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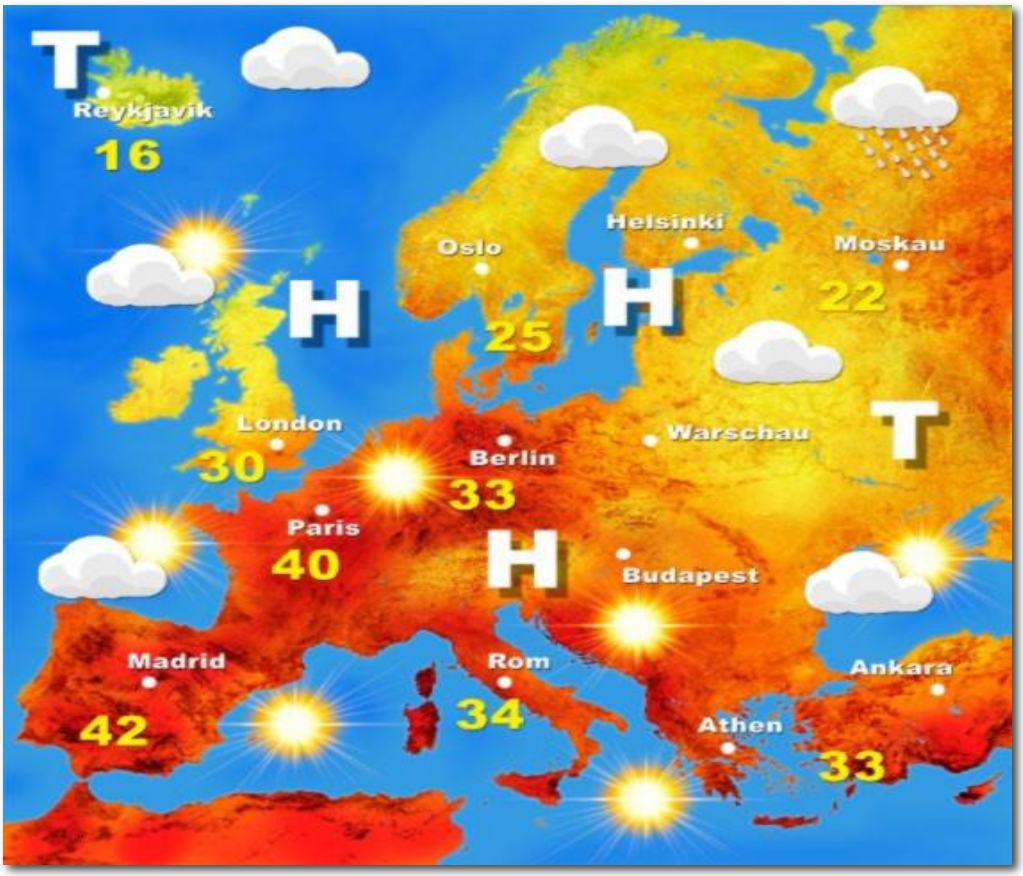
REGENERATION OF SOILS AND ECOSYSTEMS: THE OPPORTUNITY TO PREVENT CLIMATE CHANGE. BASIS FOR A NECESSARY CLIMATE AND AGRICULTURAL POLICY.



2015

International Year of the Soils

SUMMARY

We are probably at the most crucial crossroad of Humanity's history. We are changing the Earth's climate as a result of accelerated human-made Greenhouse Gases Emissions (GHG) and biodiversity loss, provoking other effects that increase the complexity of the problem and will multiply the speed with which we approach climate chaos.[1]

We explain and justify scientifically the need to give absolute priority to the regeneration of soils and ecosystems. The sustainability concept has driven positive changes but has failed on two levels: it has been easy to manipulate because of its inherent laxness, and because of the fact that since the Earth Summit (Rio de Janeiro, 1992) indicators show much worsening and certainly no improvement. Global emissions increase and soil erosion is every year hitting new negative records.

Ecological and agrosystem regeneration necessarily implies a change for the better, a positive attitude and the joy of generating benefits for all living beings, human or not. *For all, because it is the way to not only reduce emissions to the atmosphere but to allow natural, agricultural and livestock soils to* ***act as Carbon sinks, reducing the threat of an all too sudden increasing Climate Change****.*

Regeneration improves products' quality, thereby increasing their market value. It improves the properties not just sustaining but carrying them into a future of permanent virtuous processes, in the long and short run. In this way it tackles the increasing intergenerational justice problems. *By means of increasing the resilience of the agrosystems, it also substantially contributes to Climate Change adaptation.*

In this white paper we:

* Analyse Climate Change causes that are very rarely considered, all relating to the *soil destruction* to which Humanity seems to be committed. This also has dramatic implications for water availability.

* Explain why GHG emissions reduction will not be sufficient to avoid the worst scenarios for Climate Change.

* Discuss the relationships between *Carbon, plants and soils*. In addition we assess the reasons why it has been degraded, and how its regeneration can help avoid further deterioration.

* Carry out a critical analysis of *industrial agriculture*, its failure and the consequences of this.

* Present the consequences for *water availability* of a variety of soil management approaches.

* Show the *importance of prairies and old-growth forests* as Carbon sinks.

- Present different *systems and techniques for regenerative management.*

- Deconstruct various arguments based on *possible areas of uncertainty*.

[1] Isaac Asimov:"Our angry earth" In Bibliography.
[2] Source 1. UNEP 1992 & GRID Arendal. GEO: Global Environment Outlook
Source 2. http://www.unep.org GEO: Global Environment Outlook

- Give examples on how this knowledge is *changing politics, finance and economic reasoning.*
- Provide other examples of *social initiatives and changes* that would help and support the application of regenerative policies.
- Present examples of mass soil and ecosystem regeneration, which provide experience and hope for the results of our regenerating efforts.
- Discuss the situation in the European Union.

Acknowledgments

The first version of this work *("Regeneration: The necessary change of course")* was produced solely for the purposes of spreading information. However, the interest that it provoked encouraged us to expand it and refer to the scientific research that supports its arguments. We would like to offer particular thanks to the Rodale Institute, which shared many of these in its own proposal for Regeneration while describing the various regenerative techniques.

Acknowledgements are due to all the persons whose work is used in this report, and the authors of the publications listed in the "Bibliography". In the sphere of soil and ecosystems regeneration, we are especially grateful for all efforts, since, as John D. Liu stated, this is the ***"great task of our times."***

I would like to thank very much Charlotte Sophie Beauclerck for the generosity with which she has undertaken the translation of this paper, and Rose Cobbe for the hours spent to give this report its final shape in its English version instead of having a stroll under the Tuscan sun.

Íñigo Álvarez de Toledo, MSc

Research Assistant: Luna Politi

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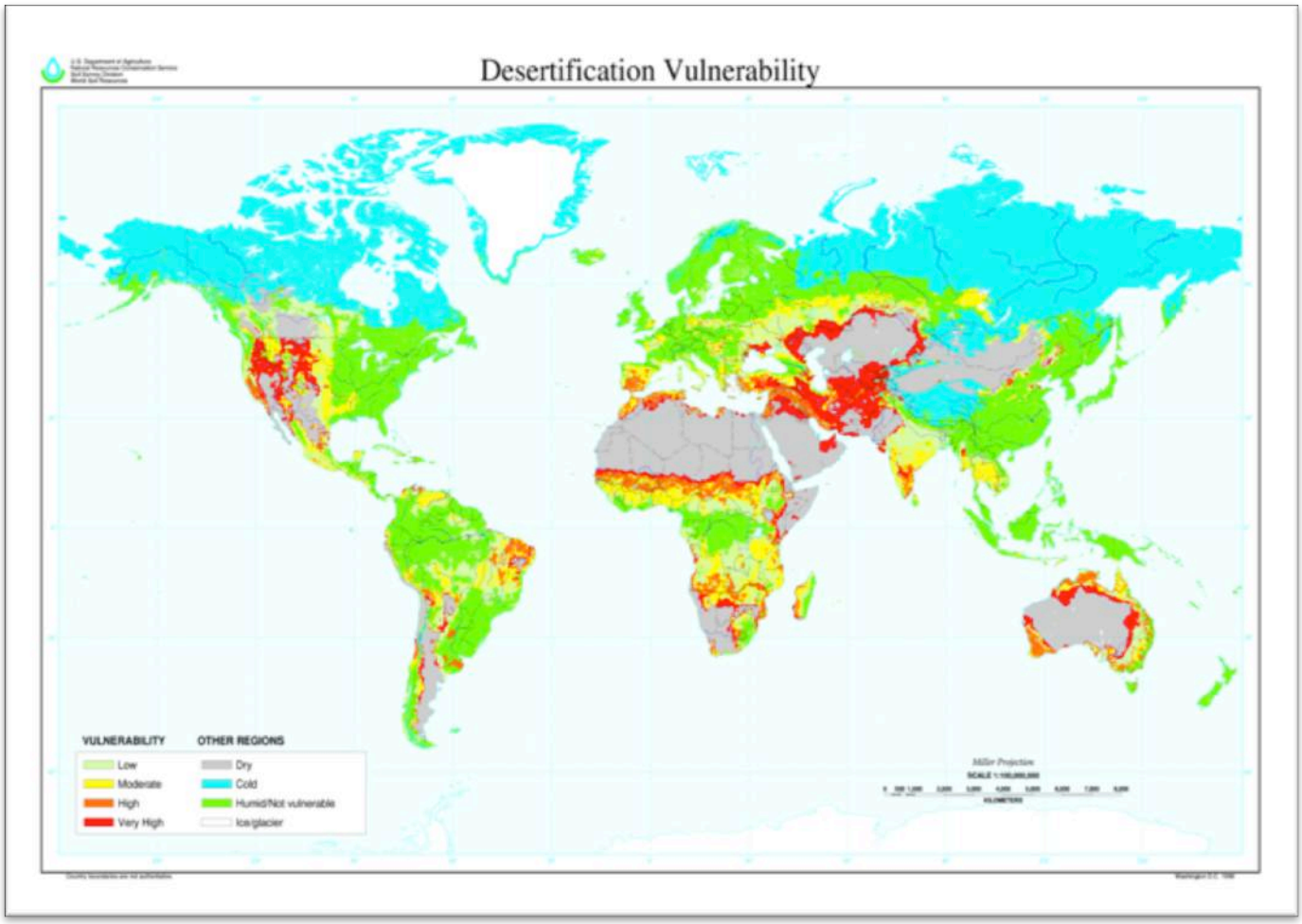
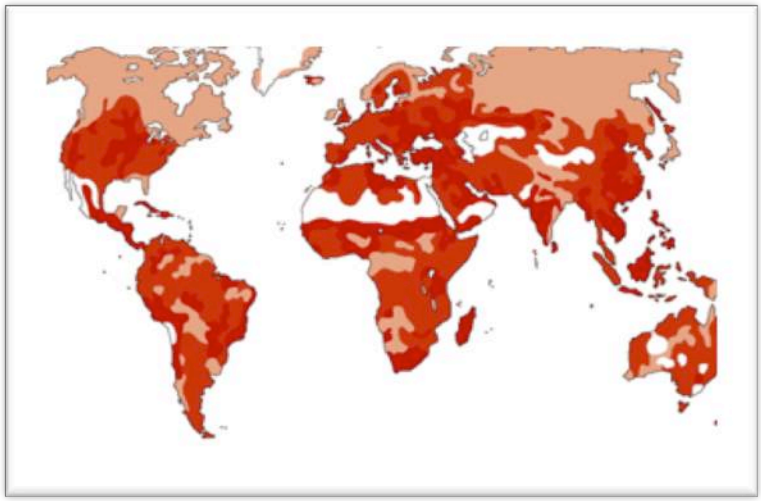
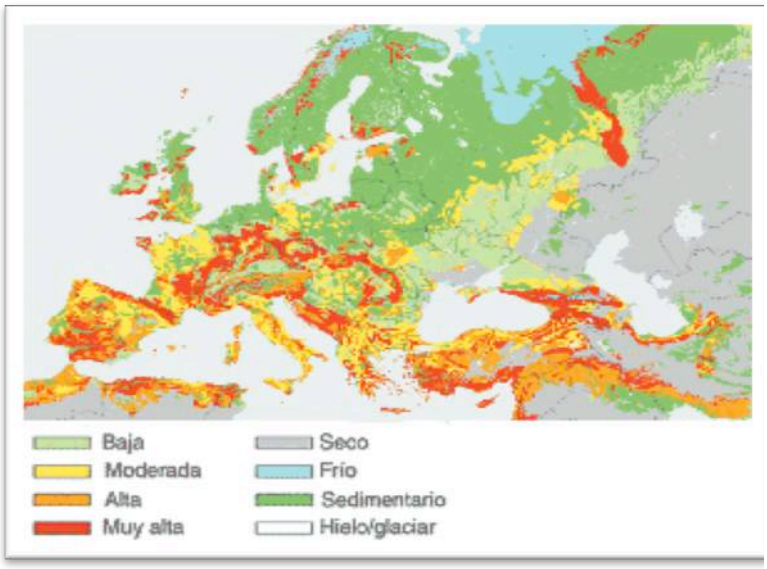

Desertification Vulnerability
VULNERABILITY
Low
Moderate
High
Very High
OTHER REGIONS
Dry
Cold
Humid/Not vulnerable
Ice/glacier

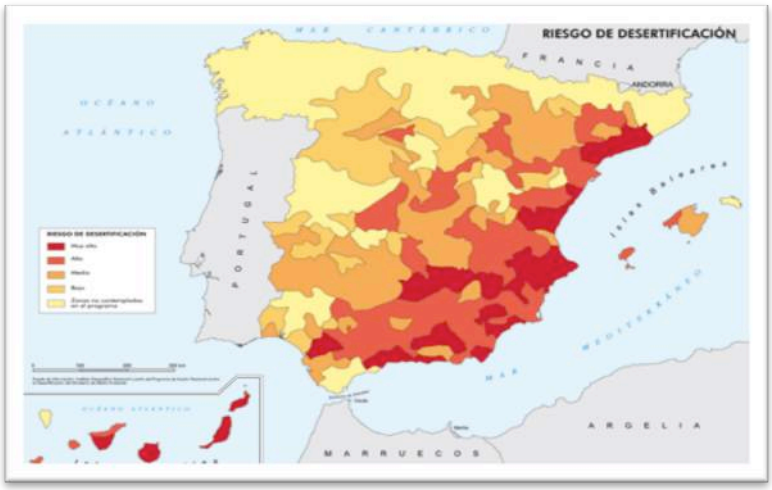
INTRODUCTION[2]: A MATTER OF CIVILIZATION (AND LIFE) AS WE KNOW IT



1. Soil degradation worldwide.



2. Soil erosion in Europe.



3. A dramatic example in Europe: soil desertification in Spain.

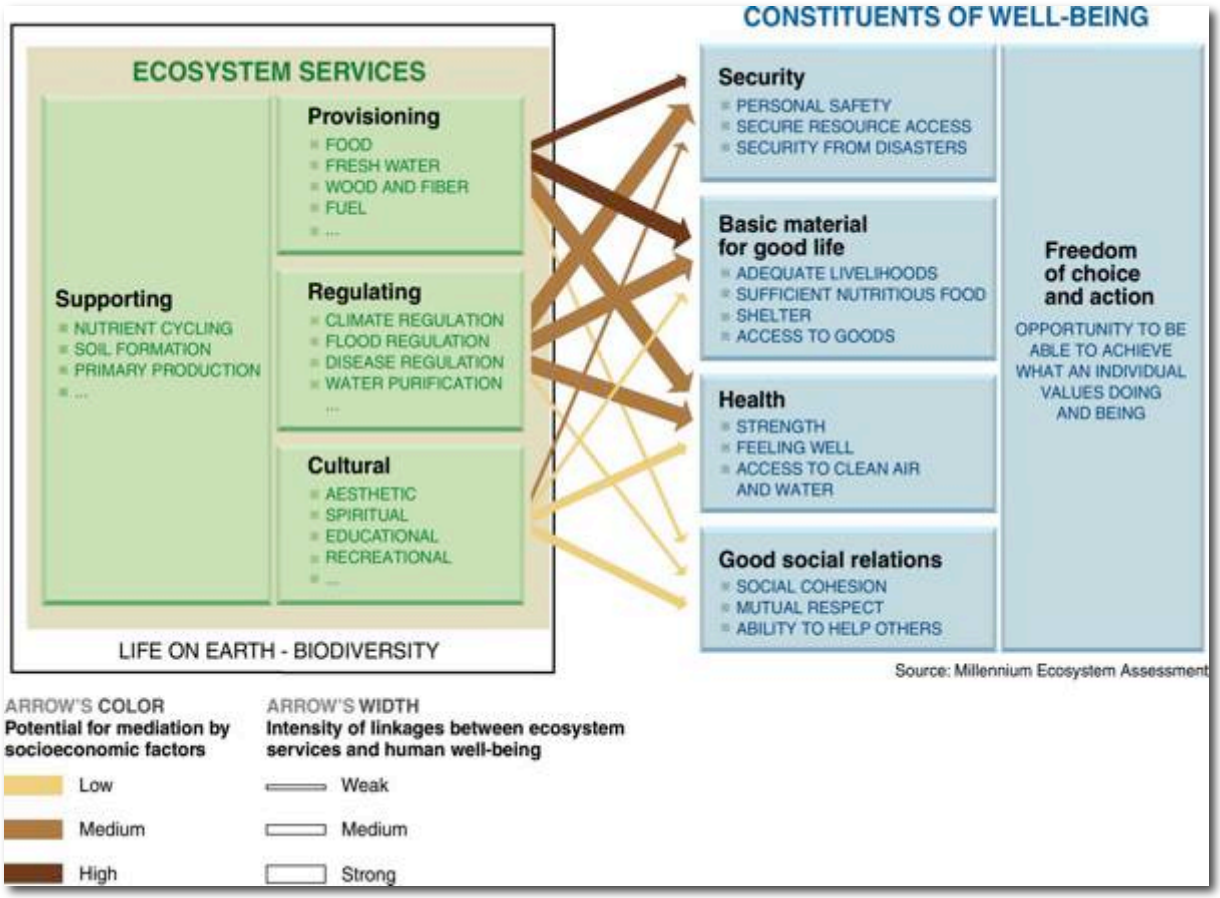
[2] Source 1. UNEP 1992 & GRID Arendal. GEO: Global Environment Outlook
Source 2. http://www.unep.org GEO: Global Environment Outlook
Source 3. Instituto Geográfico Nacional. At http://www.ign.es

Civilizations rise and fall, as does the quality of their soil. We now have the opportunity to act in accordance with the lessons learnt from history. Jared Diamond has studied this issue, and examines it effectively in his book *Collapse*[3]. A number of ancient societies experiencing severe environmental problems managed to deviate from this destructive course in time, this avoiding decline and eventual collapse. The Icelandic people did so, but the Sumerians and Mayans did not, and vanished from History.

For those interested in the general consequences of Climate Change, *Global Crisis*[4], published recently by Geoffrey Parker, studies in greater depth the tremendous implications of the "Small Climate Change" of the 17th century.

These civilizations, and other ancient ones, were relatively local, with limited processes of decline. The current context is very different. The ***Assessment of Ecosystems of the Millennium***[5] – a global study carried out by 1,360 scientists over the course of four years - determined that 15 of the 24 primary ecosystemic services are undergoing degradation processes, and no improvements can be observed.

According to a range of scientists, our current system of exploitation and consumption will only last between 50 and 60 years before Nature is no longer able to provide crucial services in terms of water, soil and air.[6]



Relationship between ecosystemic services and quality of human life.

[3] In Bibliography
[4] Id
[5] Id
[6] Mercola, J: Carbon Sequestration- The Climate Change Solution That Virtually All Climate Activists Ignore. At http://www.iqfit.com/carbon-sequestration-the-climate-change-solution-that-virtually-all-climate-activists-ignore/ (2015)

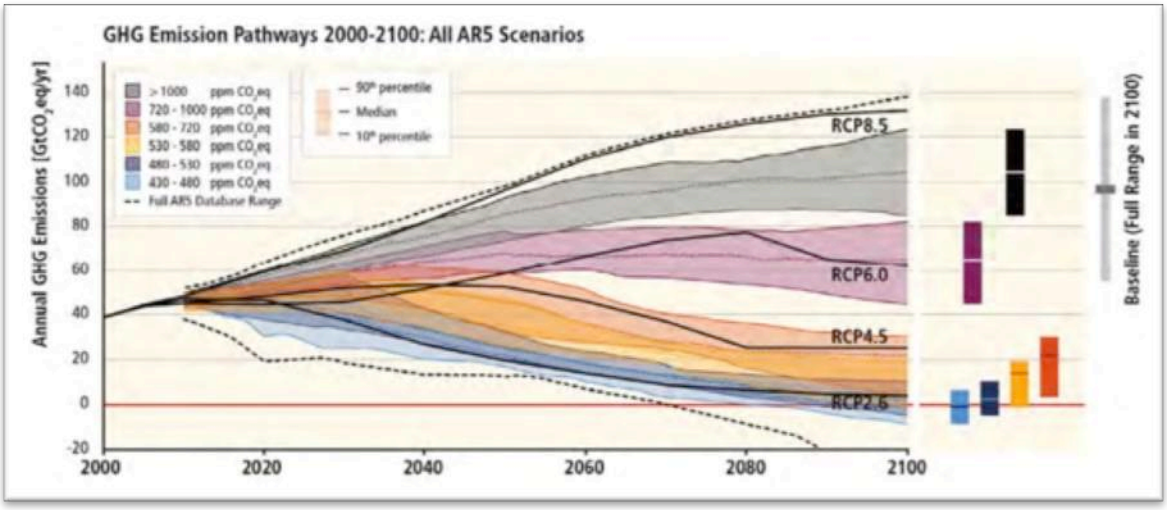
All efforts to date have involved reducing the direct emissions produced by our activities. This is not effective, for at least three reasons:

1. *The atmosphere has an oversupply of GHG, and climate change is fully underway*. We entertain the hope - or illusion - that this will limit climate change, though no certainty exists on this point.[7] However, eminent scientists have solid reasons to be less optimistic. James Hansen (University of Columbia) states that an average increase of 2°C will cause *unsustainable damage*[8], and proposes reducing global emissions by 6% a year for 40 years. Meanwhile, Kevin Anderson, also a climatologist, considers that they must be decreased by 10%[9] (see also *"Ecological-Systemic urgency"*). As regards the objective of maintaining the average temperature increase at 2°C, he has argued: "Perhaps this goal could have been achieved after the World Summit (1992) or the arrival of a new millennium, but Climate Change is an accumulative issue. Today, after two decades of promises and lies, what remains of this objective requires a revolutionary change."[10] *As a matter of fact, the European Commission believes that its proposals for Paris 2015 only provide a "good chance" that the average global temperature will not rise by over 2°C.*[11]

2. *The political effort invested since 1992 is proving to be insufficient*: we must counter the emissions produced by a wide variety of activities and sectors across the world. The fact is that, year after year, global emissions are rising.

