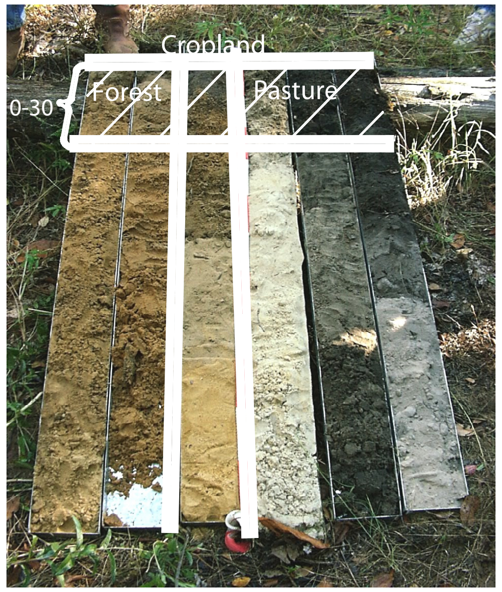
...categories shall be added to, or subtracted from, the assigned amounts for Parties included in Annex I, taking into account uncertainties, transparency in reporting, verifiability, the methodological work of the Intergovernmental Panel on Climate Change.

Kyoto focused on agricultural soils. Expansion of the Protocol on other soil types raises the importance of making country-wide inventories of soil carbon pools and develop new transparent, verifiable and cost-effective methods for the verification of carbon change in soil.

Verification of the carbon changes in mineral soils of the EU

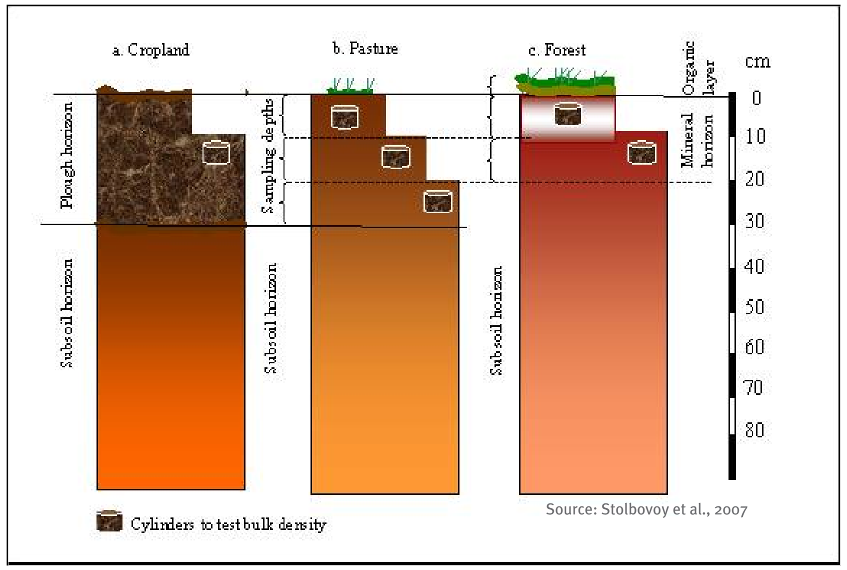
The International Panel of Climate Change (IPCC) identifies all soils by one standard 0-30 cm topsoil layer and by its use (see figure below).

A lack of systematic data across the EU leads to the masking of differences in the accounting of carbon content of different soil types. This results in artificially high variability of carbon content, which makes the verification of the carbon stock uncertain and soils sampling cost prohibitive. A new Area-Frame Randomized Soil Sampling scheme has been developed by the JRC in an attempt to address the problem.



