Climate change and Mediterranean soil management

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A quick look at the Mediterranean soils

Twenty-two countries surround the Mediterranean Sea and a few more experience similar climate and soil conditions. In fact, the term Mediterranean type of climate is often used to characterise also areas such as southern California, parts of Chile, Argentina, Australia and New Zeeland that are thousands of kilometres far from the Mediterranean region. Mediterranean soils show a great diversity due to variations in soil forming factors including parent material, climate, relief, and biota all acting over very long periods of time. Erosion has been a dominant factor in carving landscapes and influencing soil distribution.

Nevertheless the human impact on soil formation and derived properties of Mediterranean soils is probably more present here than in many other regions around the world. Major soil classification systems such as the World Reference Base for Soil Resources (otherwise known as WRB) sponsored by FAO and developed by major national and international soil science institutions has recognized at the higher level of classification 32 major Reference Soil Groups. The Mediterranean has at least 25 of them. However the best-known Mediterranean soil is represented by the famous "Mediterranean terra rossa" typical for the red colour due to high iron content and a special mineral called hematite.

Other peculiar soils are the WRB classified Anthrosols and Technosols that are soils deeply changed and transformed by humans. One good example for Anthrosols is in the Province of Bari in the Apulia region, where about 20,000 hectares have been converted from pastures and grazing lands to arable land for growing grapes and cereals. All has been done by deep ploughing and "grinding" by mechanical power the rocks and the topsoil up to 60-70 cm deep. Technosols on the other side represent soil permanently sealed or "cemented" by urbanisation. They cover now almost 40 per cent of the Mediterranean coast and may reach as much as 50 per cent in the next decade, provided the sealing rates will remain the same as present.

Malta is another typical example for the expansion of Technosols occupying around 30 per cent of the whole country. Globally 12 million hectares of land each year are lost to sealing while the EU-28 countries continue to lose 275 ha each day. When a soil is sealed, it loses its major functions, such as filtering and storing water, sequestrating carbon, and above all biomass production is totally lost.

Understanding the formation and behaviour of Mediterranean soils is still a challenge that requires the inputs of many pedologists. The dominant parent materials of southern Europe and the Middle East are the limestones and dolomites that gave rise to the development of the typical karstic ecosystem spread throughout the Mediterranean. Furthermore, special attention is needed to understand the past and present role of wind-borne materials from the Sahara desert into the region's soil formation. It is well documented that such process has fertilised naturally for millennia the soils of Northern Mediterranean and Turkey especially with Phosphorous and Potassium; an African contribution that is taken for granted and little known to those outside soil scientific circles.

On the other side the Mediterranean is an "open laboratory" for soil research. This is thanks to the high natural diversity that expands from the fertile Andosols (soils formed on volcanic ashes) of Etna and Vesuvius to Vertisols (high clay soils) of Tavogliere delle Puglie in Italy, to Arenosols (sandy soils) and Fluvisols (soil formed by fluvial depositions) of Egypt, Phaeozems and Kastanozems (high fertility soils that must be protected from any form of degradation) that are distributed throughout the region from the lower valleys to the mountains. On the contrary there are problematic soils such as the saline and sodic ones that cover about 10 million ha region wide with Spain topping the list with 3.4 million ha. Other examples include Histosols (organic soils), Leptosols (shallow soils), Calcisols (calcaric soils), Luvisols (well developed soils) and Cambisols (fertile soils in the process of continued evolution) and a few more.

Mediterranean soils are under pressure from degradation and mismanagement

Despite continued efforts from both local, regional and international institutions operating in the region, soil degradation continues to be a very threatening problem. Zdruli (2014) reports that water and wind erosion, soil sealing and urbanisation, loss of organic matter and biodiversity decline, nutrient mining, chemical pollution and contamination, floods and landslides, salinisation, overgrazing and degradation of vegetation cover as well as unsustainable irrigation practices are the main soil degradation factors in the Mediterranean. Another threatening problem is the "littoralisation" or the cementation of the coastal areas with grave repercussions on the sustainability of fragile coastal ecosystems as well as inland areas.

Pedologists know how to "read" the landscape. The figure below is a good example to show the distribution of soils and the related degradation processes. This approach is very useful to design soil conservation measures and implement them through collaboration actions between decision makers and local communities.

Nonetheless, the main shortcoming is that region-wide soil degradation studies are rare or missing and due to lack of harmonisation of methodologies for estimating the extent of the problem comparisons between countries are difficult, even within short distances. Such weaknesses raise again the need for establishing reliable and up-dated Mediterranean digital soil databases. Due to lack of funding, little is done since almost two decades ago when the CIHEAM - Bari started a programme of soil data collection and reinforcement of national Mediterranean soil institutions (Zdruli et al., 2001). It is equally clear that increased food, water and soil security concerns (Amundson et al., 2015) merged with equitable, productive and sustainable utilization of land and water resources could provide a measure of relief, and increase the well being of the most vulnerable people in the region.