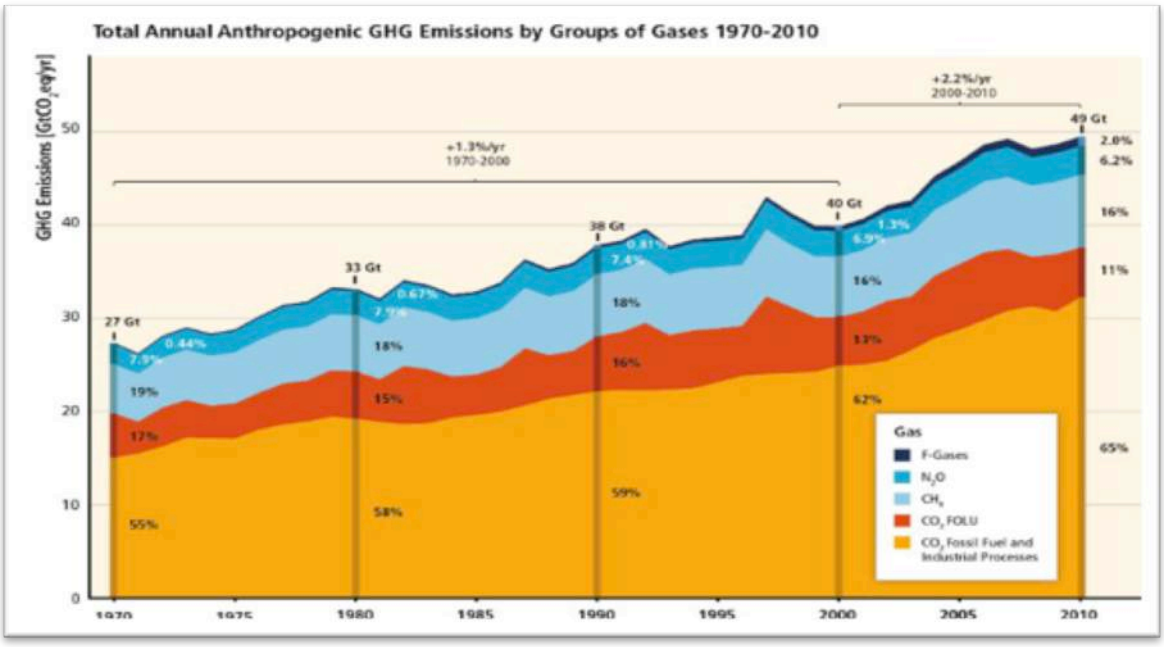
3. *The emissions are not only caused by the burning of fossil fuels:* soil degradation emits carbon into the atmosphere, whereas it used to fertilise these soils –and we have become proficient at soil degradation and desertification.

Climate Change has accelerated in recent years due to our intensive use of fossil fuels, but also because of the expansion of deserts, including "agricultural deserts." It is a fact that we are causing the soil degradation and increase of deserts, to the detriment of formerly fertile land.[12]



Possible emissions scenarios, up to 2100 (IPCC).

[7] Rogelj, J., McCollum, D. L., O'Neill, B. C. & Riahi, K. 2020 emissions levels required to limit warming to below 2°C. Nat. Climate Change (2013).
[8] Hansen, J: Assessing dangerous climate change En Plos One http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0081648 (Diciembre 2013).
[9] Anderson, K. Avoiding dangerous climate change demands de-growth strategies from wealthier nations. At http://kevinanderson.info/index.php
[10] Anderson, K. More information can be found at http://kevinanderson.info/index.php
[11] European Commission: COMMINICATION TO THE EUROPEAN PARLIAMENT AND THE COUNCIL. The Paris Protocol. (2015)
[12] Savory, Allan. Holistiv Managment. In Bibliography



Total Greenhouse Gas Emissions, by type (IPCC).

The crisis caused by Climate Change forces us to consider innovative alternatives to resolve it. Achieving zero emissions globally (which per se is virtually impossible, at least in the next 100 years) would not prevent the potentially catastrophic consequences for life on Earth as we know it due to the current level of approximately 400 ppm of CO2 in the atmosphere. We have crossed the boundaries of the acceptable for human life as its now organised.[13]

Unfortunately, the situation would not improve in the event of a return to 350 ppm, which would only imply decelerating climate change to 1988's already alarming levels.[14]-[15] It could even reach a worse level than this, due to the accumulation of past and current damage, which undermines the planet's ability to absorb excess heat. The effects will probably be irreversible if the concentration of GHGs does not return to preindustrial levels, that it, under 300 ppm.

Consequently, achieving this heroic objective requires not only ceasing to produce GHGs, but also removing over 100 gigatonnes (GT) of CO2 from the atmosphere.

The emission of CO2 and other GHGs by burning fossil fuels is not the only cause of climate change and probably is neither its principal cause. There are factors that are not usually considered by scientists and ecologists: human beings began to change the climate in ancient times, and destroyed entire living communities. Ancient practices, which are still carried out today, degrade the earth and increase carbon dioxide and other GHGs in the atmosphere, whereas they used to fertilise the soil.

This process of environmental destruction wiped out many civilizations, even before coal and oil were discovered.

[13] Hansen, J: Target atmospheric CO2: Where should humanity aim? In *Open Atmospheric Science Journal* (2008).
[14] Hansen, J Shabecoff :"Global Climate Changes as forecast by Goddard for Space Studies three-dimensional model". In *Journal of Geophisycal Resarch*. (1988).
[15] Shabecoff, P:Global Warming Has Begun, Experts Tells Senate. In the *New York Times* (1988).

As a result, even if the world were to achieve zero fossil fuel emissions overnight, the burning of pasture and savannahs would still continue as would the use of degrading industrial agriculture: ***desertification would continue to accelerate, due to the soil's inability to store carbon and water. The climate would continue to change.***[16]

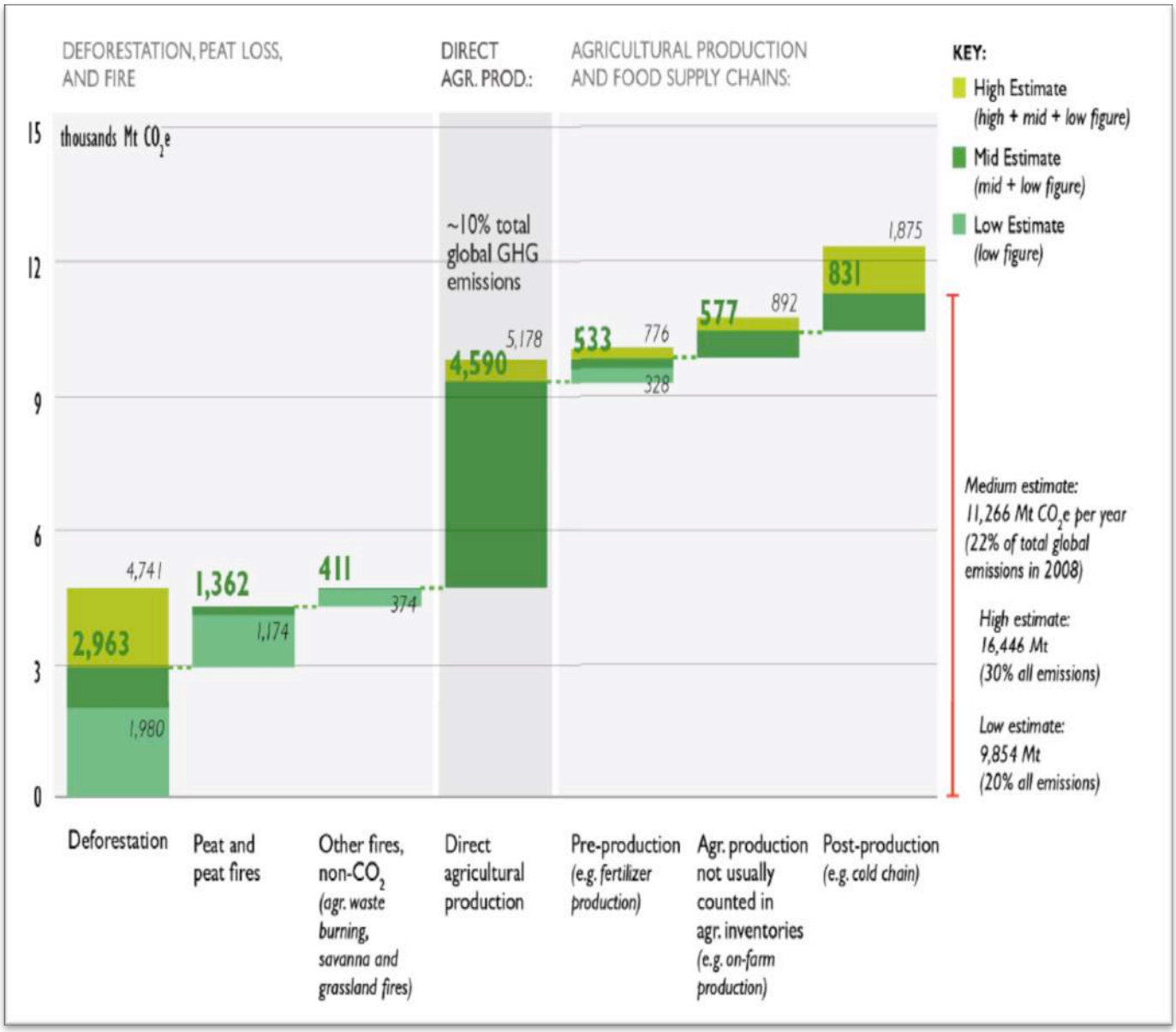
Suppressing live and dead vegetation cover also causes the soil to emit carbon stored within it, thus contributing to climate change.

Soil degradation and climate change are inseparable*, and have taken place throughout history,* destroying civilizations in many different regions of the world. It is therefore almost pointless to be concerned solely with GHG emissions caused by burning fossil fuels and not by the loss of biodiversity and soil degradation. *It is impossible for the climate not to change, as it depends on the life of the planet.*[17]

The crucial question is, how the Earth can return to storing the vast quantities of carbon that are currently in the atmosphere. It also needs to do so naturally, without risk, and affordably. The biological systems on land are capable of this (as do the oceans, though now reaching a saturation point).

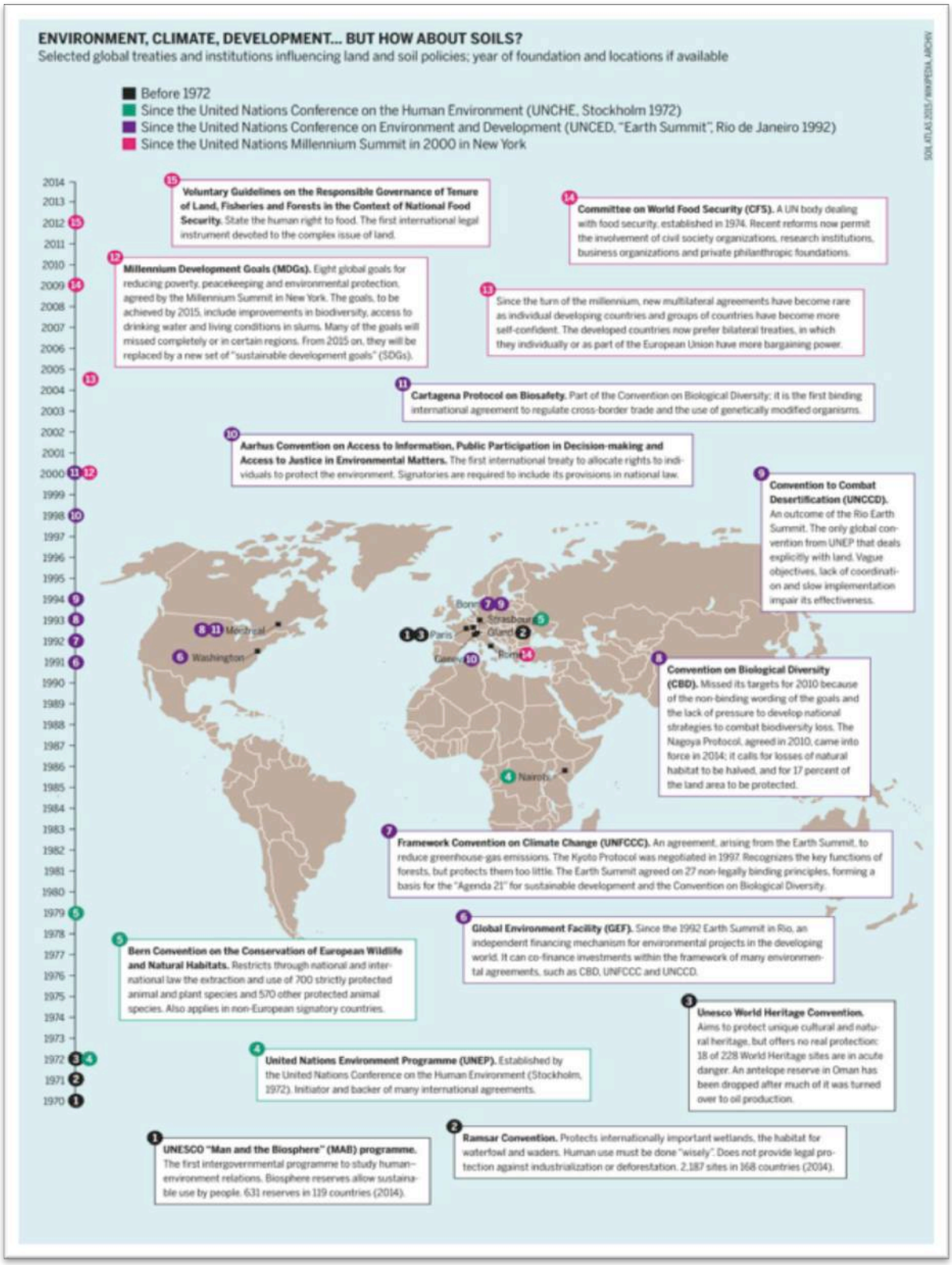
This can only be done through an extensive global regeneration of soils and ecosystems.

[16] Allan Savory: Holistic Managment. In Bibliography.
[17] James Lovelock: The ages of Gaia. In Bibliography.



GHG emissions from the Agricultural Sector.[18]

[18] Climate Focus/CEA (California Environmental Associates):"Report 2014 .Strategiesfor Mitigating Climate Change in Agriculture.".In Bibliography



Environment, Climate, Development… and what about soil? Global treaties and institutions that influence policy on soils. The only treaty directly devoted to this is the convention against desertification (UNCCD, 9).[19]

[19] Source: Soil Atlas 2015. In Bibliography

Premise

It is when carbon is in the form of carbon dioxide gas in the atmosphere that it has its effect on climate change. One tonne of carbon is equivalent to 3.67 tonnes carbon dioxide.

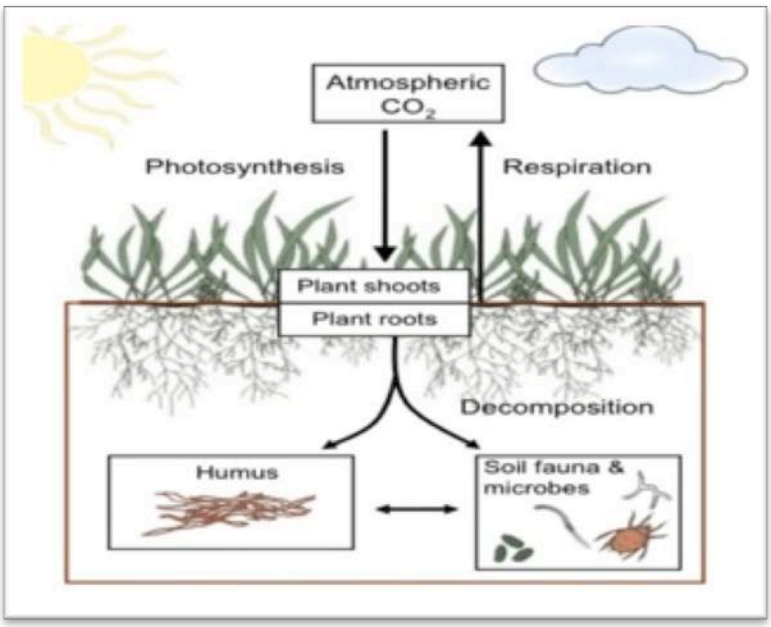
Through photosynthesis, plants absorb carbon from the atmosphere. They emit the excess through the roots as a sugar, to feed organisms in the soil. There, the carbon is humidified, and thus stabilizes. The carbon is the principal component of the organic matter in the soil, and gives it its *capacity for water retention, structure and fertility.* Some carbon deposits in the soil aggregate are so stable that they can remain there for thousands of years.

In the upper part of the soil there are the "active" deposits; there is a constant flux between its organic life and the atmosphere. We must facilitate the growth of stable deposits.

95% of the terrestrial biodiversity is in the soil, and only 5% is above it. Carbon provides the necessary energy for the functioning of this system, and the roots form the habitat. Life (vital processes) gives the soil its structure, allowing the infiltration and retention of moisture, restoring balance in water distribution and curbing desertification processes. Life restores natural fertility, and captures the carbon, nitrogen and sulfur from the atmosphere. The life of ecosystems favours the accessibility of phosphorus and other elements in the roots. The question is then how to give life back to the soil, and produce while preventing the synthetic chemistry that kills it, as will be discussed later.

Many forms of life require carbon for their growth and reproduction. Trees, pasture and crops need the carbon dissolved into the sap. Animals' growth depends on digesting carbon and transporting it in blood to the cells. The formation of the mould in the soil is a result of photosynthesis and the transportation of the carbon in plants into the soil, through microbial action.

Carbon is the main currency in use in the majority of transactions between living beings, and this is most patently in soil. Mycorrhizal fungi, which are entirely dependent on the carbon from green plants, exchange it with colonies of bacteria in their hyphae by obtaining macronutrients such as phosphorus, nitrogen and calcium, elements including zinc and copper, and other substances that stimulate growth.[20-21]



Atmosphere-earth carbon cycle

[20] Killham, K. :Soil Ecology. En Cambridge University Press (1994)
[21] Leake, J.R, Johnson, D., D.P., Muckle, G.E, Boddy, L and Read, D.J.: Networks of power and influence: the role of mycorrizhal mycelium in controlling plant communities and agroecosystem functioning. Canadian Journal of Botany (2004).

Historical fertility, current fertility

The then famous explorer and geologist Count Strezelecki travelled across the southeast of Australia between 1839 and 1843, visiting farms and analysing the soils. One of the principal premises of his research was finding the factors that determine soil productivity. He collected 41 samples from various soils, and his analysis demonstrated that the most determining factor is the quantity of organic material (or carbon) in the soil. The ten most productive soils had levels of organic material of between 11% and 37,75%. The ten least productive ranged between 2,2% and 5%.[22] *Today, any agricultural soil with a level of 5% is considered extremely rich.*

Degradation

"Degradation" of the soil generally refers to the process through which human action decreases the soil's current or potential capacity to produce goods and services.[23]

The bareness of the soil throughout most of the year degrades it, and the use of poisons and synthetic chemical fertilisers exacerbates the problem. "Industrial agriculture", which involves both practices, has obtained impressive short-term increases in production but has been shown to destroy life in the soil, thus causing it to fail – as is already occurring.

Across the world the majority of agricultural land, including irrigated land, has lost a considerable part of its organic matter and life, which is responsible for the greatest soil erosion observed in history.[24]

During the second half of the 20th century, the mass adoption of this kind of agriculture, which includes nitrogenous fertilisation, deep tillage, monocultures and the massive use of synthetic chemical poisons, has accelerated the destruction of soils and their carbon reserves.[25]

Bare soil indicates that it only minimally absorbs or retains carbon. It also signifies that it is exposed to the wind and water, which strips off its first layer, which is fertile and rich in carbon. As a result, there are many less plants to increase the quantity of carbon in their biomass. Soil subjected to ploughing, to atmospheric agents and erosion undergoes a break in its structure, which causes the carbon - formerly stable – to be emitted into the atmosphere as a Greenhouse Gas.[26]-[27]

Tilling also undermines the development of mycorrhizae, which play an important part in the formation of aggregates. Many synthetic chemical inputs, whether pesticides, herbicides or soluble fertilisers, also weaken, destroy or inhibit them.

Moreover, during the decade between 2000 and 2010, emissions in the agricultural sector increased by 1% a year. The system as a whole, comprising the creation of fertilisers and biocides, animal feed, production, transport, refrigeration, waste management, represents over 30% of global GHG emissions into the atmosphere.[28]

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[22] Strzelecki, P.E: Physical description of New South Wales and Van Diemen's land: accompanied by a geological map, section and diagrams, and figures of organic remains. Printed by Longman, Brown, Green and Longmans London (1845).
[23] European Parliament 2009, in Suolo, patrimonio dell'Umanità: quanto ne stiamo perdendo per erosione, inquinamentoe cementificazione? Marco Nuti. At http://agrariansciences.blogspot.it/2014/11/suolo-patrimonio-dellumanita-quanto-ne.html (2014).
[24] UNEP: Global Environment Outlook 3. At http://www.grid.unep.ch/geo/geo3/spanish/141.htm#fig65
[25] Khan, S. A., Mulvaney, R. L., Ellsworth, T. R. & Boast, C. W. The Myth of Nitrogen Fertilization for Soil Carbon Sequestration. J. Environ. Qual. (2007).
[26] Lal, R. Soil erosion and the global carbon budget. Environ. (2003).
[27] Montgomery, D. R. Soil erosion and agricultural sustainability. Proc. National Academy Sci104, 13268 (2007).
[28] Vermeulen, S. J., Campbell, B. M. & Ingram, J. S. I. Climate Change and Food Systems. Annu. Rev. Environ. Resour. (2012).

In terms of net carbon emissions, *"industrial agriculture"* is also a failure, for both its direct emissions and its destruction of the soil's storage capacity.