Interpretation of photograph made by Erika Micheli

A strategy to sampling soil profile

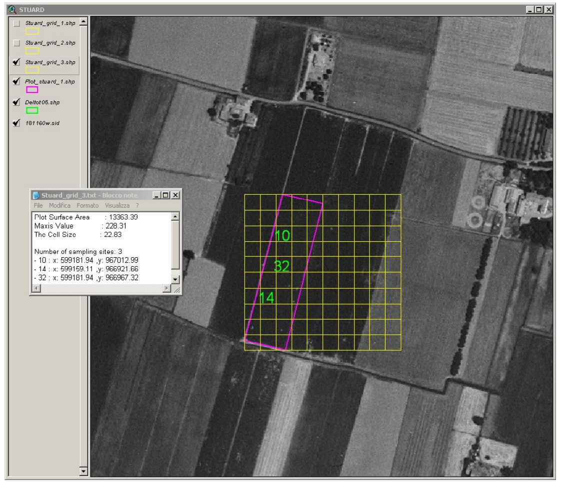


Source: Stolbovoy et al., 2007

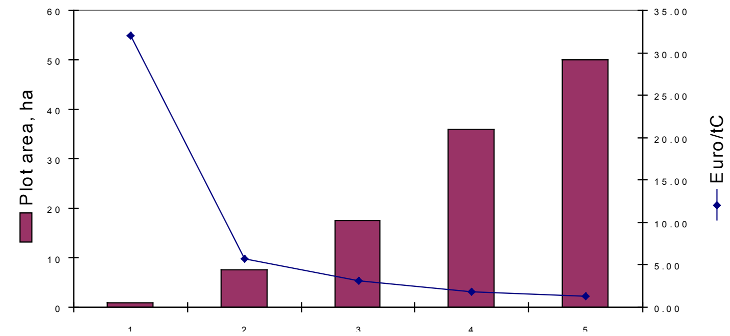
Topsoil characteristics of different soil types vary dramatically.

Cropland soil has a well mixed topsoil and needs one sample to characterise its carbon content. Pasture soil exhibits a gradual decline of carbon with depth and requires at least three samples. Forest soils have complex litter horizons and a stratification of the topsoil that needs separate samples.

Individual samples of mineral layers from one soil profile can be mixed for carbon analysis in the laboratory.



Automatic positioning and definition of the geographical coordinates of samples within an Area-Frame Randomized template for an agricultural location in Italy.



Source: Stolbovoy et al., 2007

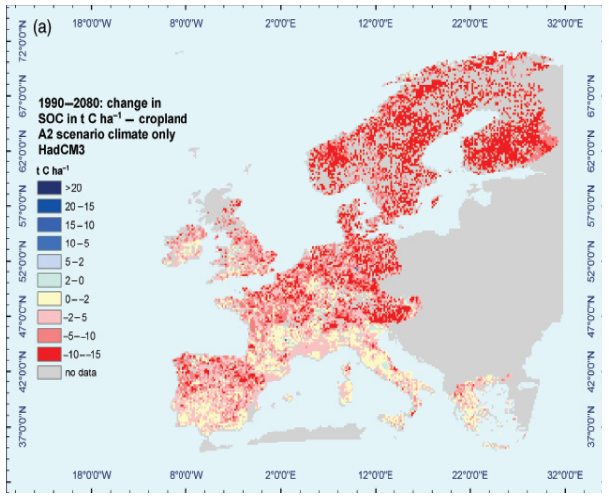
The laboratory cost to verify the changes of carbon in soils are lower for the larger fields and varies at practical level. Conditions: average carbon sink is 1.5 tC/ha; the cost of lab determination is 16 euro per sample.

Differences in mean carbon stocks between 2080 and 1990 (modeling)

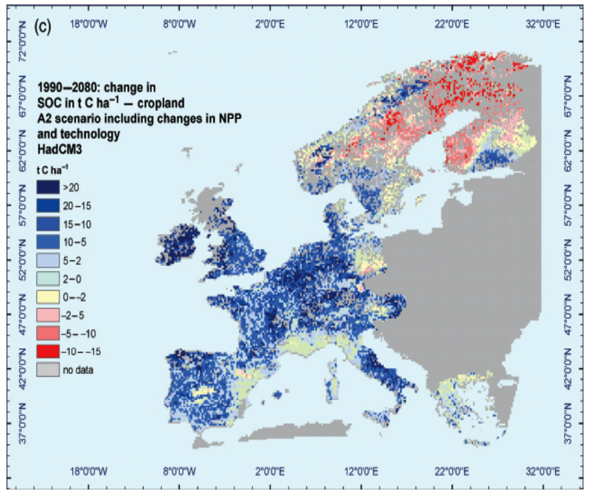
Models show that climate warming will stimulate a loss of carbon (red colour in right side maps) from cropland and pastures of the EU. These losses can be as high as 5 - 15 tC ha.