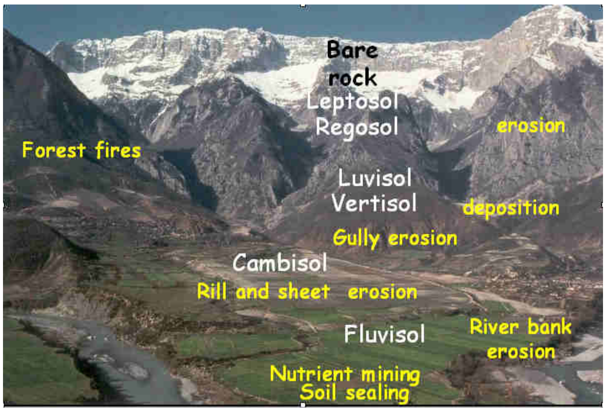
Soils as a remedy to climate change

Soils are both sinks and sources of carbon (C). Global estimates indicate that they contain between 1,206 Pg C (1,301 billion tonnes) of soil organic carbon (SOC) to 1-m meter depth to more than 1,550 Pg (1,659 billion tonnes) C since many soils are deeper than 1 m. This is twice the amount of C present in the atmosphere. Soil organic matter contains more organic carbon than global vegetation and the atmosphere combined (Lehmann and Kleber, 2015).

However, overall the C stocks could reach as much as five times that of the atmosphere. The annual flux of carbon dioxide (CO_2) between soil and the atmosphere globally is estimated at seven times that derived from fossil fuels. The large amount of C stored into the soil is equivalent of about 300 times the amount released annually from burning fossil fuels. Despite not being present in the Mediterranean, it is worth mentioning that a special type of soils called Cryosol (permafrost soils of the Arctic regions) contain enormous quantities of C and greenhouse gasses (GHGs) such as methane (CH_4) and nitrous oxide (N_2O). If the permafrost layer would be affected by thawing or wetlands will dry up, given the fact that CH_4 is between 18 to 25 times more potent GHG than CO_2, in such worst case scenario climate change may get out of control.

Instead, emissions from land use change are estimated to make up between 20 per cent of atmospheric CO_2 through loss of biomass and SOM to 25 per cent (Le Quéré et al. 2014). Agricultural activities contribute, both directly and indirectly, about 30 per cent of the total anthropogenic emissions (IPCC 2014). Therefore, agriculture must be integral to any agenda to mitigate the climate change effects. Finally the significant effects of land use intensification on soil ecosystems may help to improve predictions regarding their response to climate change. This makes GHG emissions from soils a key topic in global change issues, in climate research, and for agricultural and forestry management. Since people started agriculture it is estimated that the world's cultivated soils have lost between 50 to 70 per cent of their original carbon stock.

Figure 1
Schematic correlation between the soil name and soil degradation processes



EU soils contain more than 70 billion tonnes of organic carbon (Lugato et al., 2014), which is equivalent to almost 50 times the EU annual greenhouse gas emissions. In 2009, European cropland emitted an average of 0.45 tonnes of CO2 per hectare (much of which resulted from land conversion). The conversion of peatlands and their use is particularly of concern. For instance, although only 8 per cent of farmland in Germany is on peatland this area is responsible for about 30 per cent of the total greenhouse gas emissions of the whole farming sector.

The Mediterranean land area covers only 6.3 per cent of the global land cover, therefore both its impact on carbon emissions from agriculture activities as well as the sequestration potential may not be too high. Studies (Fantappiè et al., 2010) show that Italy for instance has a capacity to store up to a depth of 50 cm between 2.93 Pg C to 3,32 Pg C (3,3 billion tones of C). Overall the whole region may sequester in its soils less than 7 per cent of the total global carbon stocks. Nevertheless, this doesn't mean that the region should not "play" it's part of the climate change mitigation efforts. It is for this reason that the recently launched "4 pour 1000" initiative endorsed by the CoP21 on Climate Change held in Paris in December 2015 should be strongly supported and the CIHEAM is doing its part and keeping up its commitments.

The "4 pour 1000" is based on the assumption that carbon sequestration from the atmosphere into world's soils should be at the rate of 0.4 per cent per year. The idea is to combine the restoration of degraded land, food production and the fight against climate disruption by aiming to increase soil organic matter levels globally. The initiative strives to show that food security and combating climate change are complementary and to ensure that agriculture provides solutions to climate change. This initiative consists of a voluntary action plan under the Lima Paris Agenda for Action (LPAA), backed up by a strong and ambitious research programme. The "4‰" Initiative aims to improve the organic matter content and promote carbon sequestration in soils through the application of agricultural practices adapted to local situations both economically, environmentally and socially applying the principles of agro-ecology, agro-forestry, conservation agriculture, climate smart agriculture and landscape management. Most recently scientists suggest that climate smart soils (Paustian et al., 2016) should be added into the list of mitigation options.