However, certified *ecological agriculture* is not markedly different to the industrial kind. Indeed, though it does not employ chemical substances it does not correct its other defects, and involves methods that have wiped out over 20 civilizations worldwide through the loss of biodiversity and desertification.

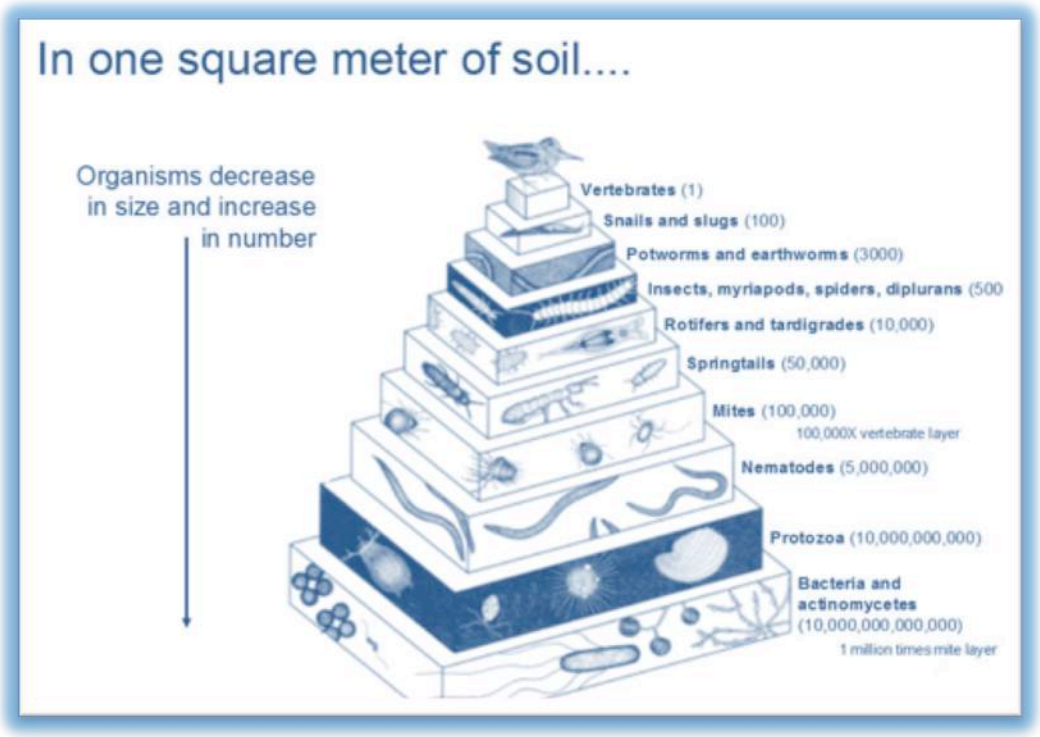
Bare soil in Córdoba (Spain) in autumn. The landscape resembles a desert, and behaves as such in many regards.

The only possible kind of sustainable agriculture has to imitate Nature in its regenerative capacity:

- restoring soil health,
- keeping it permanently covered and with healthy life processes thanks to the use of, for example, biodynamic preparations or compost tea,
- with polyculture systems,
- combined with sufficient natural vegetation.

These are *genuinely evolved forms of agriculture,* significantly different to the current conventional (and frequently even organic) kind, which consists in a single crop, leaving the soil bare between plants and rows, and entirely bare during long periods in the case of non-permanent crops. Improved management through well-known, tested and affordable practices reduces emissions and converts the soils into carbon sinks.

The first, biological layer of the soil contains a large part of its biodiversity and provides the necessary substances and services for life above the soil. One hectare of land, 25 cm deep, which weighs 3,000 tons and only contains 1,5% organic matter (such as much of the land in Mediterranean Europe) contains up to 3 tons of microbes belonging to 2,000 different species. It is a vast living biochemical library that produces a wide variety of genetic instructions.[29]



The microbes in the soil and those around the roots are almost always organised into multi-species "consortiums."

In agro-systems their role is to:

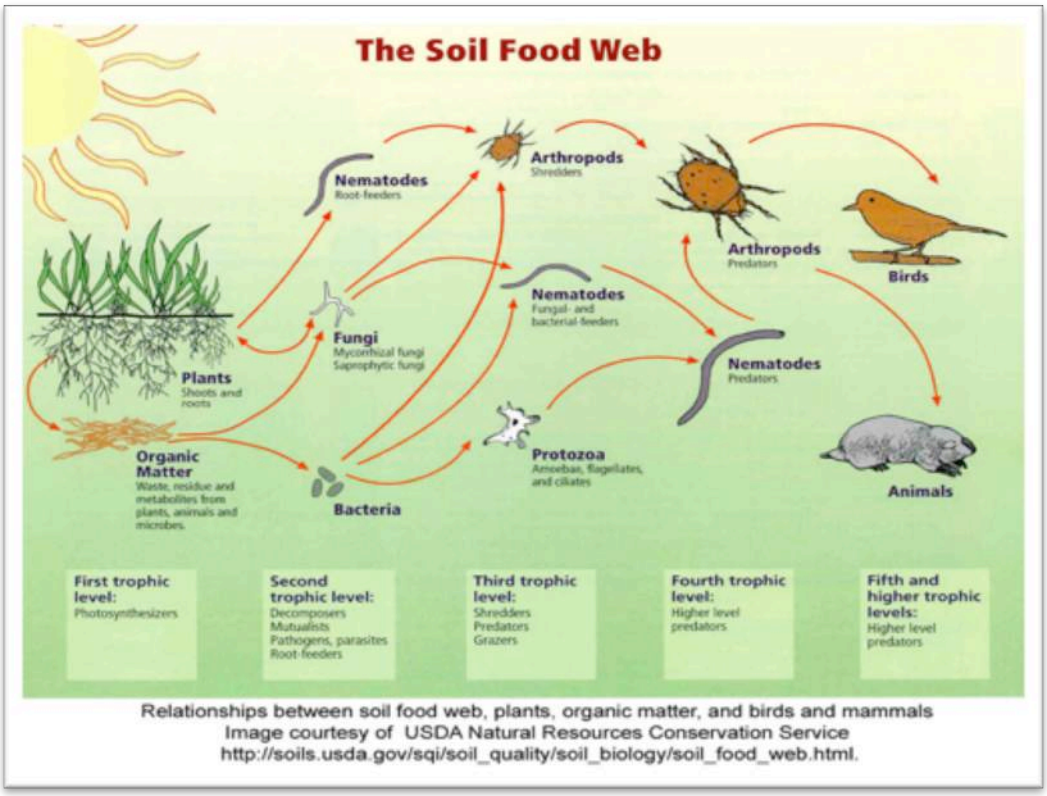
a) maintain biogeochemical cycles, including those of nitrogen, sulphur, iron and manganese;

b) interact with plants, ensuring their health and nutrition; and

c) maintaining functional biodiversity. If due to an environmental "stress" – such as pesticide use – a group becomes unable to carry out its normal function (like the process of nitrification and ammonification), another group will substitute it and these processes will continue.

However, *one factor* limits this mechanism. The quantity of organic substance in the land: indeed, ***this functional biodiversity requires approximately 3,5% organic substance in order to be active (→ c. 1,75% carbon)[30].***

[29] Nuti, M: "Suolo, patrimonio dell'Umanità: quanto ne stiamo perdendo per erosione, inquinamentoe cementificazione?" At http://agrariansciences.blogspot.it/2014/11/suolo-patrimonio-dellumanita-quanto-ne.html (2014).
[30] Nuti, M: Id.



Trophic relationships, which are necessary for living soil.

Soil degradation has been a well-known fact since the 1970s, when the then *European Economic Community* warned that "*the loss of productive soil is one of the most urgent and difficult problems facing the future of humanity*."[31]

Erosion depends on three factors: the first two are the slope and the degree of cover of the land. The combination of both, as often occurs in hills and mountain ranges and elsewhere, leads to dramatic situations that have been witnessed time and again. These are subsequently aggravated by the increase in torrential rainfall (the third factor being the rain intensity).

[31] C.E.C 1977, in M. Nuti.. id

"One of the principal environmental problems caused by olive growing is soil deterioration of the soil" caused by "unsuitable practices, such as mechanised ploughing and the use of pesticides (herbicides and insecticides) and synthetic chemical fertilisers." It also has "a harmful effect on wildlife, having suppressed large natural habitats."[32] Naturally, this can be applied to practically any other conventional agricultural production.

Indeed, in the case of agricultural fields, the surface of the soil is yellow, grey, reddish or brown, and in general light tones predominate, entirely at odds with the normal conception of soil! The surface horizon - black, fertile and rich in organic matter, has disappeared from many of our fields.

This is due to:

- depletion (without replenishment);
- mineralisation (the lack of vegetation cover increases the temperature of the soil), and mineralisation prevails over humidification);
- erosion.

Principal issues and dangers associated with conventional agriculture (in semiarid and arid zones in particular) are:[33]

A) The high degree of soil erosion and degradation,

The greatest ecological and territorial problem in many countries worldwide, and which must be resolved most urgently. This is caused by inadequate management, which includes:

- compacting soil using machinery,
- bare soil, and
- lack of knowledge regarding processes of natural organic fertility.

[32] LIFE: entre los olivos. European Commission, 2010.
[33] Adaptation from: Sanz Cañada, Javier: Investigación e innovación en el sector del aceite de oliva en España. Problemas, oportunidades y prioridades de I+D+i. At ALENTA, Plataforma Tecnológica del Olivar. (2012).

Soil degradation and loss is an unsustainable decrease in the natural productive heritage. which jeopardises the future in many zones.

To reverse these processes, the following must be done:

1- increase life in the soil and subsoil,
2- crop systems with vegetation cover,
3- the use of waste, most efficiently if composted.

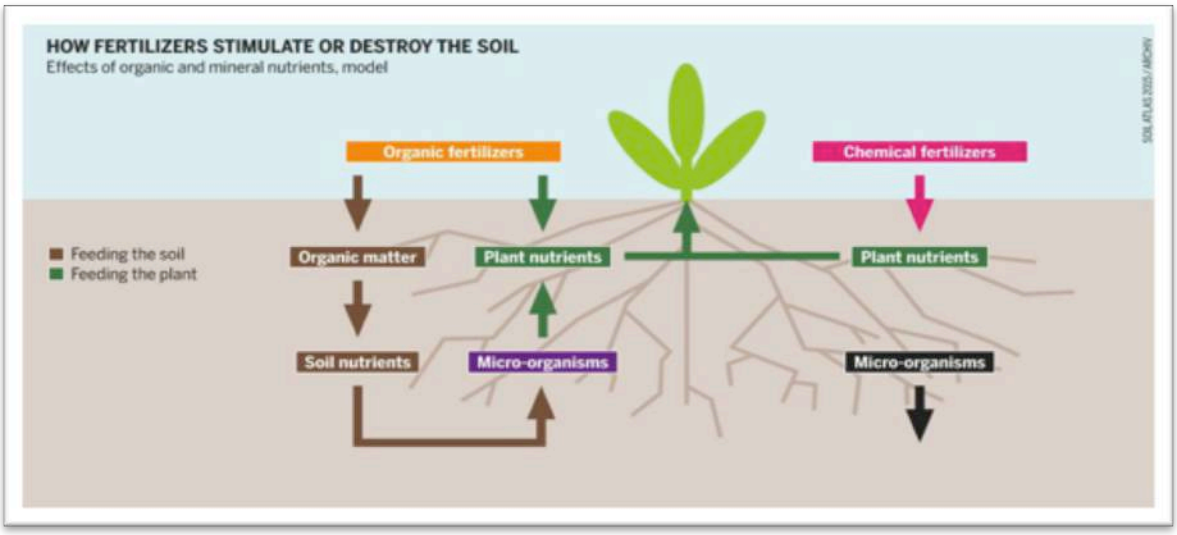
B) The unchecked use of biocides (herbicides, insecticides, fungicides) and synthetic fertilisers, which causes:

- contamination of soil, waterways and aquifers,
- death of animals and plants other than crops,
- food security risks, and
- contamination of reservoirs for irrigation and supplying the population.

Logically, it also kills the soil life and consequently its fertility, which leads to erosion.

Solution and alternatives:

- pest control by strengthening plants and increasing biodiversity. To do so, the following are necessary:
- increase life in the soil and subsoil,
- crop systems with vegetation cover,
- the use of waste, most efficiently if composted.



How fertilisers, depending if ecological or chemical, stimulate or destroy the soil.[34]

C) Decrease in biodiversity and landscape diversity.

This is once again linked, in addition to the intensification of monocultures, to the use of synthetic chemical poisons, which wipe out the animal and plant life in the soil and subsoil, and the wildlife.

The solutions are:

1. increasing species of tree and scrub,
2. increasing life in the soil and subsoil,
3. crop systems with vegetation cover,
4. the use of waste, most efficiently if composted

[34] Source: Soil Atlas 2015. In Bibliography

The soil must be kept covered to foster organic matter and life in it, and to store atmospheric carbon. ***Relatively small rises in organic matter across large areas of soil imply millions of tons of stored carbon.*** Our greatest hope for (earthly) salvation lies here.

D) Available water resources.

The expansion of irrigation for intensified agriculture has required a large increase in water consumption. Many zones have reached their limits of water availability. The solution to this (which will also prevent erosion) is soil that is fertile and rich in vitality, with a capacity for rainwater absorption and retention. To this end, the following is once again necessary:

1 - increasing life in the soil and subsoil,
2 - crop systems with vegetation cover,
3 – the use of waste, most efficiently if composted.

WATER

In many zones of the world, the greatest challenge posed by climate change will be water availability. According to the Intergovernmental Panel for Climate Change, the following factors:

- increase in temperatures,
- increase in solar radiation in numerous places,
- reduction in rainfall, and/or
- greater irregularity of rainfall

will exacerbate soil degradation and desertification.
Desertification is often accompanied by salinisation (and vice versa), which currentlyaffects 7% of the earth and 20-25% of irrigated soil. Moreover, irrigation represents 70% of water use worldwide.[35]
This will place a heavy pressure for direct food production, questioning the very existence of gardens, golf courses, vineyards and even olive groves.[36]

The issue of water cannot be perceived as independent to other climate-related topics: N2O and CO2 emissions from agricultural land arguably contribute more than any other source to the Greenhouse Effect, but these emissions depend on the soil's water and organic matter content.

Any increase in the soil's organic matter improves the former's structure which increases its capacity for the infiltration and retention of water and oxygen. ***The quantity of water that can be stored in healthy soil dwarfs the amount held in all the world's reservoirs.*** This is closely linked to strategic security, in a world in which in the future wars are likely to be waged over water.

The absorption capacity also contributes to minimising the frequency and severity of ***droughts and floods and their effects, which are often caused by the soil degradation, rather than by changes in rainfall patterns.***[37]

[35] UNEP: Global Environment Outlook. At http://www.grid.unep.ch/geo/geo3/spanish/141.htm#fig65
[36] Álvarez de Toledo,I: Vino, Viticultura y Cambios Climáticos. In Bibliography.
[37] "The water cycle". In Bibliography.

One part of humus (a very stable form of edaphic carbon) can contain, on average, a minimum of four parts water.[38] This permits the calculation that ***for every 1% increase in carbon, every square metre can store 16,8 litres of water in the first 30 cm of the soil (in soils with a volume density of 1,49/cm^3). This signifies that it can store 168.000 extra litres of water per hectare.***[39]

In Australia, for example, carbon levels have decreased by at least 3% since the arrival of the European settlers. This reduction means that the soil is incapable of storing a huge quantity of water per hectare, which would have been available for the plants, particularly in periods of scarce rain.[40]

Carbon-poor soil after the rain (right).[41]

One consequence of physical soil erosion is ***chemical erosion***: solubilisation and lixiviation drag the nutrients through the run-off waters and they end up in rivers and reservoirs, thus polluting the latter. The aquatic ecosystems "defend themselves" through a process of anaerobic decomposition, emitting toxic gases that spread the pollution for many kilometers around. Other chemical compounds are also lixiviated, such as for example the herbicides from the group of triazines, which pollute surface and underground water in rivers, reservoirs and wells.

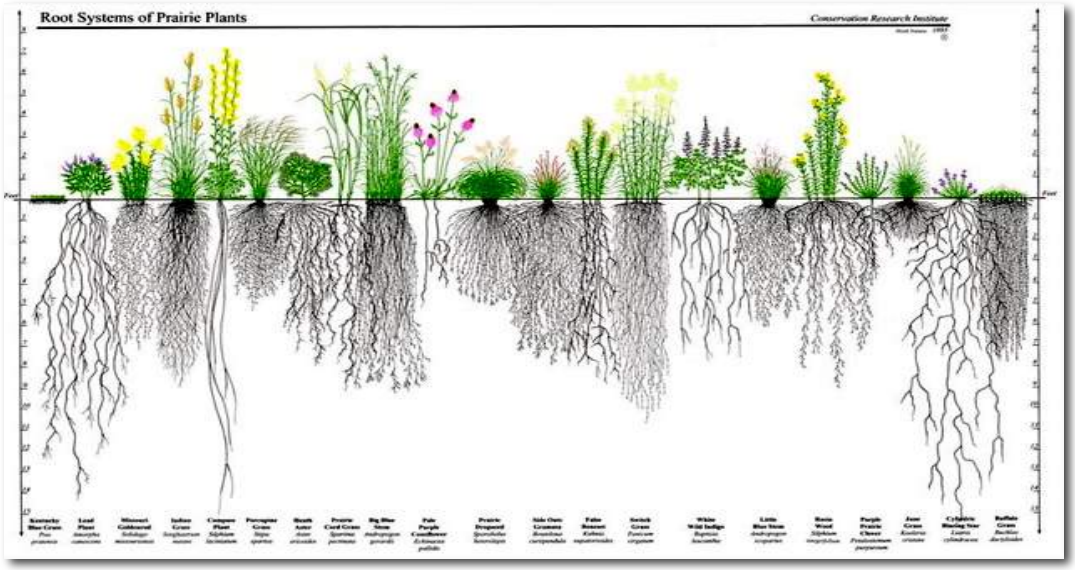
[38] Morris, G.D: Sustaining national water supplies by understanding the dynamic capacity that humus has to increase soil water-holding capacity. University of Sydney (2004).
[39] Jones, C.E: Carbon and catchments. National "Managing the Carbon Cycle". At www.amazingcarbon.com (2006).
[40] Jones, C.E: Soil Carbon – can it save agriculture's bacon? At www.amazingcarbon.com (2010)
[41] Jones, C.E: Farming a climate change solution. At www.amazingcarbon.com (2009)

PASTURE

According to the United Nations, 1/3 of the Earth's surface (4,000 million hectares) are threatened by desertification. The majority of these are pastures, meadows and savannahs. Together they form the greatest ecosystem in the world and the largest carbon sink. Depending on their definition, they cover between 26% and 40% of the Earth's ground and contain between 20% and 35% of its carbon.[42] Like in agricultural land, if the soil is bare it becomes degraded and releases previously stored carbon (in addition to losing water storage capacity and a long list of crucial ecological services).

Importantly, very often the pastures that appear in good condition from a distance have between 50 and 90% bare soil between the plants, even in hunting reserves without livestock. In general, it is considered that overgrazing is responsible for the majority of this damage. However, *the problem is not the quantity of livestock but how long the plant is exposed to being eaten by it*.

Simply reducing the number of heads of cattle is not achieving the result hoped for, which is not surprising, as it is not a few herbivores roaming idly that has formed and maintained these ecosystems for centuries until we arrived to manage them. As a matter of fact, on a positive note, the increase in cattle, together with a careful planning, can be credited with restoring the pastures and their services in semiarid and arid zones, which is where most of the world's pastures are located.[43]



Radicular systems in pasture and meadow plants.

Pasture in good condition can store more carbon than arable land, for two reasons:

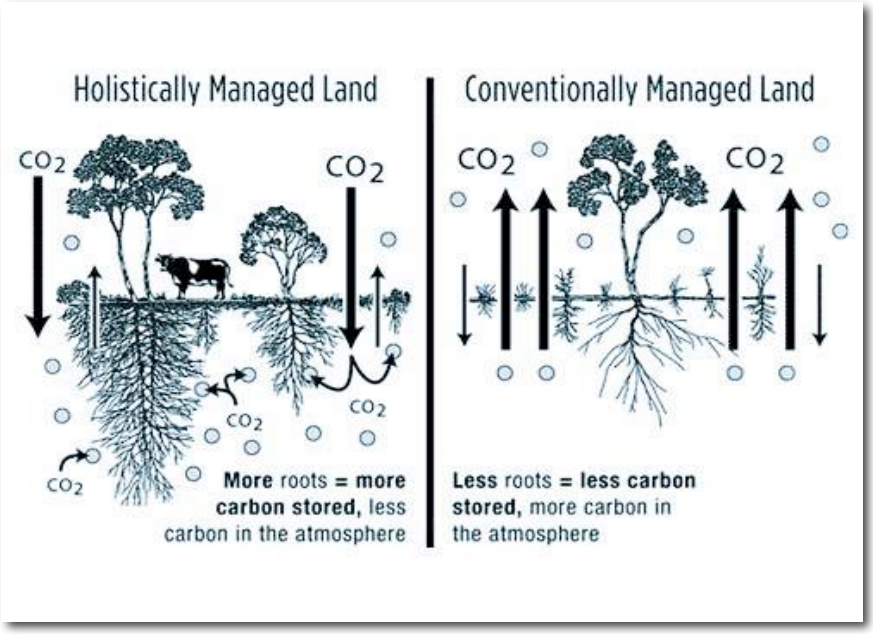
a. pasture land occupies a far larger area worldwide than arable land;

b. the majority of the crops have roots that are smaller and shallower than those of the perennial plants in healthy pastures. *The volume and depth of the roots is a crucial factor for both carbon and water storage.*

[42] FAO:"Challenges and opportunities for Carbon sequestration in Grassland systems: Technical Report on grassland management and climate mitigation." Rome (2010)
[43] Savory, Allan: "Holistic Managment". In Bibliography.