The increase of productivity together with carbon enhancement technologies and crop manipulations can make the soil of croplands and pasture CO_2 sinks across the EU (blue colour in left side maps).

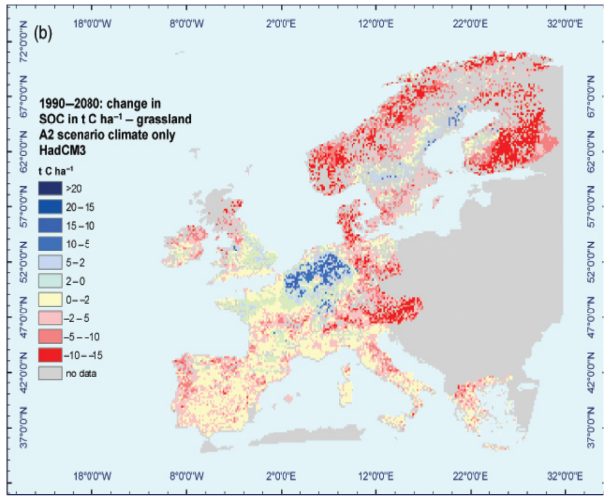
Climate-cropland



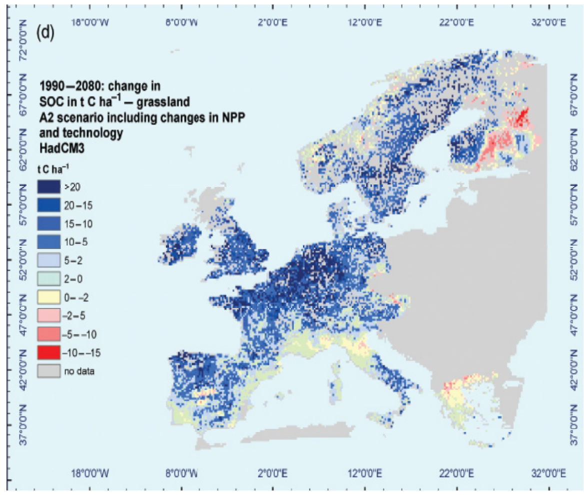
Climate+productivity&technology -cropland



Climate-grassland



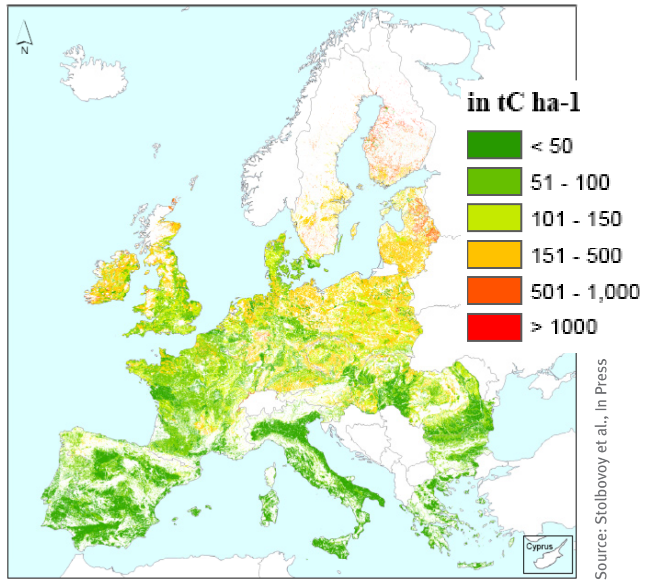
Climate+productivity&technology -grassland