Skeptics to "4‰" Initiative i.e. Stabinsky (2015) argue that it is practically impossible to reach the target of 4‰ increase of SOM globally and might be some truth on it. However, no one doubt that increasing SOM has enormous benefits for both soil quality, food production, farming sustainability and climate change mitigation. In that context the 4‰ should be supported as it is the first time that soils reach such high level into the climate change negotiations agenda.

To reach maximum benefit of carbon sequestration the 4‰ must be implemented along with other practices such as, cover cropping and conservation agriculture following a systematic approach. Lal (2015) stress out that the 4‰ is not a silver bullet to solve climate change and estimates that it could offset between 10 to 15 per cent of anthropogenic emissions through C sequestration in soils of managed agro-ecosystems. He emphasize the potential of such initiative to make an important contribution in the long battle with climate change by providing also numerous additional benefits such as advancing food and nutritional security and improving water quality.

Conclusions and the look forward

The diversity of landscapes and natural conditions has created tremendous opportunities for economic development in the Mediterranean but has increased also environmental concerns. Human-induced pressures on soils are on the rise throughout the region, competing interests for soil and water resources are having their impact on these limited natural resources compromising the long term sustainable development of the region, which is far from being achieved. Due to increased anthropic pressures throughout the region, but most importantly in the Middle East and North Africa (MENA region) the endorsement of long-term policies for soil protection is not a choice but a prerogative to enhance sustainable development, reach food security objectives, meet the goals of poverty alleviation and confront the huge challenges deriving from climate change. But, unless there is political will to confront these realities chances for success may be limited and the region may continue to accelerate his path towards instability with severe consequences for all the countries in the region.

In order to tackle climate change a number of initiatives are ongoing, some were already mentioned. At recent times, the term carbon farming is also being used. It means that farmers could soon reap up profit if they increase carbon content into the soil. Environmentally-minded farmers are well aware that building up soil carbon is the first step to achieve high yields without chemical inputs. It's through the expansion of global carbon markets, however, where polluting corporations purchase "carbon credits" to offset their carbon emissions. This means that "good" farmers are paid for adopting these practices, especially in degraded lands.

The problem is that carbon prices have been low until present times, and the other difficulty derives from handicaps in evaluating the real carbon stocks as well as monitoring their trends, despite efforts are well under way (especially by the USDA in the USA) that is developing easy-to-use web based systems that will help farmers assess the carbon stocks on their farms.

An important way for moving carbon into the soil is the root, or mycorrhizal fungi, which control the interactions of water and nutrients between the plants and the soil. Plants with mycorrhizal connections can transfer up to 15 per cent more carbon to the soil than their non-mycorrhizal counterparts. The most common mycorrhizal fungi are marked by threadlike filaments called hyphae that extend the reach of a plant, increasing the intake access. These hyphae are coated with a sticky substance called glomalin, discovered only in 1996, which is instrumental in soil structure stability and carbon storage. If land users protect glomalin by minimizing tillage and use of chemical inputs their benefits are higher especially if they combine it with practices such as cover crops that keep living roots in the soil.

Target 15.3 of the Sustainable Development Goals (SDGs) requires that "By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world". This target is paramount also in the efforts contributing to other SDGs, including those related to climate change mitigation and adaptation, biodiversity conservation, ecosystem restoration, food and water security, disaster risk reduction, and poverty reduction (Reed and Stringer, 2016).

It is also complementary to CIHEAM's 2015 Agenda and in particular to strategic goals 2. Natural resources and energy, 5. Agro-ecology and 13. Climate change. We propose that soil issues should find a place in the agenda of CoP 22 of the UNFCCC to be held in Marrakech before the end of 2016. Most likely this could be done in the context of the activities to be held for the "4 pour 1000" Initiative.

As clearly shown, soils have the capacity to remedy and mitigate climate change impacts, but only through sustainable soil management. Knowledge and experience to reduce erosion soil losses to sustainable rates by means of using catch and cover crops, straw mulches, vetiver, reforestation and afforestation, expanding indigenous vegetation, organic residue management, reduced or No-Tillage, conservation agriculture, well designed and implemented terraces, improved cropping systems, contour and strip farming, crop rotations, biochar for its ability to turn problem soils into productive sites while building soil carbon, and agro-forestry is vast and well documented both regionally and globally.

However, this would require the willingness of local people to implement such positive technologies and they should think twice before deciding to plough up and down the slope!

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