These ecosystems have a carbon capture potential of probably between 88 and 210 GT, the equivalent of 41 and 99 ppm of CO2 in the atmosphere, which is sufficient to drastically reduce climate change.[44]

These figures are conditional on using regenerative systems such as Holistic Management to manage herds and flocks. Pastures, savannahs and meadows are capable of storing carbon for thousands of years.[45]



[44] PlanetTech ASSOCIATE : Upside (Drawdown). (2014). In Bibliography.
[45] Rabbi, S.M.F *"Mean Residence Time of Soil Organic Carbon in Aggregates Under Contrasting Land Uses Based on Radiocarbon Measurements."* Radiocarbon (2013)

REGENERATIVE AGRICULTURE AND DISRUPTIVE AGRICULTURE

Carbon and water farming

Well-designed agricultural and livestock systems that conserve and store carbon in the soil (referred to as "carbon farming") include techniques such as:

- focusing on property's internal resources.
- 100% of the soil's vegetation cover, to prevent the erosive action of wind and water on it. It also makes it possible to store a great deal more microbial life.
- Using perennials plants, which have deeper roots than annual plants.
- Pasture management that imitates the movement of wild herds of mammals.
- Enabling natural herbs to grow among the crops, combining them with the latter's fallow periods.
- Using compost.
- Avoiding using synthetic chemical elements, which poison life under the soil.
- Living vegetation cover.
- Mulching the soil with straw or other dead vegetation. This protects the soil from the sun, wind and rain, allowing water to be stored and microbial life to be formed.
- Regenerative agroforestry systems, which combine trees and bushes with agriculture or livestock farming.
- Crop rotation.
- Conservation agriculture without using synthetic chemicals.

Regenerative Agriculture improves and increases the resources that it uses instead of degrading or decreasing them. This is a systemic and holistic vision of agriculture that involves the objective of regenerating and constant innovation to achieve ecological, social, economic and even mental wellbeing. These practices minimise the alteration of the soil life and its erosion, incorporate compost and retain roots and stalks, thus contributing to carbon sequestration by extracting it from the atmosphere through photosynthesis and retaining it in the organic matter in the soil.[46-47]

These practices can be combined very effectively with Organic Agriculture to produce healthy soil, healthy food and clean water and air, all of this using inputs that can be created directly from the exploitation as far as possible.

This results in soil health and resistance to pests and diseases.

[46] Lorenz, K. & Lal, R. in Recarbonization Biosphere (Lal, R., Lorenz, K., Hüttl, R. F., Schneider, B. U. & Braun, J. von) Springer Netherlands (2012).
[47] Lal, R. Soil carbon sequestration to mitigate climate change. Geoderma (2004).

Combining several techniques there are systems that successfully focus on regeneration. The most well-known and generalised of these are:

a) ***Biodynamic Agriculture***, which uses a series of unique preparations, including the "500", which aims to foster soil life;

Organic roots and biodynamic roots

b) ***Permaculture***, with its emphasis on design and diversity, which also results in abundant production and improved general ecology, and in particular that of the soil.

c) ***Holistic Management***, a livestock management system that generally increases the quantity of animals and focuses on soil regeneration;

Holistically managed property and conventionally managed property

d) ***Keyline***, a design system that involves "non-invasive" ploughing and the conservation of water on slopes while improving soils.

The most practiced techniques used to regenerate are the following:

Direct Sowing, which consists in avoiding ploughing, either completely or to a great extent. Almost all of the studies carried out show that these improve the structure of the soil, reduce CO2 emissions and contribute to increasing the quantity of carbon in the soil.[48] However, these effects are only significant when the conservation is done as part of an organic agriculture system. E.g. carbon conservation is negatively compensated by the N2O emission from nitrogenous fertilisation.[49]-[50] Also, phosphoric fertilisation curbs the growth of fungi and mycorrhizae, affecting the carbon storage potential and proper development and strength of the plants.[51]

Direct Organic Sowing is still a minority practice, but should be promoted, since to avoid adventitious weeds a dense vegetable cover is necessary, which together with other agro-ecological practices has demonstrated its ability to increase carbon in the soil by 9% in two years and by 21% in six years.[52]-[53] The improvement is particularly marked when the technique is combined with ***crop rotation***.[54]-[55]

Fertilisation using synthetic nitrogen is commonly practiced but is fundamentally flawed, as it transforms the carbon in the soil into CO2. Scientists from the University of Illinois analysed the results from 50 years of tests and discovered that the carbon disappeared from the agricultural waste and that approximately 10,000 kg of carbon were lost yearly from every hectare of soil. The scientists demonstrated that the higher the dose of nitrogenous fertiliser, the greater the loss of carbon in the soil. [56]

Moreover, the application of synthetic nitrogen also decreases the nitrogen naturally stored in the soil. Adding soluble nitrogen destabilises the plant-soil ecosystem, by reducing the activity of the mycorrhizae and the nitrogen-fixing bacteria. The high levels of soluble nitrogen in the water inhibit the microbial associations that fix the atmospheric nitrogen.[57] ***This disproves the theory that nitrogenous fertilisation is necessary to achieve stable carbon; the reality is exactly the opposite.***[58]-[59]-[60]

The use of organic nitrogen through mycorrhizae (see page 29) prevents the acidification of the soil, the volatilisation of nitrogen in the atmosphere and its lixiviation into aquifers, streams and rivers. The soils, thus balanced, are also less prone to being invaded by various species of adventitious plants, whose germination is stimulated by the availability of nitrates.[61]

Since approximately 50% of the carbon in agricultural land is fixed in the vegetable biomass[62], the ***cover crops*** and incorporation of waste are clearly very important for carbon capture.

Moreover, they reduce nitrogen loss, erosion from wind and water, adventitious plant invasions, water loss and evaporation. They also increase water infiltration and the fixing of atmospheric nitrogen if leguminous plants are grown, and improve soil structure.[63]

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[48] Abdalla, M. et al. Conservation tillage systems: a review of its consequences for greenhouse gas emissions. Soil Use Manag. (2013).
[49] Skinner, C. et al. Greenhouse gas fluxes from agricultural soils under organic and non-organic management — A global meta-analysis. Sci. Total Environ. (2014).
[50] Khan, S. A., Mulvaney, R. L., Ellsworth, T. R. & Boast, C. W. The Myth of Nitrogen Fertilization for Soil Carbon Sequestration. J. Environ. Qual. (2007).
[51] Jasper, D. A., Robson, A. D., & Abbott, L. K. Phosphorus and the formation of vesiculararbuscular mycorrhizas. Soil Biology and Biochemistry. (1979).
[52] Carr, P., Gramig, G. & Liebig, M. Impacts of Organic Zero Tillage Systems on Crops, Weeds, and Soil Quality. Sustainability. (2013).
[53] Gadermaier, F., Berner, A., Fließbach, A., Friedel, J. K. & Mäder, P. Impact of reduced tillage on soil organic carbon and nutrient budgets under organic farming. Renew. Agric. Food Syst. (2011).
[54] De Moraes Sá, J. C. et al. Carbon Depletion by Plowing and Its Restoration by No-Till Cropping Systems in Oxisols of Subtropical and Tropical Agro-Ecoregions in Brazil. Land Degrad. Dev. (2013).
[55] West, T. O. & Post, W. M. Soil Organic Carbon Sequestration Rates by Tillage and Crop Rotation. Soil Sci. Soc. Am. J. (2002).
[56] Larson, D.L: Study reveals that nitrogen fertilizer deplete soil organic carbon. In *News from the University of Illinois*. (October 2007)
[57] Jones, Christine: Soil Carbon – can it save agriculture's bacon? At www.amazingcarbon.com (2010)
[58] Jones, Christine: Nitrogen: the double edged sword. At www.amazingcarbon.com (2014)
[59] Khan, S.A et al: The myth of nitrogen fertilization for soil carbon sequestration. In *Journal of Environment Quality*. (2007)
[60] Mulvaney, R.L et al: Synthetic nitrogen fertilizer deplete soil nitrogen: a global dilemma for sustainable cereal production. In *Journal of Environmental Quality*. (2009)
[61] Jones, Christine: Soil Carbon – can it save agriculture's bacon? At www.amazingcarbon.com (2010)
[62] Montagnini, F. & Nair, P. K. R. Carbon sequestration: An underexploited environmental benefit of. Agrofor. Syst. (2004).
[63] Hartwig, N. L. & Ammon, H. U. Cover crops and living mulches. Weed Sci.(2002).

When the cover comprises perennial plants the carbon capture is even greater, thanks to the more complex and deep root system.[64-65]

The change from the rotation of monocultures with bare soil to ***polyculture rotation*** without fallow increases the biodiversity of the soil and carbon retention.[66]
Passing from wheat/fallow/sunflower to wheat/leguminous plant increases carbon levels.[67]

Incorporating vegetable waste after the harvest, instead of burning it or removing it, is also important.[68-69] Using this waste for bioenergy reduces the organic matter in the soil.[70]

Composting waste also increases carbon capture. This involves the aerobic decomposition of organic matter (plants, animals and excrement). Its application onto the soil fosters biodiversity, including microbial life, promoting ecological services (recycling nutrients, strengthening plants against pests or diseases, and increasing soil structure).[71]

It also improves the soil's health and productivity[72], and these benefits all occur fairly rapidly. If compost is used instead of nitrogenous fertilisation, the roots grow in quantity and quality, fixing more atmospheric carbon.[73]

Worms play an important part in compost, and there are even compost systems designed to increase their quantity. A number of researchers argue that they are the basis of a *"second (genuinely) Green Revolution"*, substituting destructive agro-chemicals entirely. The worms in the earth improve soil fertility and increase crop production. Their excrement, both liquid and solid, is a nutritious ecological fertiliser that is rich in humus, micronutrients and beneficial microbial life. It fixes nitrogen, solubilises phosphorus, and contains plentiful amounts of these elements and potassium.[74]

In experiments with corn, wheat, tomatoes and aubergine, using worms produced positive results in factors such as plant height, leaf colour and texture and appearance of flowers and fruits, in comparison with both conventional crops (using chemicals) and crops with normal compost. They also proved to be less affected by diseases and pests and require less water. These studies also show growth 30 to 40% higher than conventional crops, and with greater nutritional and organoleptic qualities. *Moreover, these methods cost 50-75% less than chemical fertilisers.*[75]

The quantity and stability of the carbon in the soil also depends on the ***abundance of fungi*** in it.[76]
The association between roots and fungi is a determining factor in achieving the suitable structure, to avoid the carbon being emitted into the atmosphere as CO2.[77-78]

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[64] Le Quéré, C. et al. The global carbon budget 1959–2011. Earth Syst. Sci. Data 5 (2013).
[65] Conant, R. T., Paustian, K. & Elliott, E. T. Grassland management and conversion into grassland: effects on soil carbon. Ecol. Appl. (2001).
[66] West, T. O. & Post, W. M. Soil Organic Carbon Sequestration Rates by Tillage and Crop Rotation. Soil Sci. Soc. Am. J. (2002).
[67] Id.
[68] Wang, Q., Li, Y. & Alva, A. Cover Crops in Mono- and Biculture for Accumulation of Biomass and Soil Organic Carbon. J. Sustain. Agric. (2012).
[69] De Moraes Sá, J. C. et al. Carbon Depletion by Plowing and Its Restoration by No-Till Cropping Systems in Oxisols of Subtropical and Tropical Agro-Ecoregions in Brazil. Land Degrad. Dev. (2013).
[70] Blanco-Canqui, H. Crop Residue Removal for Bioenergy Reduces Soil Carbon Pools: How Can We Offset Carbon Losses? BioEnergy Res.(2013).
[71] Ingham, E. How the soil food web and compost increase soil organic matter content. in Org.- Solut. Clim. Change 13 (2006). At <http://www.ofa.org.au/papers/OFA_Conference_Proceedings.pdf#page=27>
[72] Lal, R. Soil Carbon Sequestration Impacts on Global Climate Change and Food Security. Science (2004).
[73] Khorramdel, S., Koocheki, A., Nassiri Mahallati, M., Khorasani, R. & Ghorbani, R. Evaluation of carbon sequestration potential in corn fields with different management systems. Soil Tillage Res.(2013).
[74] Sinha,R. , Agarwal, S. , Chauhan, K. And Valani, D. (2010) The wonder of earthworms & its vermicompost in farm production: sCharles Darwin's "friend of farmers", with potential to replace chemical fertilizers.
[75] Id.
[76] Vries, F. T. de et al. Soil food web properties explain ecosystem services across European land use systems. Proc. National Academy of Sciences (2013).
[77] Kell, D. B. Breeding crop plants with deep roots: their role in sustainable carbon, nutrient and water sequestration. Ann. Bot. (2011).
[78] Heitkamp, F. et al. in Recarbonization Biosphere (Lal, R., Lorenz, K., Hüttl, R. F., Schneider, B.U.& Braun, J. 2012).

This symbiosis, called ***mycorrhizae***, governs the exchange between plants, which with mycorrhizae can transfer up to 15% more carbon into the soil than plants without this association.[79] In addition to giving the plant access to more nutrients, it protects it from climatic extremes.

The most common *mycorrhizae* have filaments called ***"hyphae"*** that give the plants' roots greater reach, thus improving their access to nutrients and water. The hyphae is covered with a sticky substance that was discovered in 1996 and called ***"glomaline"***. It is crucial for soil structure and carbon absorption The Department of Agriculture of the United States already recommends its protection, to *minimise labour and chemical use*, and use living vegetable cover[80]

Chemical use in agriculture inhibits the interactions of mycorrhiza and microbes that store carbon. *Hyphae increases whenever there is a higher concentration of CO2 in the atmosphere![81] A lengthy field experiment* using various management systems demonstrated a positive relationship between the abundance of hyphae, soil aggregation and carbon and nitrogen capture.

These findings signify that the loss of mycorrhizae has severe consequences for ecosystems. It has also been shown that applying fungicides reduces hyphae and glomaline.[82] If aggregates are not produced in the soil (due to the absence of mycorrhizae), significant stable quantities of carbon will not be fixed, neither will atmospheric nitrogen be fixed.[83]

The network of filaments, rather than the roots on their own, is the principal structure enabling plants to absorb many vital nutrients.

When the fungi deteriorates the carbon remains stable for decades, giving the organic matter time to forge links with metals and minerals, thus producing composites that can remain in the soil for thousands of years.[84] Another means of obtaining these benefits is inoculating the soil with fungi, in particular when conventional tilling and/or synthetic chemical use have destroyed the native population.[85]-[86]

[79] Christine Jones at http://www.amazingcarbon.com/
[80] Schwartz, Judith. Soil Carbon Storehouse: new weapon in climate fight? In Environment360 04/03/2014
[81] Comis, D. Glomalin: hiding place for a third of the world's stored soil carbon. Agric. Res. 4, (2002). Rillig, M. C., Wright, S. F., Allen, M. F. & Field, C. B. Rise in carbon dioxide changes soil structure. Nature(1999).
[82] Wilson GW[1], Rice CW, Rillig MC, Springer A, Hartnett DC. Ecol Lett. "Soil aggregation and carbon sequestration are tightly correlated with the abundance of arbuscular mycorrhizal fungi: results from long-term field experiments." Epub 2009 Mar 23.
[83] Christine Jones: Nitrogen, the double edged sword. At http://www.amazingcarbon.com/ (2014).
[84] Lorenz, K. & Lal, R. in Recarbonization Biosphere (Lal, R., Lorenz, K., Hüttl, R. F., Schneider, B. U. & Braun, J. Von Springer Netherlands. (2012)
[85] Douds, D. D., Nagahashi, G. & Shenk, J. E. Frequent cultivation prior to planting to prevent weed competition results in an opportunity for the use of arbuscular mycorrhizal fungus inoculum. Renew. Agric. Food Syst.(2012).
[86] Douds Jr., D. D., Nagahashi, G. & Hepperly, P. R. On-farm production of inoculum of indigenous arbuscular mycorrhizal fungi and assessment of diluents of compost for inoculum production. Bioresour. Technol. (2010).

Since *roots are necessary* for this process to take place, agricultural management has to include perennial plants, ecological conservation tillage, and long roots with complex structures: wooded areas, natural areas and biodiversity.

Trophobiosis[87]

Trophobiosis is the symbiotic association between organisms where food is located. It also *explains the resurgence of pests in crops to which biocides have been applied, causing a greater dependence on them*.

Insects are very effective, as they use amino acids to form their own proteins, which are more complex structures. However, they cannot feed themselves directly from proteins as they are not able to divide them into their basic parts, amino acids. Their basic diet consists of free amino acids and sugars.

When the plant is at rest it has a low level of amino acids, as these were employed to prepare this state. When it is growing vigorously, the amino acids are used immediately to fuel the growth. The insects can live off the plant but not grow in number, as they need a greater availability of food to build their own proteins, DNA and other substances. They need greater amounts of soluble amino acids, sugars and minerals.

What makes them grow faster, decreasing their vulnerability? Living, rich and biodiverse soil.

Plants that are not nutritional for insects are not palatable. Those that are nutritional for them have an excessive quantity of soluble nutrients and a metabolic imbalance. *This imbalance is often caused by excessive ploughing of the soil and by keeping it bare.*

However, the most effective means to alter plants' metabolism is using pesticides, herbicides, fungicides and artificial fertilisers. Any deficiency, in particular of micronutrients, inhibits the protein synthesis process (the conversion from amino acid to protein), with a corresponding increase in free amino acids, which are those favoured by insects.

All synthetic chemicals commonly applied to crops provoke similar reactions:

- decrease in protein synthesis;
- increase in available amino acids;
- increase in soluble sugars;

which make plants more palatable for insects and prone to infections.

Nitrogenous fertilisers decompose into amino acids, making crops more vulnerable.

The use of synthetic chemical fertilisers, in particular nitrogenous ones, increases the soluble nitrogen in plants' tissue, making them attractive and vulnerable to insects and diseases.

Furthermore, they only provide only *three elements: Nitrogen, Phosphorus and Potassium*. But plants require a minimum of 43 elements, and to achieve such minimum a rich and healthy agro system is necessary.

[87] Chaboussou, Francis: "*Healthy Crops: A New Agricultural Revolution*". Ed. Paperback (2005). In General Refrences.

This underlines the considerable imbalance experienced by a plant that develops in a nutritionally impoverished soil with access to only three elements, putting into question its nutritional capacity for human beings or livestock.

When insects detect abundant quantities of amino acids and sugars the following behaviors are altered:

- increase in fertility,
- increase in lifespan,
- shorter reproductive cycles,
- increase in egg production, and
- increase in number of females in relation to males.

Through the intensification of agriculture bacteriological diseases are harder to control as a result of the use of **herbicides and pesticides** - which are sold and applied without serious analysis of their effects on the biochemical balance.

Herbicides, with their specific and drastic toxic effects on all plants, inhibit the protein synthesis processes and can therefore be a factor causing the increase in viral diseases. It is therefore difficult to eliminate a viral disease without taking into consideration the plant's physiological condition, which depends on its "diet", the climate and its poisoning by synthetic chemical substances.

Rather than the development of pest resistance - an explanation that also enables agricultural chemical companies to propose new, apparently indispensable products - the problem lies in the essence of the concept: these chemicals alter the metabolism and biochemical balance of the crops, thus favouring various insects and pests.

This does not suggest that pesticides are an ineffective biocide, but by altering the biochemical balance they make plants more nutritional and palatable for insects.

To summarise:

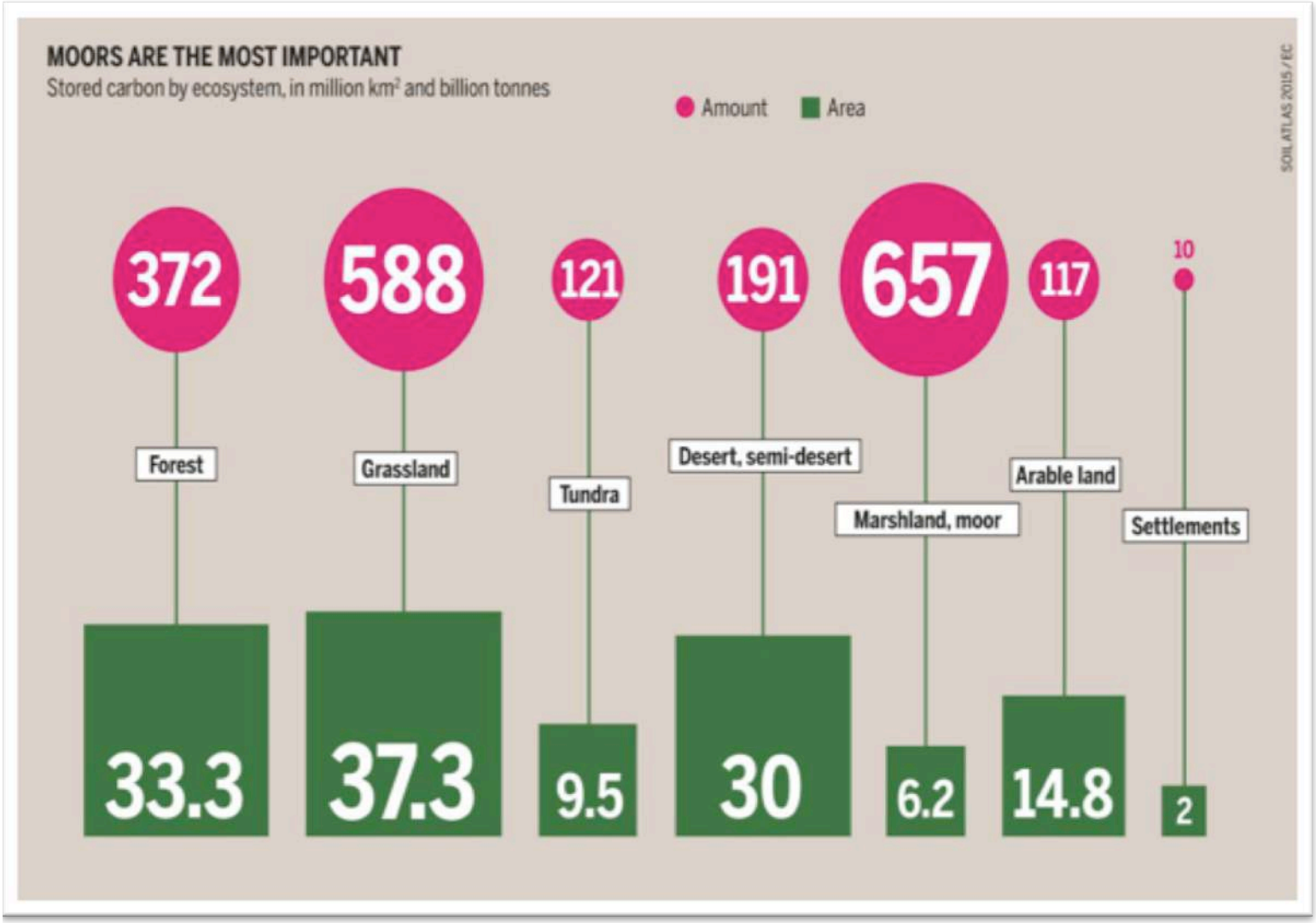
1. Applying synthetic chemicals inevitably causes pests and diseases to increase.