Source: Smith et al., 2005

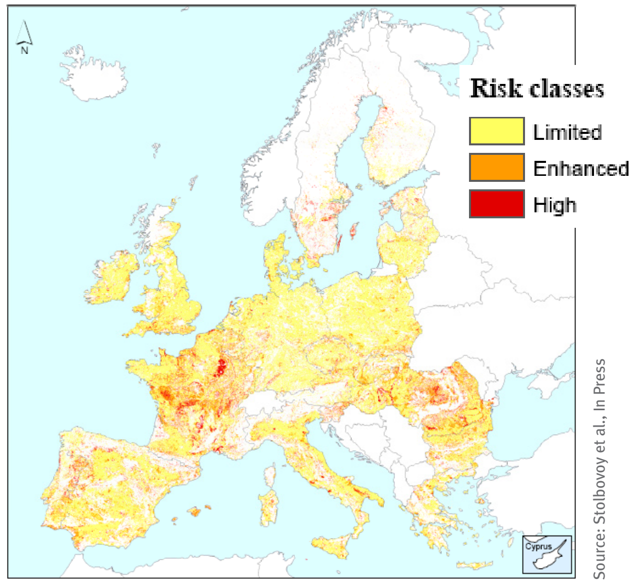
Estimating potentials and vulnerability of soil in the EU to carbon loss

The potential for carbon loss is defined as the difference between actual and minimum carbon contents. Minimum carbon content is controlled by texture and clay mineralogy of soil.



Source: Stolbovoy et al., In Press

The map shows potential for carbon loss (tC ha) in the EU. The highest amounts (more than 150 tC ha) of carbon can be potentially lost in the northern regions of the EU. The central regions of the EU demonstrate a complex distribution of the potential for carbon loss ranging from less than 50 tC ha to more than 150 tC ha. The southern regions of the EU have low potentials to carbon loss, less than 50 tC ha.



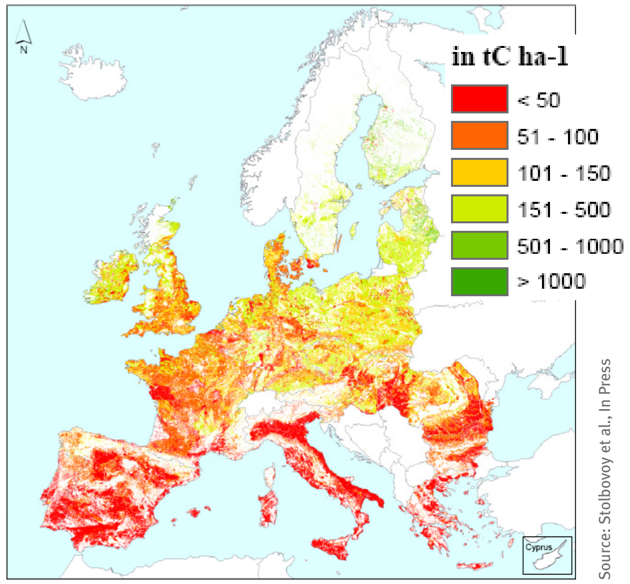
Source: Stolbovoy et al., In Press

The map illustrates zones vulnerable to carbon losses from soils in the EU. In general, the distribution of vulnerable zones is complex. Most soil types in the northern (Scandinavian) regions have an elevated vulnerability (orange) to carbon loss. Soils in western and eastern parts of the EU have considerable areas at high risk (red) while soils in southern parts of the EU have also a rather complex pattern of regions with low and high risks of carbon loss.

The loss of carbon from soil depends on the nearness of the actual content of carbon to the minimum threshold value for a given type of soil.

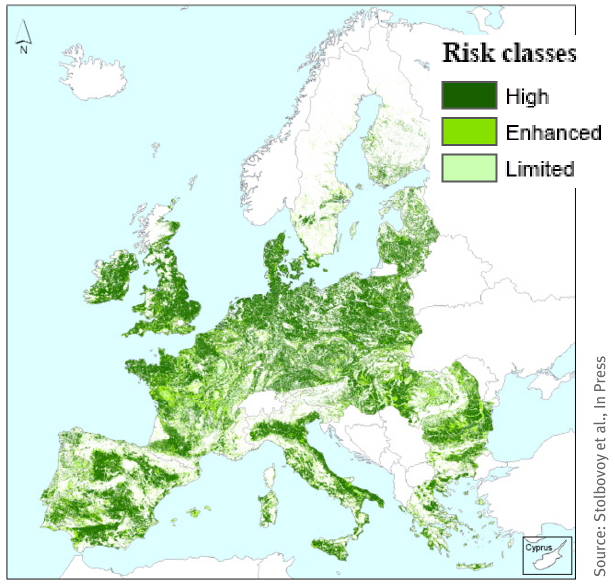
Estimating potentials and rates of carbon gain by soil in the EU

The potential for carbon gain is defined as a difference between actual and maximum carbon contents. The maximum carbon content in cropland soils is often controlled by land management practices.



