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QUANTIFICATION OF SOIL LOSSES DUE TO EROSION, POLLUTION AND URBANIZATION

by Marco Nuti February 13 2015

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Soil deterioration includes both natural and man-made events, with the latter usually being called “soil degradation”. This process causes a decrease in the soil’s actual or potential capacity to give rise to products or services. Hereafter only events of anthropic origin are dealt with. Soil is a complex ecosystem formed by four phases: skeleton, gases, water, and biophase. The latter gives the soil the traits of a living organism, formed by a variety of microbes as well as micro- and meso-fauna. The microbial community represents a relevant component by weight. One hectare of land at a depth of 25 cm, weighing 3,000 t and with 1.5 % organic matter (the majority of Italian agricultural soils) contains up to 3 tons of microbes, i.e., 109 microbial cells belonging to up to 2,000 different taxa. In other terms, one gram of soil is a huge biochemical library producing a variety of genetic instructions, which have been present on the earth for 4 billion years. In one gram of soil, there is enough DNA for 1,598 km. The microbes in bulk soil and around roots (i.e., the rhizosphere) are almost never alone. Rather, they are in micro-colonies or micro-aggregates, are never mono-specific, but in microbial multi-specific consortia instead. These play the following roles in the ecosystems: (a) maintain active biogeochemical cycles; (b) interact closely or loosely with the plant root canopy, ensuring plant nutrition and health; and (c) maintain functional soil biodiversity, i.e., the capacity to perform physiological functions irrespective of their taxon. If an environmental stress (e.g., anoxia, pesticides) causes the inhibition or slowdown of one component of a functional group (e.g., ammonia oxidizers or lignocellulose degraders), another component, belonging to a different taxon, will replace the functions of the former and the overall biogeochemical function (e.g., ammonia oxidation or lignocellulose turnover) will go on. However, the limiting factor of the above functional soil biodiversity is the content of organic matter, namely about 1.75 % or organic carbon corresponding to about 3.5% organic matter. Below this threshold, the environmental stress (pH variations, inorganic fertilizations, pesticides, anoxia, etc.) compromising one or more functions cannot be compensated, unless significant, biologically active, organic matter provision is delivered to restore its content to above 3.5%. The fundamental role of biodiversity for the maintenance of our life quality on Earth is underlined by the United Nations: *"Biodiversity, including the number, abundance, and composition of genotypes, populations, species, functional types, communities, and landscape units, strongly influences the provision of ecosystem services and therefore of human well-being"*. Anthropogenic soil losses have been known for more than four decades. As early as the 1970's, the OECD and ECC-affiliated member States were already warning that the *"Loss of productive soil is one of the most pressing and difficult problems facing the future of mankind"*. Annual losses through erosion have been 0.3% of total areas in emerging countries, and 30% of the plowing layer has been affected by degradation in USA in the last 200 years, along with yield decreases and a subsequent need for higher energy inputs in agriculture. Already 40 years ago, due to an increase in salinity and alkalization, 200-300,000 ha/y were lost in industrialized countries, while 0.3% of irrigated land was lost in developing countries. Because of urbanization, 0.1-0.8% of soil was lost annually in OECD Countries (only 1 million ha in USA). Twenty years later, the European Environmental Agency listed the soils affected (in million ha) as: 115 for erosion, 42 for wind, 85 for acidification, 180 for pesticide pollution, 170 for nitrate- and phosphate pollution, 33 for compaction, 3.2 for organic matter loss, 3.8 for salinization, and 0.8 for waterlogging/anoxia. A few years later, aiming at countering the progressive soil losses, the European Commission officially listed the following causes: erosion, pollution (localized and widespread), salinization/alkalization, a decrease in organic matter content (today 84% of agricultural soils in the EU is below the threshold of 3.5%), uncontrolled urbanization and overbuilding, flooding, compaction, and loss of soil biodiversity. The major role was played by agriculture (inappropriate management, intensive practices, increased specialization and monoculture, insufficient or excessive usage of fertilizers/pesticides, compaction by overgrazing, unbalanced decline of organic matter, and loss of biodiversity). Household activities can cause soil erosion through deforestation (for household heating and cooking), excessive silage, and overcutting of rare woods. All (bio)industrial activities (power, heat, mining, waste recycling, infrastructures, etc.) cause soil pollution, salinization, and overbuilding. Urbanization causes land losses for residential purposes and tourism infrastructures, while the transport chain causes overbuilding, pollution, landslides, flooding, and habitat fragmentation. In the EU, a map (PESERA Map, Pan-European Soil Erosion Risk Assessment) has been developed that identifies annual soil losses as between 1 and 50 t/ha, with Italy in pole position (often losses are 20-50 t/ha), along with the Pyrenees region and Greece, although lower degradation is widespread in the EU. In countries where there is a low soil-formation speed (as in Italy), any annual soil loss greater than 1 t/ha must be seen as irreversible in the span of 50-100 years without recovery measures. Annual direct and indirect costs of soil losses in the EU are impressive (1 billion Euros): 7.3 for erosion, 3.4-5.6 for organic matter decline, 0.15-032 for salinization, 0.01-06 for each landslide, and 0.2 for pollution. There is another relevant consequence of the carbon dynamics at the geo-climatic level: C sequestration and C sinks might help in contrasting GHG emissions into the atmosphere. Considering 1 ha of agricultural land at a depth of 33.5 cm, with a density of 1.4 t/m3 , the soil mass will be about 4,700 t. If this soil contains 1% organic matter, i.e., 47 t, there will be about 25 t of C sequestered in the soil, particularly in the humic fraction (degradable in about 100 years). But if the organic matter is brought back to 4% (i.e., above the threshold for maintaining functional soil biodiversity, as it was for most agricultural soils a century ago), we will have 100 t of C sequestered in the soil. It should be made clear that, at a global level, carbon sequestered in plants is 650 Gt and 750 Gt in the atmosphere, but it accounts for 1500 Gt in soil. It is highly possible that in the next 30 years only soils will be able to immobilize significant amounts of carbon and therefore reduce the actual levels of CO2. Alternative strategies require more than 30 years to capture amounts of CO2 relevant to counter climatic changes. Maybe this is the reason why we should start talking about “regenerative agriculture” and “regenerative soils” as an approach of a true eco-sustainable agriculture at the global level. This would certainly help the celebration on 5th December 2014 of World Soil Day and 2015 as the International Year of Soils, both declared at the 38th United Nations General Assembly on 2nd December 2013, following the FAO Resolutions no. 4/2013 and no. 5/2013 adopted on 22nd June 2013.

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