2. A biodiverse, healthy and living soil is the key to obtaining healthy, resistant, vital and nutritional crops, and makes it easier to manage possible "attacks" of insects and diseases.

Soil as a methane sink

Humid zones, rivers, oceans, lakes, plants, decomposing vegetation, in particular in humid climates, and many types of animal from termites to whales, have produced methane during their lifetime. Ruminants including buffaloes, camels, giraffes, antelopes and bison existed in greater numbers before the Industrial Revolution than today. The atmosphere would have a vast accumulation of methane had it not been absorbed or eliminated over the course of millennia.

In addition to the "deactivated" methane in the atmosphere[88] , biologically active soils serve as methane sinks, thanks to the presence of methanotrophic bacteria which use methane as their energy source.[89] These bacteria are, like any living being, affected in their functions by the use of synthetic fertilisers, herbicides and pesticides, but also by the acidification of the soil and its excessive alteration.

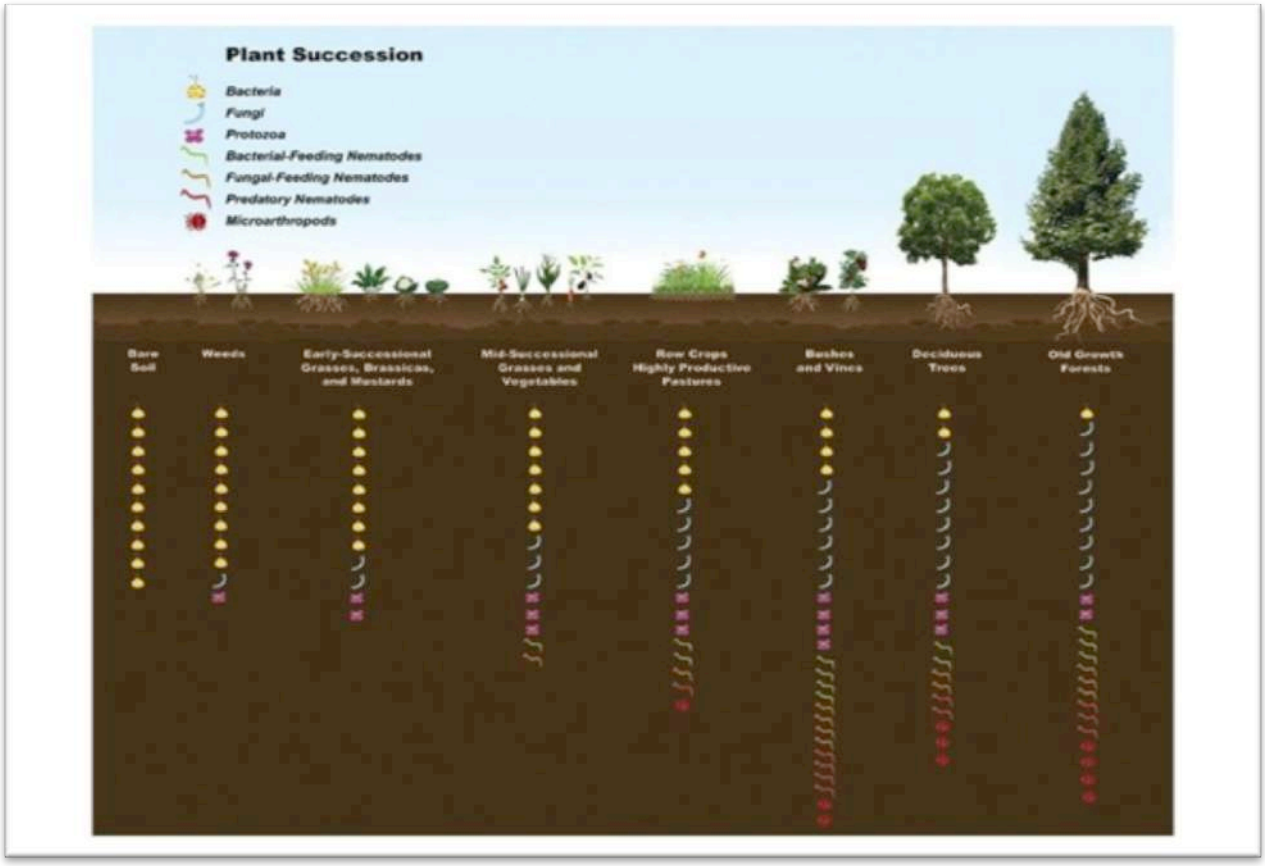


Carbon stored, by type of ecosystem (in millions of km²and thousands of tons). Marshy zones store the greatest quantity, followed by meadows and forests. They must be protected, and the zones that contain the least carbon must be regenerated, to increase their accumulation capacity.

[88] Quirk T.W: Twentieth century sources of methane in the atmosphere. Energy and Environment (2010).
[89] Dunfield, P.F: The soil methane sink. In D.S Reay, C.N. Hewitt, K.A Smith and J. Grace, eds Greenhouse gas sinks. United Kingdom (2007).

Old-growth forests as Carbon sinks

Old-growth forests remove CO2 from the atmosphere at a rhythm that varies based on the climate and nitrogen cycle. Carbon accumulates in the wood and in decomposing organic matter. They are not protected by international treaties, as it is believed that they cease to accumulate carbon once they reach a certain maturity. However, recent studies have shown that they capture approximately 1.3 GT of carbon every year. Much of this carbon returns into the atmosphere when these forests, which constitute around 15% of the global wooded area, are altered.[90]



Vegetable ecological succession and the corresponding succession in the rhizosphere.

Industrial forest plantations

One related idea, in the context of forest industry, is that monocultures can help to resolve the problems described above. But forest monocultures are usually referred to as "green deserts", requiring a permanent struggle against the natural tendency to complexity.

A recent study carried out in eucalyptus plantations confirms that a ''significant loss of organic material and an increase in acidity, associated with an alteration of the physiochemical properties"[91], the waterproofing of the soil and the possible toxicity for other plants and microorganisms, even years after the eucalyptus have disappeared. Furthermore, cutting down trees releases the carbon captured in them.

[90] Luyssaert, S et al «Old-growth forests as global carbon sinks.» Nature 451 (2008).
[91] Savannah ter Veer, Andrea Bautista. "Will the removal of Eucalyptus trees alter soil pH?" Advanced Placement Environmental Science Program. San Diego (2013).

A DOUBLE-EDGED SWORD AND THE POTENTIAL CO2 SEQUESTRATION

Many voices in the scientific community consider that all the carbon emitted by human beings could be absorbed by agricultural and pasture land if managed adequately, *thus converting industrial and transport emissions into a local problem.*

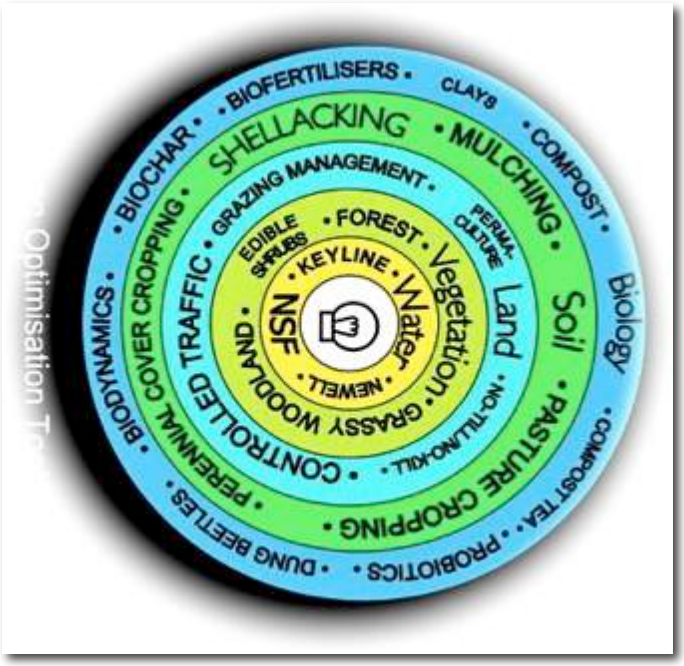
Soil contains the largest reserves of carbon in its terrestrial cycle. It is considered that the first metre of depth contains 1.500 Gigatons (1 GT = 1.000 million tons) of organic carbon[92], approximately double that in the atmosphere, while vegetation contains approximately 600 GT (270 GT in forests)[93].

The United Nations' Environmental Program (UNEP) has calculated that every year the regenerative management of all the agricultural land would enable over 40% of annual emissions (21 GT) to be captured. If pasture land is added to this, another 71% (37 GT)[94] would be captured.

We are therefore wielding a double-edged sword of massive proportions and potential consequences:

a. ***We still have a great potential to exacerbate the situation***, by releasing even more carbon into the atmosphere through our industrial "extractive" agriculture and ecosystem destruction.

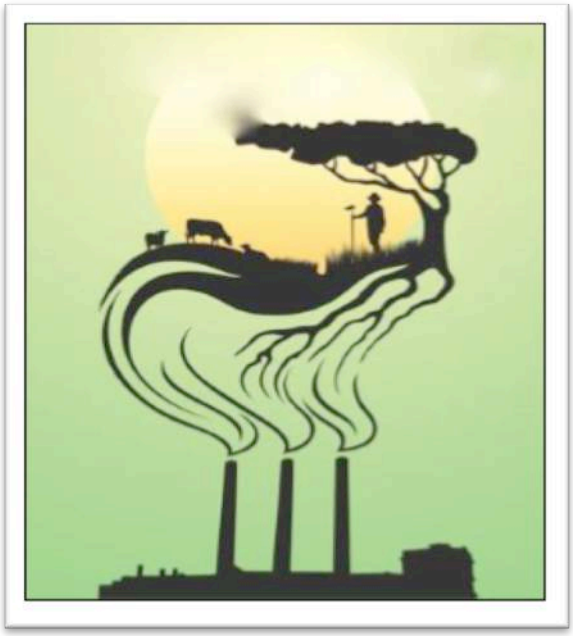
b. ***There is considerable potential to resolve this dangerous situation*** efficiently, rapidly, simply, affordably and without risk – qualities that generally elude geoengineering projects.



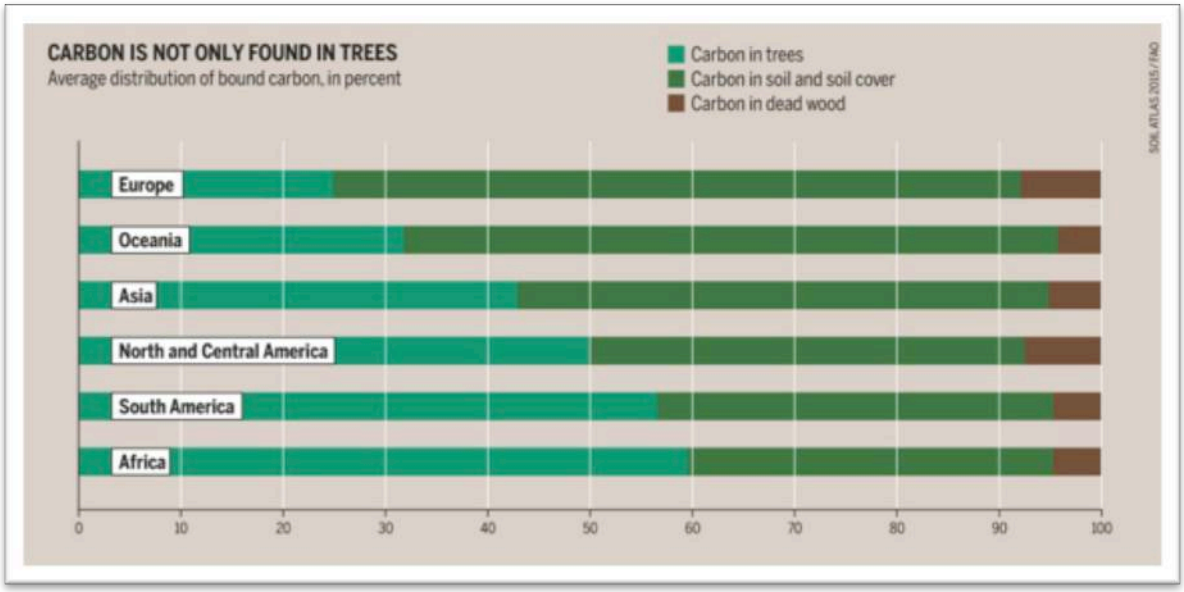
Soil carbon optimisation tools

[92] Gerber, P.J., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., Falcucci, A. & Tempio, G. (2013). Tackling climate change through livestock – A global assessment of emissions and mitigation opportunities.Rome, Italy: Food and Agriculture Organization of the United Nations.
[93] Id.
[94] UNEP. The emissions gap report 2013. (United Nations Environment Programme, 2013). In Bibliography.

The calculations by *UNEP* reach the same conclusions regarding the actions to take: industrial agriculture prevents the soil from fixing carbon. Indeed, soil can fix it in large quantities through organic matter that is rich in nutrients for vegetation, fertility and the movement of water. *UNEP proposes financial incentives and a global climate agreement that includes carbon credits for soil.*



However, the carbon fixed is very vulnerable to human activities: approximately 60% of the carbon stored in the soil and vegetation has been emitted into the atmosphere as a result of the change of use of land. Around 24% of the soil worldwide has undergone a decline in its productivity in the last 25 years due to unsustainable use. The rising global population and consumption have only exacerbated this trend.[95]



Carbon is not only contained in trees: the light green band shows the carbon stored in trees; the dark green that in the soil and in its vegetation cover, and the brown that in dead wood.

[95] FAO: Scarsità e degrado del suolo e dell'acqua: una minaccia crescente per la sicurezza alimentare. At http://www.fao.org/news/story/it/item/95268/icode/ **(2011)**

UNCERTAINTY?

The technical storage potential for any given hectare depends on:

- type of soil;
- topography;
- climate;
- biomass available;
- capacity to change management systems.[96]

Though a certain degree of uncertainty surrounds these conditions, there are regenerative systems that demonstrate that the difficulties can be overcome and the improvements achieved on the short term. This is demonstrated by the aforementioned *Biodynamic Agriculture, Permaculture, Holistic Livestock Management* and *Key Line.*

These systems, together with other analogue technologies, can be referred to generically as Regenerative Systems, because of their focus on (re)generating the most optimal possible conditions (beyond restoration), beginning with the soil, upon whose "revitalisation" upmost importance is placed.

It is accepted science that having thousands of species acting inside the soil produce stable carbon molecules from the atmospheric CO2 captured by the plants through photosynthesis. A ***qualitative methodology*** can therefore be formulated that overcomes the difficulties associated with quantitative measuring, in terms of time, exactitude, cost and technological requirements.[97]

Attempting to achieve total knowledge poses the risk of not doing anything, and paying the price. Regeneration can be observed in between one and three years in a plot of land left deserted by poor management: water, mammals, birds, insects, plant, fungi and microbial life return. The same goes for carbon. Nature has worked in this manner for thousands of years, it is indeed entirely predictable.[98]

A soil rich in carbon and diversity indicates:

- *Food Security.*

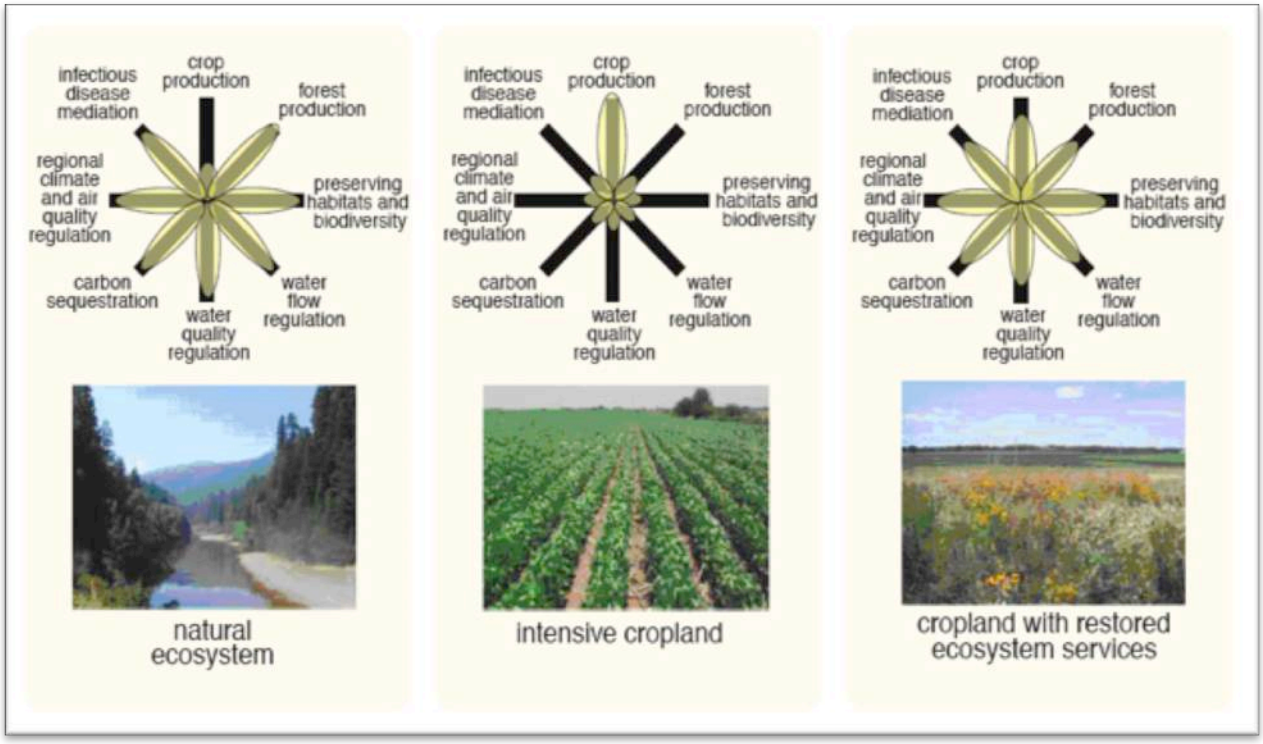
- *Adaptation and resilience to climate changes*

Practices that increase the carbon content in agricultural and livestock farming soils are beneficial in themselves, and increase harvests.

The ***economic viability of the agricultural sector,*** as well as individual, family and social wellbeing, are inextricably linked to soil health. The functioning of soil, vegetation and water flows is seriously compromised, if not severely damaged or altered by its impoverishment, which results in lesser resistance and adaptation to climate variability.

The most significant indicator of the health of the agro-system (and the nation's long-term resilience) is whether the soil is forming or degrading. A loss in soil also means a loss in ecological and economic foundations.

[96] Gerber, P.J., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., Falcucci, A. & Tempio, G. (2013). Tackling climate change through livestock –A global assessment of emissions and mitigation opportunities. Rome, Italy: Food and Agriculture Organisation of the United Nations.
[97] Adam D. Sacks: Carbon farming: paying for results, not for data. In *Savory Institute Newsletter* 08/04/2014
[98] Id



Quality of ecosystemic services, based on soil use. (Environmental Protection Agency, United States). The first option is the natural system, which does not produce large harvests but is necessary because of its various ecosystemic services. The second option is unsatisfactory as it destroys everything except for, momentarily, production amounts. The third option combines production with regeneration, thus also providing ecosystemic services.

Harvest abundance is a key issue in this argument, as supporters of conventional/chemical agriculture maintain that abandoning its use would reduce production on the short term. Organic production tends to be lower if it simply replaces chemical inputs by ecological ones, and maintains all the other practices (monocultures, bare soils, etc).[99] When regenerative systems are applied holistically organic harvests *have exceeded the quantity* produced by conventional ones in almost all crops, including corn, wheat, rice, soya and sunflower.[100] They are also more resistant to extreme climatic events.: in particularly dry years, organic harvests have proved to be more abundant (e.g., 30% more corn than in conventional agriculture).[101]

The common argument that *the increasing world population* requires a rise in global harvests is false: hunger and access to food do not depend on harvests, but on political, economic and environmental decisions.[102-103] Access would increase were small-scale regenerative agriculture to be supported[104], and encouraged to spread into cities (terraces, communal vegetable gardens, gardens that "produce food, not lawn").

[99] Seufert, V., Ramankutty, N. & Foley, J. A. Comparing the yields of organic and conventional agriculture. Nature (2012).
[100] De Ponti, T., Rijk, B. & van Ittersum, M. K. The crop yield gap between organic and conventional agriculture. Agric. Syst.(2012).
[101] Pimentel, D., Hepperly, P., Hanson, J., Douds, D. & Seidel, R. Environmental, energetic, and economic comparisons of organic and conventional farming systems. BioScience (2005).
[102] Magdoff, F., Foster, J. B. & Buttel, F. H. Hungry for profit: the agribusiness threat to farmers, food, and the environment. (*Monthly Review Press*, 2000).
[103] McMahon Paul, Feeding Frenzy 2013. In Bibliography.
[104] UNCTAD (United Nations Conference on Trade and Development). Trade and Environment Review 2013, Wake up before it is too late: Make agriculture truly sustainable now for food security in a changing climate. At <http://unctad.org/en/pages/PublicationWebflyer.aspx?publication id (2013).

Depth of carbon storage

Is probable that that carbon holding capacity of regenerated soil has been underestimated. This is because measurements tend to be made to a "ploughing depth", whereas it has been recently discovered that often over half of the carbon is located at a depth of between 20 and 80 cm. Beyond 30 cm the age of the carbon increases, and can remain for thousands of years.[105] In land with grass with deep roots, carbon has been recorded at a depth of between 5 and 40 metres.

Consequently, the regenerative strategies (deep roots, compost, herbs and legumes and worms) are suitable to carry the carbon to depths at which it would remain stable.