Source: Stolbovoy et al., In Press

The map shows potentials of carbon gain (tC ha) in the EU. The highest amounts of carbon (more than 150 tC ha) that can be potentially gained occur in the northern regions of the EU (green). The central regions demonstrate a complex distribution of carbon gain potentials ranging from less than 50 tC ha to more than 150 tC ha. The southern regions of the EU have potentials to gain less than 50 tC ha.



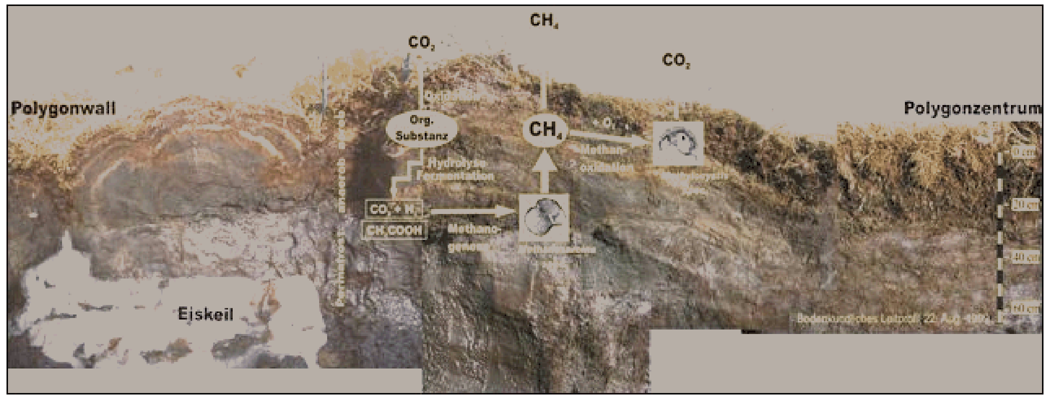
Source: Stolbovoy et al., In Press

The map illustrates the potential rate of carbon gain in the EU. Most of the soils in the northern (Scandinavian) regions have a limited potential rate to gain carbon (light green). The rest of the EU has a complex pattern of regions with combination of limited (green) and high (dark green) potential rate of carbon gain.

The gain of carbon from soil depends on the nearness of the actual content of carbon to the maximum threshold value for a given type of soil.

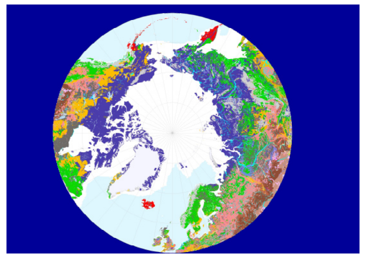
Atlas of Northern Circumpolar Soil

Soils in the northern latitudes are very sensitive to climate change. Increased temperatures will lead to a thawing of the permafrost and stimulate the decay the remains of poorly decomposed vegetation and emissions of carbon dioxide. In anaerobic waterlogged conditions methane is released.

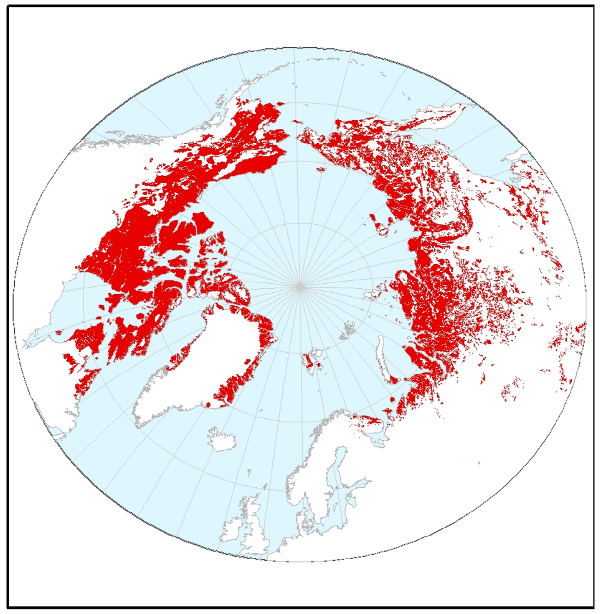


Eva-Maria Pfeiffer1

The JRC SOIL Action is coordinating the development of the first ever atlas of northern circumpolar soil. The atlas provides the latest information on the state of soils and risk from climate change.