Virtuous consequences

This is a beneficial process for all parties concerned, as, in addition to reducing emissions from the Agricultural Sector and "putting back carbon where it belongs – in the earth", it involves:

- improved soil health, a foundation of life and therefore our existence;
- increased soil fertility, boosting production and its competitiveness sustainably over time;
- increased water retention capacity, reducing droughts and floods;
- improved water quality;
- eliminating or considerably reducing erosion;
- eliminating or considerably reducing salinisation;
- increased food security;
- a general improvement in the environment, including wildlife for which we are also responsible;
- lesser dependence on volatile input markets;
- increased income for better production and payment for environmental services;
- fixing and increase of rural population, thanks to the rise in income and reduction in costs;
- greater capacity for adapting to climate change.[106]-[107]

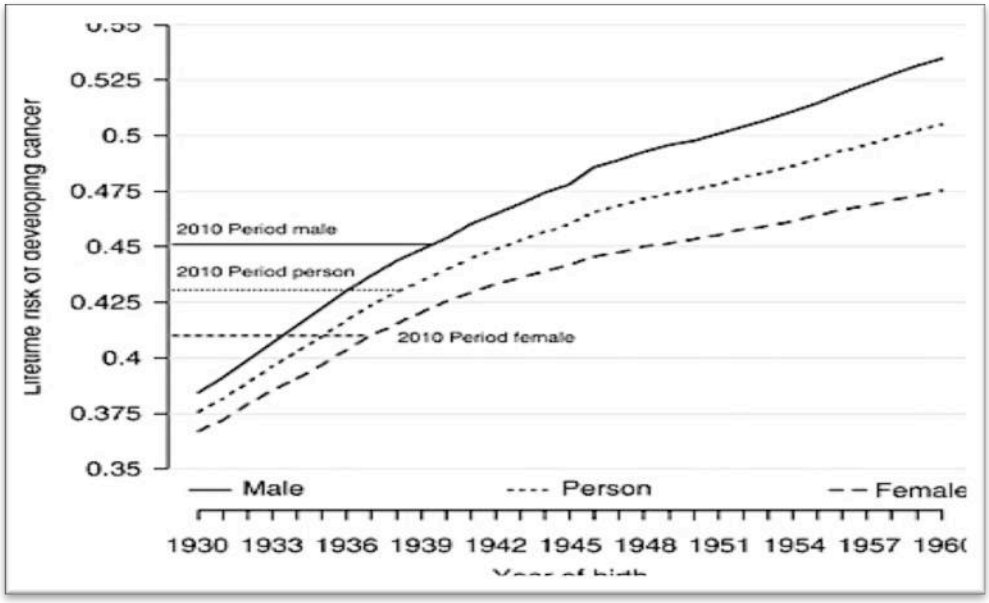
The exception comes with chemical input producers with their technicians, distributors, consultants and other dependent parties, who are striving to maintain the status quo instead of redirecting their activities.

[105] Rumpel, C., Chabbi, A. & Marschner, B. in Recarbonization Biosphere (Lal, R., Lorenz, K., Hüttl, R.F., Schneider, B. U. & Braun, J.) Von Springer Netherlands, 2012.
[106] Smith, P. et al. Greenhouse gas mitigation in agriculture. Philos. Trans. R. Soc. B Biol. Sci. (2008).
[107] UNCTAD (United Nations Conference on Trade and Development). Trade and Environment Review 2013, Wake up before it is too late: Make agriculture truly sustainable now for food security in a changing climate. (2013). In Bibliography.

Human health

The nutritional level of soils, plants, animals and persons has decreased considerably in the last 50 years, to a great extent because of the decrease in edaphic carbon, the main conductor of the nutrient cycles in soil.[108] Soil health and human health are closely linked.

Food is considered from the perspective of *quantity*, therefore the "developed world" does not perceive that a problem exists. However, the food produced in impoverished soils does not contain the essential minerals for the proper functioning of our immunological system. Premature deaths due to degenerative disease such as heart disease or cancer have become far more common today than they use to be. For example, cancer has passed from approximately one case per 100 persons 50 years ago to one case per three persons today.[109]



Variation in the risk of developing a cancer in the United Kingdom, by place of birth and gender.[110]

The immune system is compromised by the growing exposure to chemicals, in addition to the insufficient levels of minerals in diets. When soils fall ill, human beings do so too as we depend on the former.[111] In 2003, a beef steak in the United Kingdom contained 50% of the iron that it did in 1940.[112] In the United States, a person would have to eat 26 apples to obtain the same quantity of iron as the fruit contained in 1950.[113]

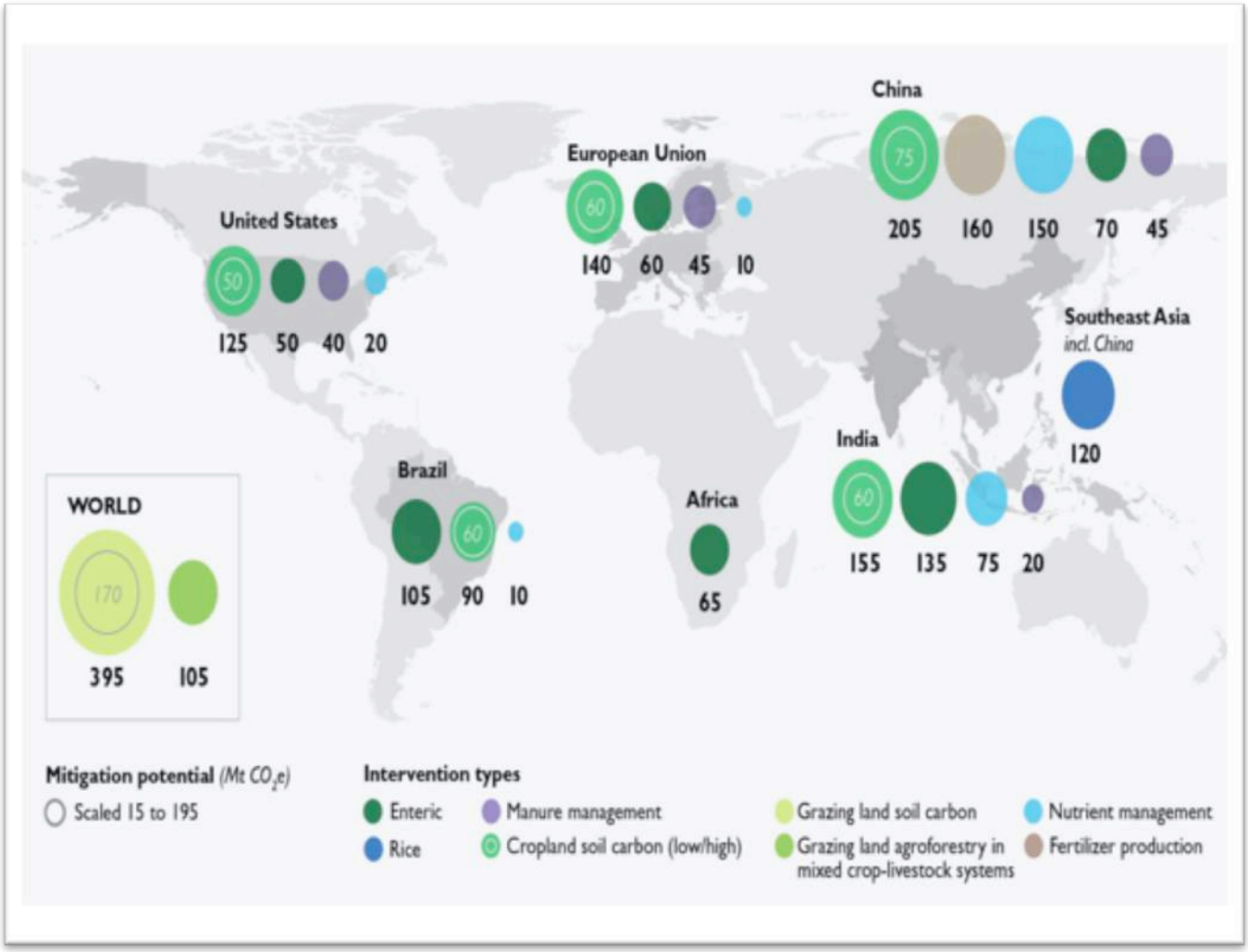
Mass chemical use is also responsible for these dramatic effects. In particular, g*lyphosate*, the basis for the most widespread herbicide in the world -Round Up by Monsanto- denies plants access to minerals and, through its heavy antibiotic action, destroys the vital processes necessary for nutrient absorption.[114] Recently, the World Health Organisation has declared that glyphosate is a "probable cancerigenic".[115]

[108] Jones, C: Soil carbon –can it save agriculture's bacon? At www.amazingcarbon.com (2010)
[109] A S Ahmad, N Ormiston-Smith and P D Sasieni: Trends in the lifetime risk of developing cancer in Great Britain: comparison of risk for those born from 1930 to 1960. En http://www.nature.com/bjc/journal/v112/n5/full/bjc2014606a.html (03 Febrero 2015).
[110] Id.
[111] *Nature*, editorial n 517. (20 Enero 2015.)
[112] Thomas, D. A study on the mineral depletion of the foods avaible to us as a nation over the period 1940 to 2002. In *Nutrition and Health* (2007)
[113] Mercola, J: How to bring minerals back into the soil and food. Interview with Doctor August Dunning. At http://www.mercola.com/ (May 24, 2014)
[114] Crawford :What if the world's soils run out? In *Time Magazine* (December 14, 2012)
[115] http://sustainablepulse.com/2015/07/30/who-publishes-full-probable-human-carcinogen-report-on-glyphosate/#.VkHv-KQdn3s

EMERGENT GLOBAL CONTEXT

In the ***United States***, the issues described above are reaching a consensus. "American Farmers' Group" has developed a credit system for carbon storage techniques. It was presented to the Government by the influential and certainly not ecologically concerned Iowa Corn Growing Association and Illinois Corn Growing Association.

The Secretary of Agriculture published an article in 2009 that discussed climate change and the rural sector in the United States. It stated: "the opportunities available to agricultural and livestock farmers through carbon markets and a new energy policy are too promising to be overlooked because …. not only would we be protecting ourselves from an impending climate crisis, but we would also revitalise the rural sector of this country." Another clear signal has come from the USDA Office of Ecosystem Services and Markets, which plans to include the regulation of water, biodiversity and carbon markets.

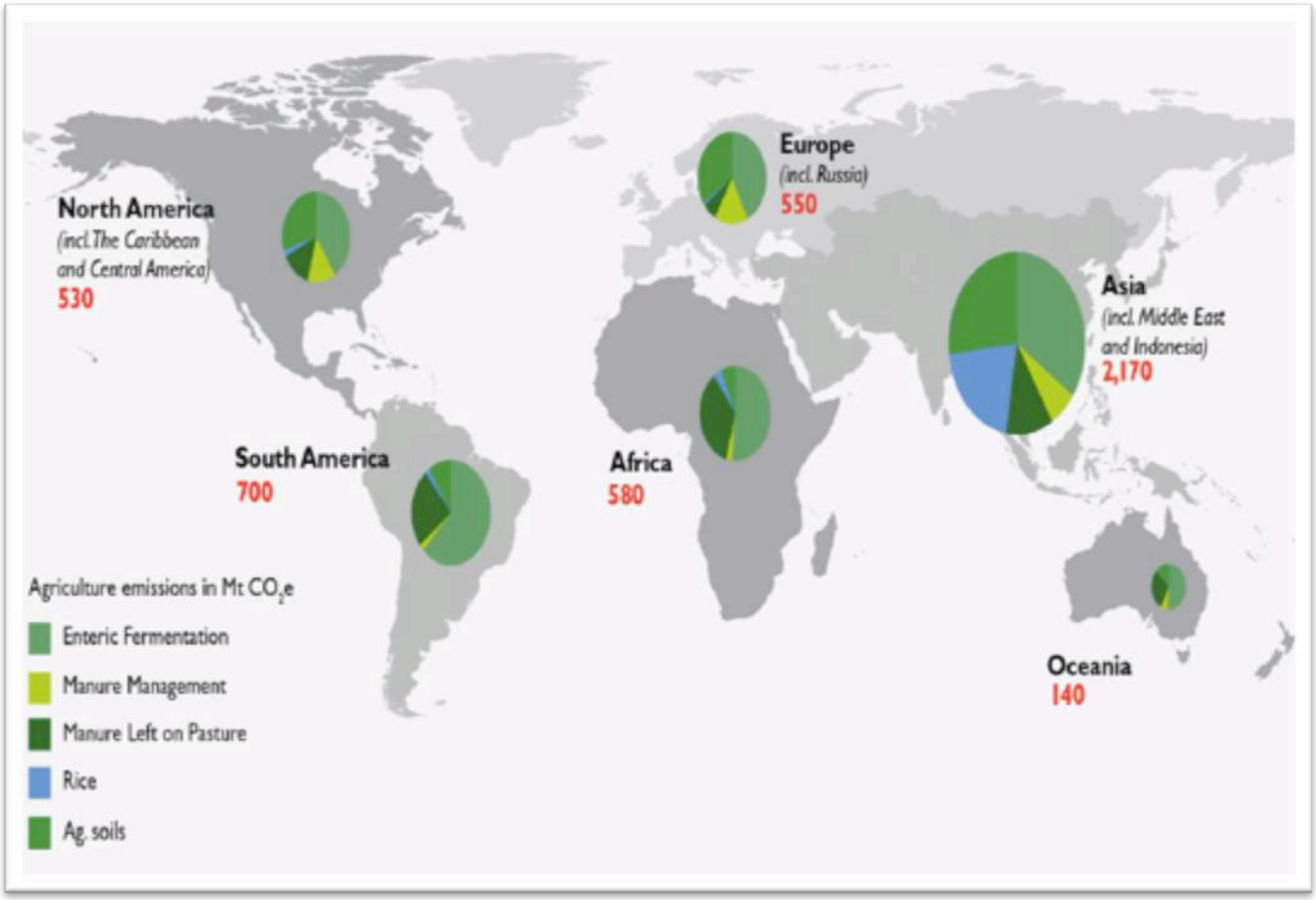


Mitigation opportunities worldwide.[116]

[116] Climate Focus / CEA (California Environmental Associates). In Bibliography.

In general, it appears that English speaking countries are home to the most active groups and associations working to this end, including the Grassland Carbon Working Group and the Carbon Coalition in ***Australia***. Its most significant scientific organisation, the Commonwealth Scientific and Industrial Research Organisation (CSIRO), declared in 2009 that carbon capture in the soil is not only possible in Australia, but a crucial part of its response to climate change.

Shortly afterwards, the Australian Labour Government introduced a payment system for agricultural and livestock farmers who stored carbon as a compensation for their environmental services.



Emissions from Agriculture, by region.[117]

In ***Portugal***, an illustrative initiative in keeping with the Kyoto Protocol has been carried out. In 2009, the government introduced payments for livestock farmers to improve their pastures in non-irrigated land to increase the carbon in the soil, water storage capacity and livestock productivity in approximately 42,000 hectares. The method consisted in establishing a range of 20 perennial herbs and legumes. The data from the project showed that organic matter increased from 0,87% to 3% in ten years[118].

[117] Climate Focus / CEA (California Environmental Associates). In Bibliography.
[118] UE Life. Proyecto Terraprima. www.terraprima.pt

Global Initiatives

The ***FAO*** is calling for a "real Green revolution" that could halt climate change by using better agricultural practices, but also:

- improve soil,
- improve product quality,
- improve the quality of the environment,
- favour biodiversity,
- contain and reverse erosive processes,
- curb desertification,
- compensate for part of the emissions from machinery (electric and industrial production and transport.)

To assist with this process, it announced a new global database for soil which, among other tasks, fosters knowledge on the potential storage. It has also created the ***Global Soil Partnership***[119] to unite efforts. http://www.fao.org/globalsoilpartnership/

The Bonn Challenge (http://www.bonnchallenge.org) is a global aspiration to restore 150 million hectares of the world's deforested and degraded lands by 2020. It was launched by world leaders at a ministerial roundtable in Bonn, Germany, in September 2011. Underlying the Bonn Challenge is the forest landscape restoration approach, which aims to restore ecological integrity at the same time as improving human wellbeing through multi-functional landscapes.

The Bonn Challenge is a practical means of realizing many existing international commitments, including the CBD Aichi Target 15, the UNFCCC REDD+ goal, and the Rio+20 land degradation neutral goal.

In the context of the **UN-REDD Programme**, in September 2014 Global leaders pledge to end forest loss and billions of tons of carbon emissions at global Climate Summit. The declaration would end billions of tons of climate pollution per year , backed with more than $1 billion down payment, and restore 350 million hectares of forest (http://www.un-redd.org/Newsletter2014October/Climate_Summit/tabid/794390/Default.aspx).

The French Government, host of the COP21 in Paris un December 2015, has launched the "**4‰ Initiative: soils for food security and climate"**, which aims to promote soil´s regeneration for the same motifs and ends presented in this Report.

The chapter **"Hope in a changing climate"** gives more information in this regard.

[119] FAO at http://www.fao.org/globalsoilpartnership/es/

Investments

In a whole other sphere, a powerful movement is leading to disinvestment in industries linked to fossil fuels. The best known case is perhaps the *Rockefeller Brothers Foundation*, which in September 2014 announced that it had disinvested 100% of its funds in these industries. This initiative have a high symbolic value, as the Rockefeller fortune was earned following the founding of Standard Oil. The president of the foundation, Stephen Heinz, declared that "John D. Rockefeller guided the United States from whale fat to oil. We are convinced that if he were alive today he would pull his funds out of fossil fuels and invest them in clean and renewable energies."

Also, over 800 global investors, including religious organisations, cities, universities, committed to drawing a total (in September 2014) of 50 billion dollars from investment in the fossil fuel industry over the next five years, because their business model is incompatible with the governments' commitments in terms of climate change.

These events are growing around the initiative *Global Divest-Invest*[120]. Other significant examples are the Universities of Stanford, Harvard - which undertook to sign the Responsible Investment Principles promoted by the United Nations -, and Canberra (Australia), the city of Seattle (United States), and institutional investors who also committed to those Principles.

The director general of the ERAFP (French public sector pensions fund) stated that "it is difficult to refute the fact that CO2 emissions are a risk, therefore how can we carry out our duty if we do not implement the necessary systems to measure the risk, in order to reduce it?"[121]

The largest sovereign fund in the world, the *Government Pension Fund Global (GPFG) of Norway*, worth 850 billion dollars, in its first *Responsible Investment Report* (published on February 5, 2015) announced that it was disinvesting in 114 companies for environmental and climatic reasons. The fund's representative said that "companies with high GHG emissions could be exposed to risks of legislative changes, among others, which would decrease demand for its products."

On the previous day, a group of medical organisations proposed that the health sector disinvest in fossil fuels, as it previously ceased to invest in tobacco, claiming that *"climate change is one of the greatest risks for human health."*[122]

Another boost to these disinvestments took place during the *Climate Summit (United Nations) of New York in September 2014*, during which a group of institutional investors committed to reducing their "carbon footprint" by 100,000,000,000 dollars by December 2015, as a first step.[123]

Underlying these genuine changes in paradigm is the understanding that companies or systems that emit an uncontrollable sub-product with a heavy global impact are more exposed to future risks and are an ineffective means of production.

[120] http://divestinvest.org/
[121] http://montrealpledge.org/the-montreal-carbon-pledge/
[122] The Guardian: Health sector should divest from fossil fuels, medical groups say. In http://www.theguardian.com/environment/2015/feb/04/health-sector-should-divest-from-fossil-fuels-medical-groups-say
[123] United Nations: Investors commit to decarbonize $100 billion in investment. At http://www.un.org/climatechange/summit/2014/09/investors-commit-decarbonize-100-billion-investments/ (2014)

If soil regeneration compensates these emissions, reduces the high global risk and enriches agricultural and livestock property and production, it will not be long before investment flows into it. This process has begun with funds coming from companies such as *Sustainable Land Management Partners,* which manages "regeneratively", to date, 480,000 hectares in Australia, providing good returns for investors[124]; or foundations like *Commonland*, with a similar activity but much broader declared objectives than financial yield.[125]

Countries such as China, Ethiopia and Rwanda are also investing in regeneration (See **"Hope in a changing climate"**).

[124] http://slmpartners.com/
[125] http://www.commonland.com/es/

URGENCY

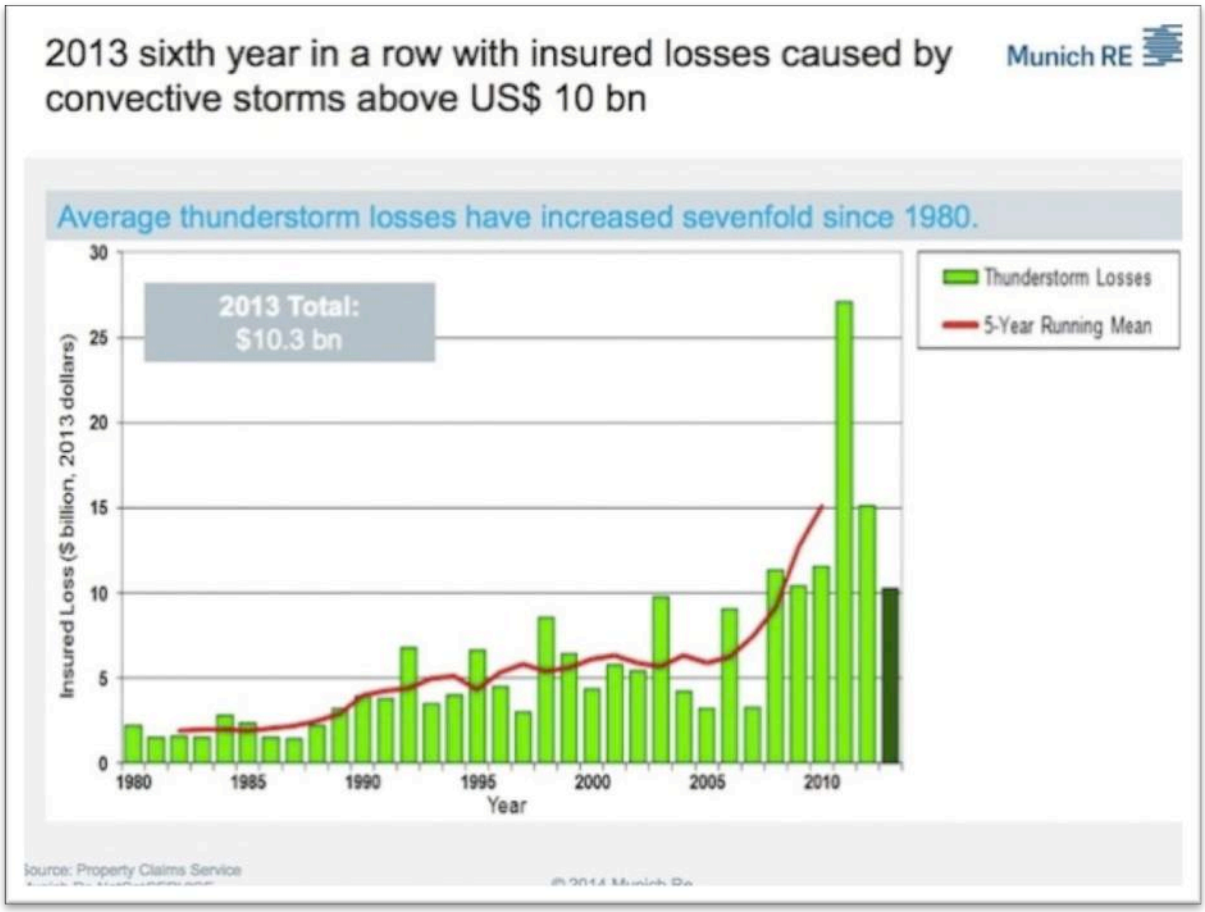
Risks, trends and certainty

The ***Insurance Sector*** is the best prepared to identify and understand the risks and trends of harmful natural events, as its benefits, losses and even survival depend on them. This report comprises some graphs by Munich Re[126] that illustrate the evolution of natural catastrophes, the types of these and the resulting losses. With the exception of "geophysical events", the others are related to the aforementioned statement on soil:

- Climatological and meteorological events are influenced by GHG emissions from soil degradation.

- The consequences of these events depends to a great extent on the situation of the soils: if they are able to absorb rain and retain themselves, plants and buildings in particularly exposed locations. This is especially relevant in the case of:

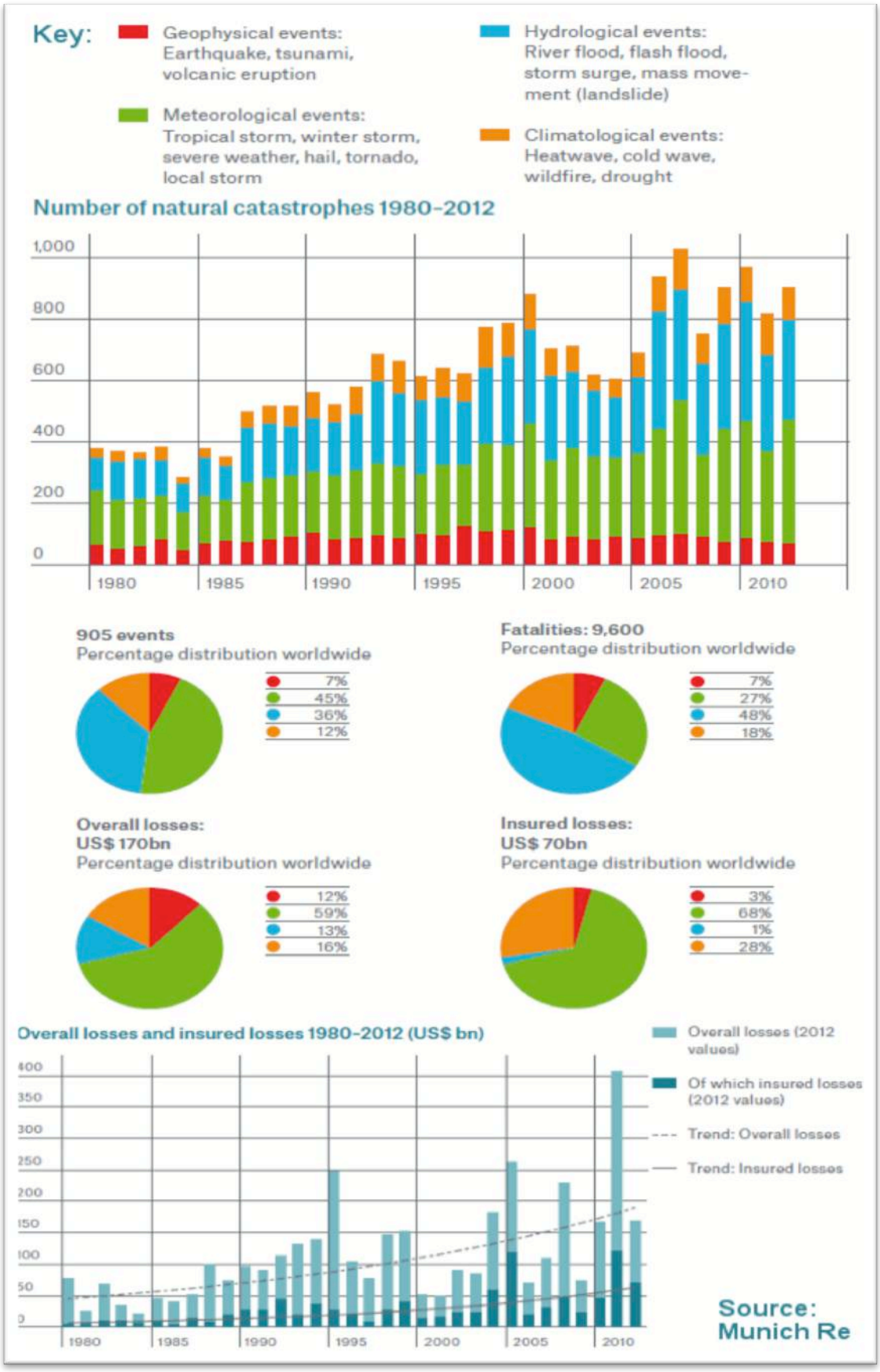
- hydrological events: floods from rain, overflowing rivers, floods from sea storms and landsides.



Evolution of insured losses caused by storms 1980 - 2013. Losses have risen seven-fold since 1980.

[126] Munich Re. At http://www.munichre.com/en/reinsurance/business/non-life/natcatservice/index.html?QUERYSTRING=NatCatSERVICE

Catastrophic events in 2014



Total losses and insured losses 1980 – 2012 in billions of dollars.
Note the evolution in the trends.

Ecological-systemic urgency

This report has presented several reasons why we may not even have the brief timeframe generally imagined. We do have the solution, which is relatively simple and affordable. In addition to the analysis of the catastrophic events of Munich Re, below are shown several relatively recent scientific discoveries that compel us to be brave, swift and *intelligent*.

- **"The increase in the acidity of oceans exacerbates climate change"**
  Plankton will emit smaller quantities of elements that form clouds in the atmosphere, according to a study by the Max Planck Meteorology Institute (Hamburg). In such an event, the effect would be an increase in heat of between 0,23 and 0,48°C if the concentration of CO2 in the atmosphere were to double by 2100, based on the moderate predicted scenario.[127]

- **"Phytoplankton is disappearing from the oceans, which are increasingly warm"**
  Microscopic marine algae is decreasing at an alarming rate. They are the base of marine ecosystems, producing approximately half of the Earth's oxygen, and absorbing CO2 from the atmosphere. The study concludes that approximately 1% is lost every year, and that the northern hemisphere has lost 40% since 1950. The loss appears to be linked to rising water temperatures. Phytoplankton also has a profound effect on the carbon cycle, and thus on the global climate.[128]

- **"Permafrost is melting in Siberia"**
  The rising temperatures of the planet are melting the frozen ground in the Arctic Polar Circle, releasing the methane captured below. Methane has a capacity for generating a greenhouse effect between 20 and 25 higher than that of carbon dioxide (CO2).[129]

- **Has the " 6th Mass Extinction" arrived?**
  Biologists and paleo-biologists suggest that the Sixth Mass Extinction could be underway given the current level of extinction of species.[130]

- **"Possible modification of the Gulf Current"**
  Canadian, American and British researchers (whose work is partly supported by the European Union's Fifth Framework Research Program) have calculated that over the last ten years global warming has modified the salinity of the oceans, which could disrupt the circulation of marine currents (thermohaline circulation).[131]

- **"Satellites reveal that vegetation across the world is transforming"**
  The J.W. Goethe University in Germany states that the "growth seasons" of plants have changed worldwide, based on satellite data obtained over 30 years. This is expected to have profound consequences on agriculture, interactions between species, the functioning of ecosystems and the carbon cycle.[132]

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[127] Eliot Barford: Rising ocean acidity will exacerbate global warming. At www.nature.com August 25, 2013.

[128] Daniel G. Boyce, Marlon R. Lewis,Boris Worm: Global Phytoplankton decline over the past century. In *Nature* 466. (July 29, 2010).

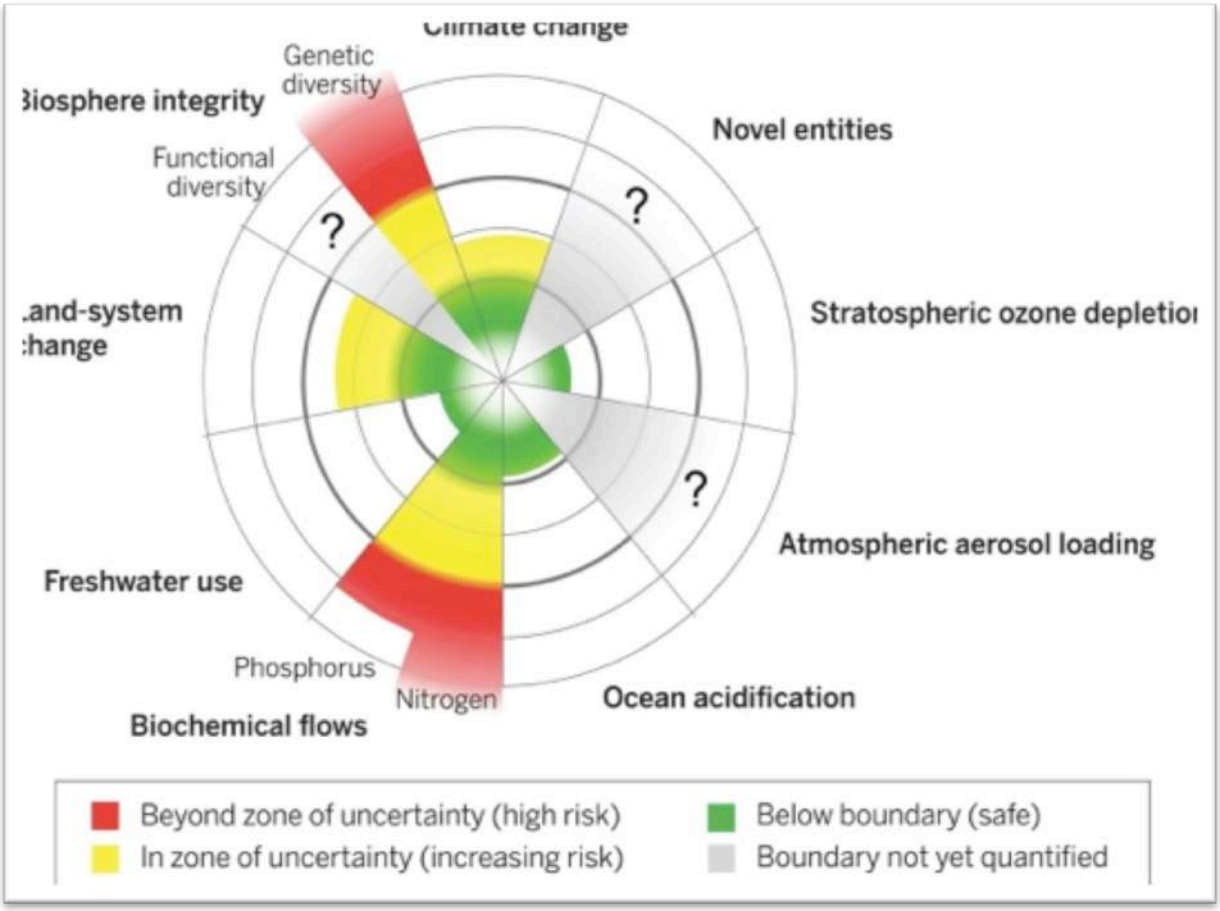
[129] K. M. Walter[1], S. A. Zimov[2], J. P. Chanton[3], D. Verbyla[4] & F. S. Chapin, III: Methane bubbling from Siberian thaw lakes as a positive feedback to climate warming. In *Nature* 443 (September 7, 2006)

[130] A.D. Barnosky et al. : Has the Earth's sixth mass extinction already arrived? In *Nature* 471 (March 3, 2011)

[131] European Commission: ¿ Y si la Corriente del Golfo se detuviese? In *I+DT info – Revista de la investigación europea*.

[132] Dr. Anke Sauter: The Green Lungs of Our Planet are Changing. At https://idw-online.de/de/news626904 (March 6, 2015)

- **"Humanity has overstepped four of the planet's nine limits"**
  Scientists have reached the conclusion that almost half of the crucial processes to maintain stability in ecosystems have already been dangerously jeopardised by human activity.
  The nitrogen and phosphorus cycles have been particularly affected.[133]



Current state of seven of the planet's limits. Green zone: safe. Yellow zone: uncertain (increasing risk). Red zone: high risk. Grey zone: not yet quantified.[134]

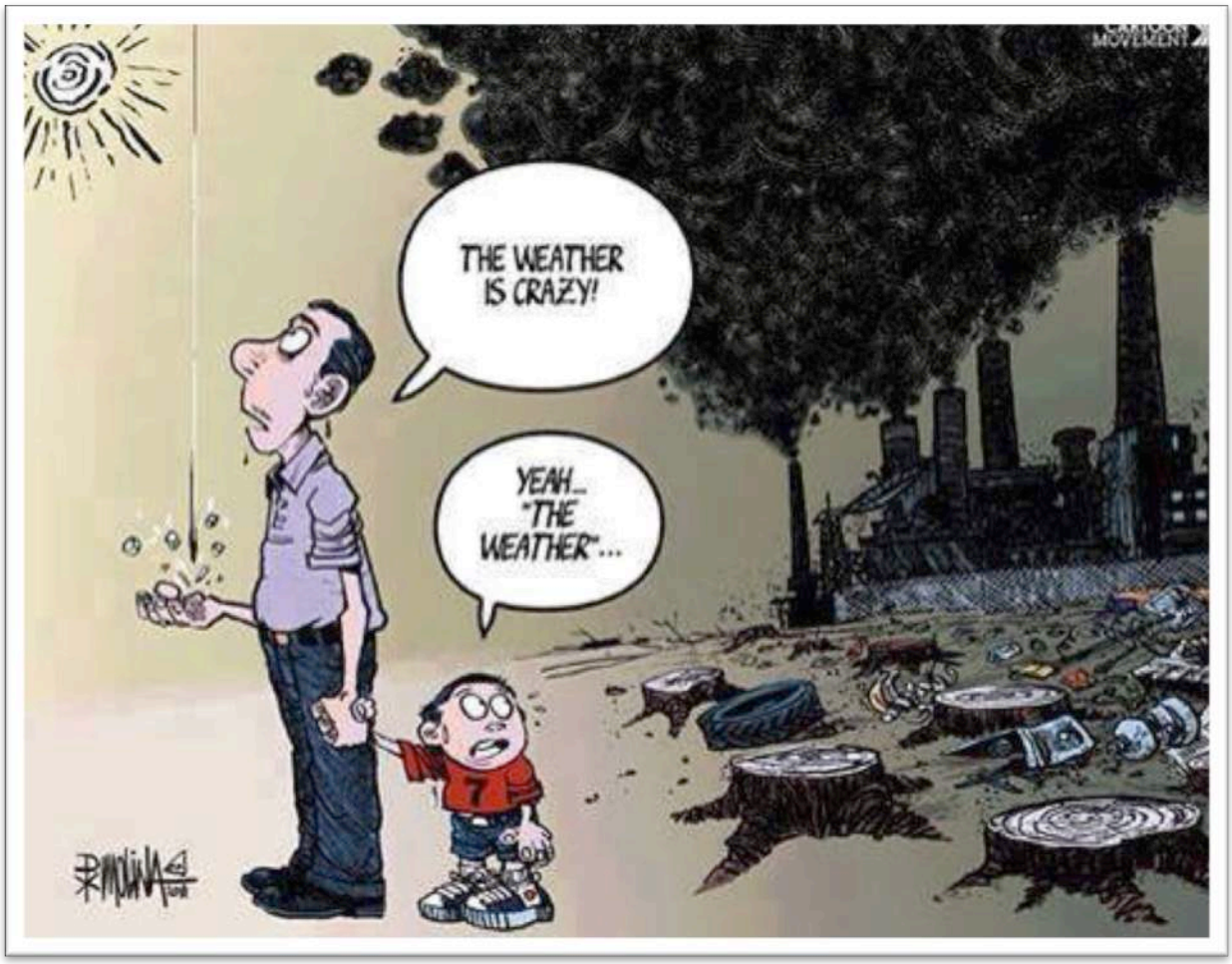
- **In the event of an increase in the average of 2°C by 2100**, the Royal Society expects 1/3 of the current agricultural land worldwide to disappear and the "stress" caused by lack of water to affect 410,000,000 people. If the change is 4°C, adaptation would not be possible in many parts of the world. Half of agricultural land would disappear, sea levels would rise by two metres and approximately 40% of species would become extinct due to droughts and fires across the world.[135]

[133] Will Steffen et al: Planetary boundaries: Guiding human development on a changing planet. In *Science,* February 13, 2015
[134] Will Steffen et al: Planetary boundaries: Guiding human development on a changing planet. In *Science*, February 13, 2015 http://www.sciencemag.org/content/347/6223/1259855.figures-only. Stockholm Resilience Centre – *Sustainability Science for Biosphere Stewardship*. http://www.stockholmresilience.org
[135] Warren, R: The role of interactions in a world implementing adaptation and mitigation solutions to climate change. At http://rsta.royalsocietypublishing.org/content/369/1934/217.full#T3 November 29, 2010

- Global carbon dioxide level just hit a disturbing new threshold

According to the National Oceanic and Atmospheric Administration (NOAA), 400.83 parts per million (ppm) was the average concentration of atmospheric carbon dioxide in March. This news from NOAA marks the first time that the entire planet has surpassed the 400 ppm benchmark for an entire month.

With the rate of growth of atmospheric carbon dioxide concentrations steadily increasing — from about 0.75 ppm per year in 1959 to about 2.25 ppm per year in 2015 — this milestone will soon be surpassed. "This marks the fact that humans burning fossil fuels have caused global carbon dioxide concentrations to rise more than 120 parts per million since pre-industrial times," "Half of that rise has occurred since 1980."[136]



[136] Phillips, A: Global carbón dioxide level just hit a disturbing new threshold. At http://thinkprogress.org/climate/2015/05/06/3655775/carbon-dioxide-new-threshold/ May 2015.

Social urgency

Within very few years, the social perception of climate change has become markedly different, shifting from being perceived as a "hippy" topic to a generalised concern.

A study carried out in October 2011 showed that over 2/3 of Europeans consider climate change a very serious problem, and almost 80% consider that the fight against it can boost the economy and employment.[137]

The European Commission, in a document from February 25, 2015 called "Questions and answers on the European Commission report: the Paris Protocol" states that just "in the last 12 months there has been a greater wave of support, both social and political, for climate action."

The heat-waves during the European winter, the extreme cold in United States, the unusually cold summers, droughts, torrential rain, cyclones where they did not previously occur, the damage to agriculture that they provoke, and other climatic variations: all of these are generally considered effects of climate change, and *are widely perceived as originating in the inaction and irresponsibility of the political and business class, which does little to nothing to prevent the predictable damage and deterioration.*

We have an unprecedented opportunity effect these changes with the appropriate communication. For the changes propounded by this paper, new resources are not needed but instead an adequate, necessary and responsible reallocation of existing ones. The increase in marches calling for climate protection, including the most recent one at the Climate Change conference in Lima[138], and the growing success of initiatives like 350.org or the "Planet Hour"[139], are evidence of this shift, as is *the Keep it in the Ground campaign, which* has as sept 2015 grown to over 400 organisations - worth a colossal $2.6 trillion (£1.68 trillion).

[137] Sondaggio Eurobarometro (http://ec.europa.eu/public_opinion/whatsnew_en.htm) cited in "Sondaggio tra i cittadini Ue: cresce la preoccupazione per il cambiamento climático". At http://www.reteclima.it/sondaggio-tra-i-cittadini-ue-cresce-la-preoccupazione-per-il-cambiamento-climatico/ (2011)
[138] UN: Multitudinaria marcha en Nueva York para exigir acciones contra el cambio climático. At http://www.un.org/spanish/News/story.asp?NewsID=30488#.VQmeM2Z7m2w (2014)
[139] http://www.horadelplaneta.es

Spiritual leaders and churches are too raising their voices and acting to prevent the worst consequences of climate change:

- **Pope Francis "If we destroy creation, creation will destroy us"**

  Speaking to a massive crowd in Rome, the Pope delivered a short address in which he argued that respect for the "beauty of nature and the grandeur of the cosmos" is a Christian value, noting that failure to care for the planet risks apocalyptic consequences.

  "Safeguard Creation," he said. "Because if we destroy Creation, Creation will destroy us! Never forget this!" Creation is not a property, which we can rule over at will; or, even less, is the property of only a few: is a wonderful gift that God has given us, so that we care for it and we use it for the benefit of all, always with great respect and gratitude". Pope Francis also said that humanity's destruction of the planet is a sinful act, likening it to self-idolatry.

In June his Enciclica on the environment and human ecology, "**Laudato Si**", has been published (https://laudatosi.com/).

- **The Church of England announced that it is selling various investments in fossil fuel industries.**

  The Church said £12 million worth of investments in companies making 10 percent or more of their revenues from the production of coal or oil from tar sands would be sold. The Church of England is not selling all its investments in fossil fuel operations, but says it wants to influence companies that contribute to global greenhouse gas emissions.[140]

[140] Id.

Business urgency

An entire economy is growing around the pursuit of sustainability, and companies and initiatives belonging to related sectors are demanding adequate measures and legislation to develop and create employment. Of these, renewable energy is the largest and most rapidly growing example. The world sits up and takes notice when business leaders who have built their fortune predicated on fossil fuels, request the same measures.

To name but one example, Richard Branson (Virgin Group) and Paul Polman (managing director of Unilever) representing BTeam[141], a group of global business leaders, have asked for a ***commitment to reduce GHG emissions to zero by 2050*** since, according to the IPCC, *achieving it by 2100 would only give us a 66% possibility of limiting the average global warming to 2%*, "a risk that neither companies not humanity can take."