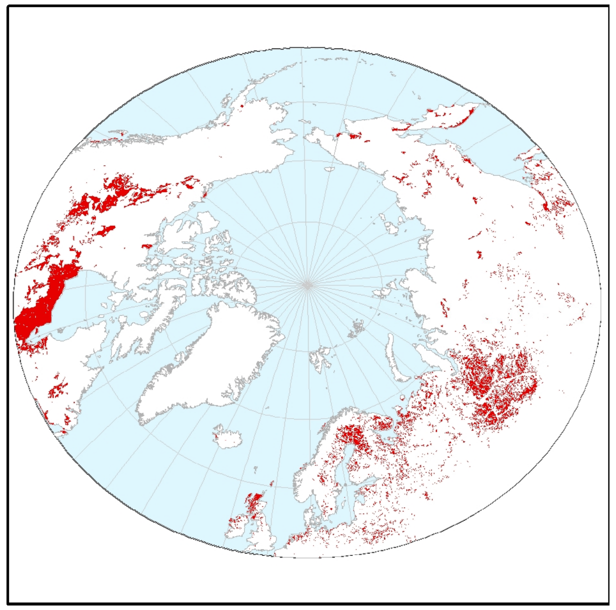


Kimble



Cryosols develop in cold regions where permanently frozen subsoil (permafrost) is found. In this type of soil, water occurs primarily in the form of ice and cryogenic processes such as freeze-thawing cycles, cryoturbation (warping), frost heave, cryogenic sorting, cracking and ice segregation are the dominant soil forming processes that result in distorted horizons and patterned ground. **This profile** from Russia shows a shallow permafrost table at 25 cm depth represented by the presence of horizontal lenses of ice in the soil. The profile appears dark due to the melting of the permafrost as a result of digging the pit. An ice-wedge can be seen to the right of the tape measure. Vertical cracks, filled with organic material, are a common feature.

Lehmann



Histosols are composed of organic material. During the development of the soil, the organic matter production exceeds the rate of decomposition which is slowed down by low temperatures or anaerobic (low oxygen) conditions. This results in the accumulation of partially decomposed organic matter. Histosols occur throughout the boreal and sub-arctic regions. Histosols are usually black or very dark brown and as seen in the **above example** from Russia, contain the recognizable remains of plants. The sharp divide in the profile at 80 cm depth is the boundary of the permafrost.

Storage of carbon in soil

Peat soils are natural 'absorbers' of CO_2 from the atmosphere. The mechanism locks carbon for thousands of years in poorly decomposed remains of vegetation.

Peter Kuhry, Atlas of forthcoming Circumpolar Soil Atlas

Marek Drewnik

Cryogenic processes such as cryoturbation in permafrost affected soils move organic matter from surface horizons to deeper layers of the soil where decay is inhibited by low temperatures. Nearly 30% of the global soil organic matter is stocked in frozen soils (Cryosols).

JRC Mission Statement

The mission of the JRC is to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of EU policies. As a service of the European Commission, the JRC functions as a reference centre of science and technology for the Union. Close to t he policy-making process, it serves the common interest of the Member States, while being independent of special interests, whether private or national.

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JRC-IES Mission Statement

In line with the JRC mission, the aim of IES is to provide scien tific and technical support to European Union strategies for the protection of the environment contributing to a sustainable development. IES works in close collaboration with official laboratories, research centres and industries of the EU's Member States, creating a bridge between the EU's policies and the European citizen. The combination of complementary expertise in the fields of experimental sciences, modelling and remote sensing puts the IES in a strong position to contribute to the implementation of the European Research Area and to the achievement of a sustainable environment.

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