Complementary to this information is the one provided in **"investments"** in the chapter **"Emerging global context"**

[141] http://bteam.org

Current and future laws: urgent changes

Additional proof of the situation presented above is the growing questioning of the current legal system, both national and international. One of the most visible initiatives is ***"End Ecocide in Europe***[142]***"*** which in February 2015 presented to the European Parliament its proposal to create European legislation to disincentive and punish "ecocide".

Another important global project is ***"Eradicating Ecocide***[143]***"*** that aims to include ecocide as the Fifth Crime Against Peace in the Rome Statute. Ecocide is defined as "damage, destruction or loss of ecosystems in a territory, caused by a human organisation or other causes, to the point of severely reducing the peaceful enjoyment of its inhabitants."

Extraordinarily, neither governments, companies nor financial bodies are legally responsible for the most severe ecocides despite the damage and risks that they cause. Supporters of the concept argue that despite the numerous international agreements on the matter the damage continues to increase because ecocide has not been outlawed.

The United States has similar initiatives and legal processes underway. The legal basis of these demands in Anglo-Saxon law is that if a nation, or a union of nations such as the European Union, depends on a stable climate, and its habitability, freedoms and even survival is in danger, judges and laws must force politics to "do its job." Governments are trustees of the natural resources that underlie common good and survival. The beneficiaries of the trust are present and future generations.

The laws of Nature are supreme, and one must act in accordance with them, yet governments are betraying both the most fundamental principle on which their mandate is based - common good - and the governed population, with the devastating consequences already evident. *This is not a purely environmental issue, but one that concerns our entire civilization.*

Other examples are:

- ***Dutch government facing legal action over failure to reduce carbon emissions***.[144] The first case in the world *to use existing human rights and tort law* to hold a government responsible for failing to reduce carbon emissions enough.

  The 886 citizens involved in the class action against the Dutch government aim to force it to take more robust action to reduce emissions, They also hope to offer a legal solution to the political impasse on international climate change action. They will ask the judiciary to declare that the Dutch government must implement policies to reduce its emissions by between 25% and 40% below 1990 levels by 2020. This was the target for developed nations – establishedby the IPCC – as necesary to create just a *50% chance of avoiding dangeorus 2ºC rise* in global temperature.

  In june (2015) the Dutch Government has been sentenced.

[142] https://www.endecocide.org/
[143] http://eradicatingecocide.com
[144] The guardian: Dutch government facing legal action over failure to reduce carbon emissions
http://www.theguardian.com/environment/2015/apr/14/dutch-government-facing-legal-action-over-failure-to-reduce-carbon-emissions

- ***A breakthrough with the Launch of the "Oslo Principles on Global Climate Change Obligations[145]" in London in april 2015.*** Created by a group of prolific judges, advocates and professors, they argue that in failing to introduce adequate policy to tackle climate change governments have already broken existing human rights, environmental and tort laws, regardless of agreements brokered at the international level.

- ***"Revolution Justified" publication by Roger Cox[146]*** who argues – alongside other legal experts – that the judiciary can play a foundamental role in tackling climate change. This book has inspired the aforementioned class action.

- **The Governor of the Bank of England** (central bank) has just made a speech to the insurance market, Lloyds of London, in which he highlighted the potential liabilities relating to Ecocide.

"Claims on third-party liability insurance – in classes like public liability, directors' and officers' and professional indemnity - could be brought if those who have suffered losses show that insured parties have failed to mitigate risks to the climate; failed to account for the damage they cause to the environment; or failed to comply with regulations" (http://www.bankofengland.co.uk/…/Pag…/speeches/2015/844.aspx).

[145] http://www.yale.edu/macmillan/globaljustice/Oslo%20Principles.pdf
[146] http://www.revolutionjustified.org/

"HOPE IN A CHANGING CLIMATE." SIGNIFICANT IMPROVEMENTS ALREADY UNDERWAY

A) Loess Plateau in China

"Hope in a changing climate" is the title of a documentary produced by the Environmental Education Media Project (E.E.M.P.) on the restoration and regeneration of the Loess Plateau in north east China In 1995. The director of the E.E.M.P., John D. Liu, was commissioned by the World Bank to record the progress of the works, and has monitored its evolution until the present day.[147]

This vast plateau, measuring 640,000 m^2, is the height of Chinese civilization and one of the first places in which agriculture was developed. Liu described an area "in which desperately poor persons attempted to earn a living in a ruined, dry and dusty landscape", and he doubted it could be restored. The Yellow River acquired its name because of the mud that is carried, which is derived from the erosion of the Loess Plateau, and the increase in the latter has caused the river to swell over history. The river is therefore known as the "sorrow of China."

Zones of the Loess Plateau before and after the regeneration

A team of experts in social and natural sciences analysed the history of the plateau and identified that the causes of the disaster were *deforestation, extractive agriculture and uncontrolled grazing of goats and sheep.* The local population was involved, and these practices were limited and replaced by regenerative systems of agriculture, with perennial and diverse plants instead of annual monocultures. Terraces were also built into the hillsides.

As a result of the visible improvements over the years, Liu realised that *"it is possible to restore and regenerate damaged ecosystems to a significant extent, and this knowledge is not simply an interesting fact but a responsibility that can change the course of human history."*[148]

[147] Liu, John D.: Hope in a changing climate. At https://www.youtube.com/watch?v=QWteolohJEA (2009)
[148] Description of the project at http://eempc.org/loess-plateau-watershed-rehabilitation-project/

B) Regeneration programme of 1/6 of the land in Ethiopia

15 years ago, the villages of Abrha Meatsbha in northern Ethiopia were on the verge of being abandoned. Indeed, the soil was eroded, the zone was suffering a constant alternation of droughts and floods, and the inhabitants depended on food aid from foreign countries. Today the area is unrecognisable, after the planting of millions of trees and bushes. The wells have been replenished, the soil is returning, fruit trees are growing and producing in the valleys, and the hillsides are green again.

This project has been very ambitious: 224,000 hectares combine crops and trees, following agroecology principles and leaving wildlife zones. Ethiopia has now committed to extend this to a further 15,000,000 hectares of degraded land.[149]-[150]

C) *Rehabilitation of the Rugezi Highland Wetlands in Rwanda*

The Rwandan Government recognises the environmental degradation of the country, which includes loss of soil fertility, unsuitable water management and deforestation. The selected zone feeds the White Nile and Congo rivers, and produces hydropower.

The area has been significantly degraded as a result of the deforestation of hillsides for agriculture, which has caused a general reduction of biodiversity, a drop in water levels, and a reduction in soil moisture, evaporation, transpiration and nutrient recycling. This has impoverished the local population, in the zones downstream and globally. The capacity for power generation has fallen, due to the lower water availability. The consequences are accumulative.[151]-[152]

"A silent revolution is taking place in Africa."[153]

- 200,000,000 trees have been planted and 45,000,0000 hectares have been regenerated in Nigeria, producing 500,000 additional tons of food.
- Between 200,000 and 300,000 hectares have been regenerated in Burkina Faso, producing 80,000 tons of food.
- 500,000 hectares have been regenerated in Tanzania.

According to the Green Belt Movement[154], Africa is experiencing the highest temperatures ever recorded, and if no action is taken these could rise by 3 to 4°C by the end of the century, with a 30% drop in rainfall in Sub-Saharan Africa. Regeneration will help to mitigate these trends and adapt to the changes taking place.

As mentioned in "**Emerging global context**" at the ***New York Climate Summit in September 2014***, governments, civil society organisations and companies *committed to restoring 350,000,000 hectares of deforested landscapes, an area the size of India.*[155]

More are sure to follow the example, as it is hoped that the Paris COP21in December 2015 will reach an agreement whereby regeneration can be exchanged for carbon credits.

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[149] Vidal, J: Regreening program to restore one-sixth of Ethiopia's land
At http://www.theguardian.com/environment/2014/oct/30/regreening-program-to-restore-land-across-one-sixth-of-ethiopia
[150] IUCN: Forest Landscape Restoration in Ethiopia. At https://www.youtube.com/watch?v=hNGJxeGSHGY
[151] Description of the project: Restoration in Rwanda. http://eempc.org/restoration-in-rwanda/
[152] Liu, J.D: Rwanda back to the garden. https://www.youtube.com/watch?v=CEDlf3M6Kho
[153] Vidal,J: Regreening program to restore one – sixth of Ethiopia's land. In *The Guardian*.
http://www.theguardian.com/environment/2014/oct/30/regreening-program-to-restore-land-across-one-sixth-of-ethiopia (2014)
[154] www.greenbeltmovement.org
[155] United Nation: Global leaders pledge to end forest loss and billions of tons of carbon emissions at global Climate Summit. In http://www.un-redd.org/Newsletter2014October/Climate_Summit/tabid/794390/Default.aspx

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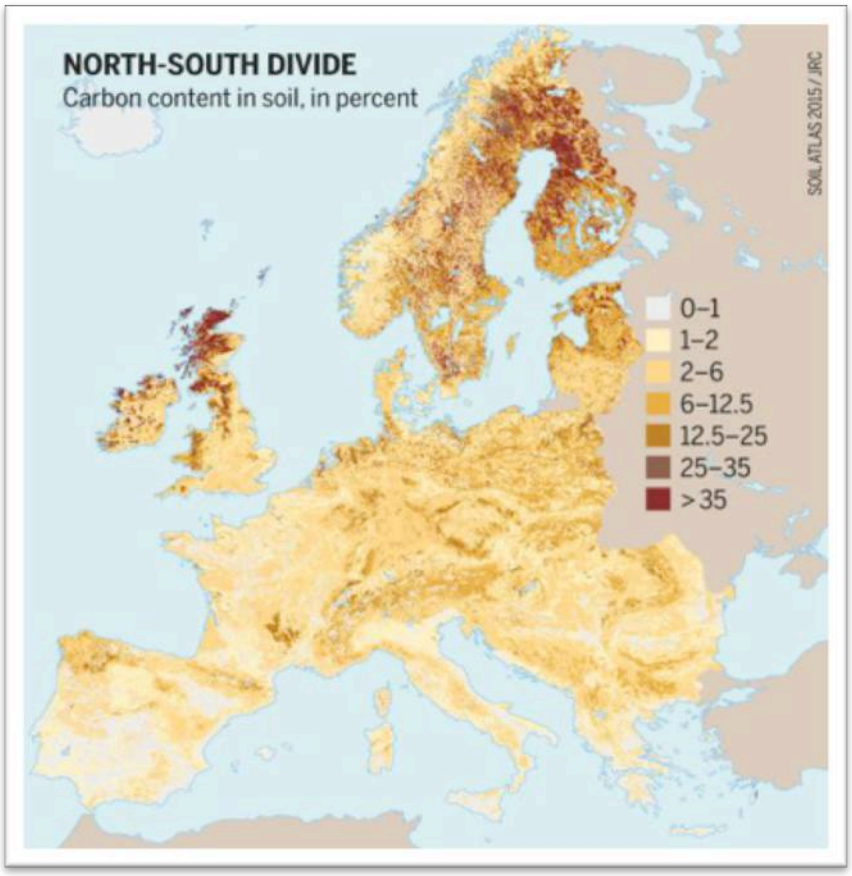
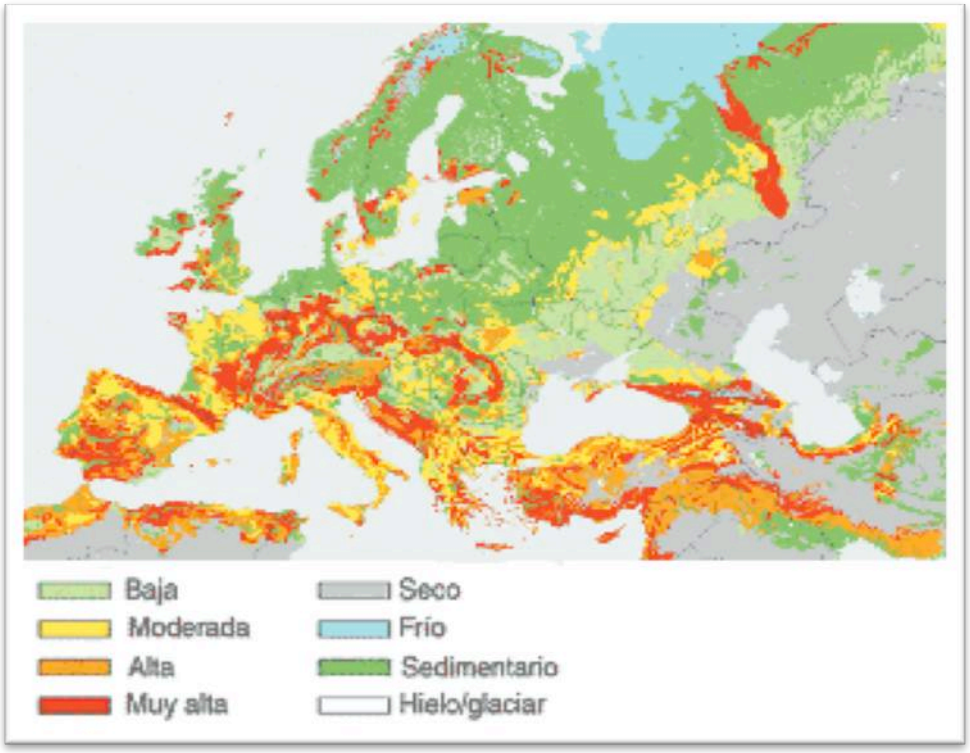


Map 1

Carbon content in European soils (Map 1[156]) and their degradation (Map 2[157]).
Note the coincidence of zones with the most severe erosion, with the exception of C.



Map 2

[156] Source: Soil Atlas 2015 at http://globalsoilweek.org/soilatlas-2015
[157] Source: www.unep.org GEO3: Global Environment Outlook

The following data and opinions appeared in "The State of Soil in Europe" (2102), produced by the Joint Research Center (JRC) in collaboration with the European Environment Agency, of the European Commission. Some overlap with the previous sections can be observed.

Edaphic carbon and global climate

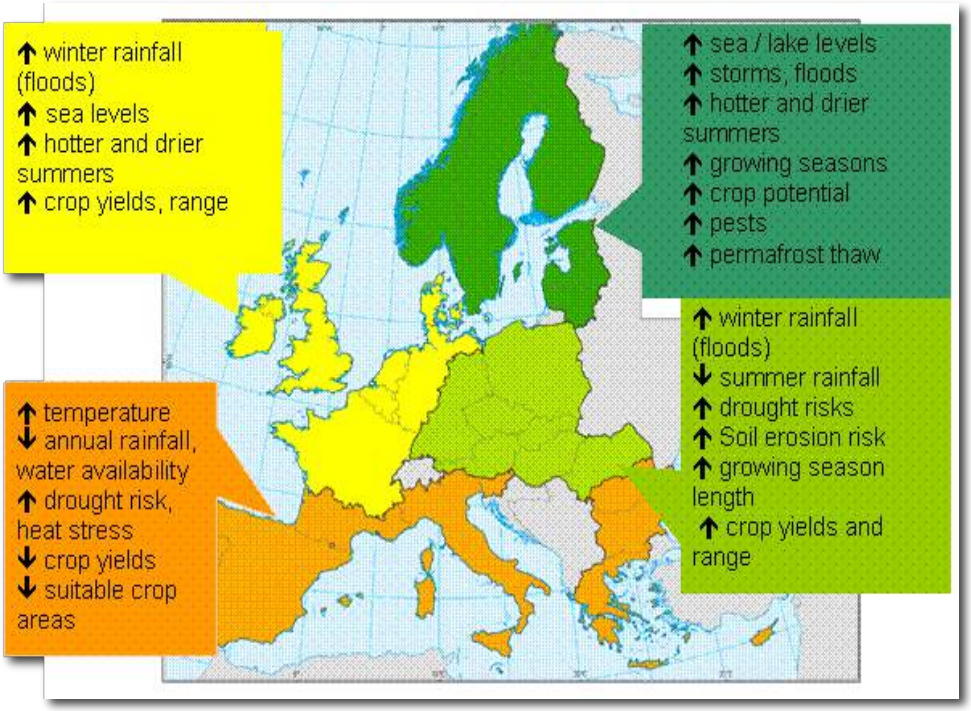
Approximately 45% of the soil in Europe contains very little to little carbon (0-2%), while the other 45% has a moderate content (2-6%) according to a study carried out in 2001 *(Rusco et al: Organic matter in the soils of Europe. Present status and future trends, in JRC)*. It is unlikely that the situation has changed in the last 14 years, in particular in southern Europe.

Vleeshowers L.M. and Verhagen A. *("Carbon emission and sequestration by agricultural land use: a model study for Europe",* in *Global Change Biology* 8) determined that the carbon content in agriculture land is decreasing.

In England and Wales, an average of 0,6% was lost every year between 1978 and 2003, with similar trends observed in France, Austria and Belgium. One cause of edaphic carbon loss is its mineralisation due to excessive nitrogenous fertiliser.

The release of a fraction of the carbon contained in European soil would negate the efforts and successes in reducing GHG emissions. Without a significant intervention in soil management, the effects of climate change could increase carbon emissions and erosion, temperatures and rainfall (northern Europe), their intensity (southern Europe), droughts and aridity.

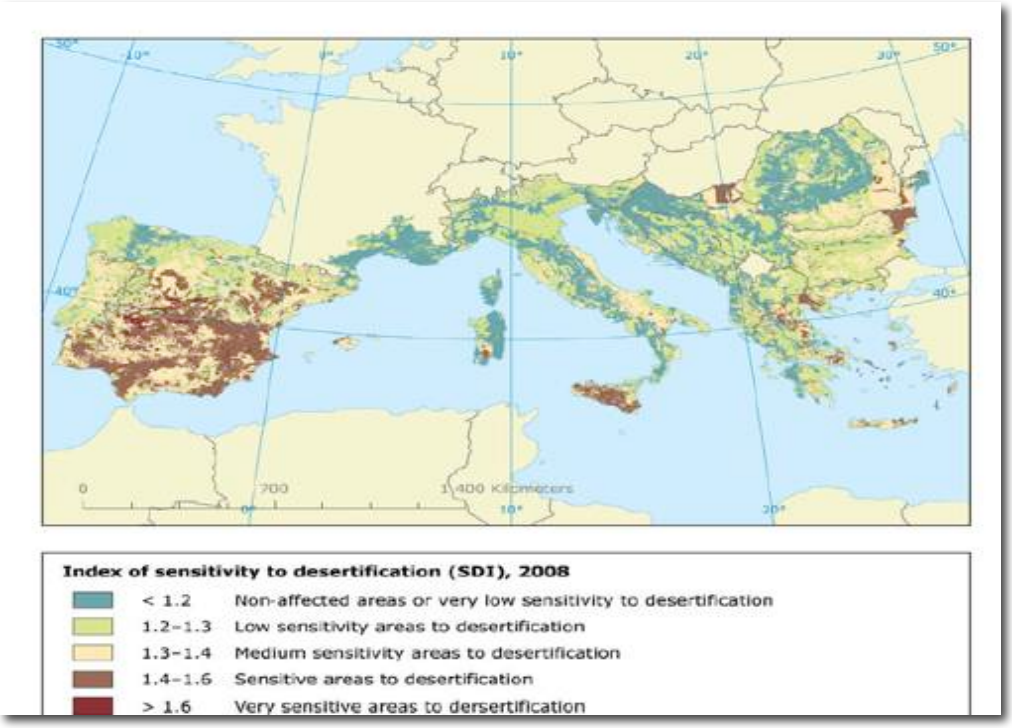
It is estimated that the agricultural land in the EU – 15 could absorb between 60 and 70 million tons of atmospheric CO2 every year, using the adequate regenerative techniques (see "Regenerative Agriculture", page 24).



Predicted impacts of climate change in different regions of the European Union.[158]

[158] Source: European Commission. Directorate General for Agriculture and Rural Development.

Desertification in Europe



Susceptibility to desertification in Europe[159]

If suitable measures are not applied, the frequent and increasingly intense and droughts will cause the collapse of the edaphic mechanisms for water retention, increasing erosion and desertification. Though the situation is variable, *processes of soil degradation are accelerating in Europe.*

Twelve European counties are considered to be affected by desertification, and the phenomenon has been included in Annex V of the UNCCD (United Nations Convention to Combat Desertification). With the exception of Latvia all countries affected belong to the south of Europe. *The situation is particularly severe across large swathes of Spain, in the south of Portugal, the south east of Greece, and areas of Bulgaria and Romania's Black Sea coast.*

Agricultural policies

The Common Agricultural Policy (CAP) is crucial for the improvement or exacerbation of the situation of soils. The current environmental measures can be useful, but do not take into account aspects such as soil sealing, pollution and salinization, nor Carbon emission or storage.

The report SoCo (JRC 2009) confirmed that there are numerous agricultural practices available, both for mitigating and reversing the degradation. (See "Regenerative Agriculture", page 24). Awareness must be raised among farmers but also lawmakers and other stakeholders on the need for these practices, ***for an agreement on the principle that "the polluter pays" as well as the public benefits for which farmers should be remunerated.***

[159] Fuente: European Environmental Agency en http://www.eea.europa.eu/data-and-maps/figures/sensitivity-to-desertification-index-map

These techniques have the advantage of already being available, relatively affordable and not requiring unproven technologies.

The objectives for soil conservation should be included more explicitly in Rural Development programs.

Mitigation and adaptation to climate change

In various documents, the European Commission recognises the crucial role played by healthy soils in extreme climatic conditions. For example, it has a capacity for carbon and water retention, relieves the consequences of drought and prevents floods, erosion and desertification.

In general, the issue is not studied in depth - not even in the "Paris Protocol"- nor are the necessary objectives or regulation established. However, the services provided by healthy ecosystems are ***essential*** to respond to the most extreme impacts.

They are also crucial for potential *climate change mitigation*, through their capacity to reabsorb atmospheric CO2.

Necessary European legislation

A healthy and fertile soil is at the heart of food security. The unsustainable use of the soil is leading to its further degradation and loss. ***The current European legislation is insufficient to guarantee an adequate level of protection for European soils,*** and is therefore unsuited to regenerating degraded or desertified soil and increasing its carbon content. The proposal for a ***Soil Directive (2006)*** has not yet materialised.

European legislation is required, over and above that implemented in each country, for:

* crucial functions carried out by the soil for European ecosystems and societies;

* cross-border effects of certain processes of soil degradation, including the loss of edaphic carbon;

* legislative differences between the various Member States to confront (or not confront) problems affecting soils;

* effects on competitiveness;

* negative effects on international environmental commitments (climate, biodiversity);

* negative effects on crucial environmental aspects and objectives, such as water, air quality, biodiversity and the carbon cycle.

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