Assessing Desertification through Soil Biological Monitoring

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Abstract

UNCCD defines desertification as "the degradation of land in arid, semi-arid, and dry sub-humid areas. It is a gradual process of soil productivity loss and the thinning out of the vegetative cover because of human activities and climatic variations such as prolonged droughts and floods. (...) Among human causal factors are overcultivation, overgrazing, deforestation, and poor irrigation practices. Such overexploitation is generally caused by economic and social pressure, ignorance, war, and drought."

Desertification is therefore strictly related to global climate change and loss of biodiversity. Synergies between the three Rio Conventions - the United Nations Convention to Combat Desertification (UNCCD), the United Nations Framework Convention on Climate Change (UNFCCC) and the Convention on Biodiversity (CBD) - are focusing more and more on soil processes and ecosystem services provided by soil biota (edaphon) to assess the impact of desertification processes and the efficacy of the measures undertaken to fight it.

Soil biological monitoring offers a unique chance to coordinate activities related to environmental protection and natural resource management and to address the complementary nature of the three conventions at all levels. Biological processes are key factors to monitor effective soil degradation and desertification intensification, though up-to-now seldom soil monitoring programmes have used soil biological assays to assess these calamities.

A review of the existing methodologies and recent updates on this issue highlight the huge potential in the assessment of the desertification effects of soil biological techniques on different processes and ecosystem services and provide useful insights on Sustainable Soil Management.

Keywords: Desertification Assessment, Land Degradation Neutrality, Soil Biological Monitoring, Italy.

1. Introduction

In 2015, the United Nations adopted the Sustainable Development Goals (SDGs): a set of 17 goals intended to be a roadmap for society to move from exploitation to the sustainable use of our planet's resources.

The UNCCD is the custodian agency for SDG indicator 15.3.1 ("Proportion of land that is degraded over total land area") to monitor progress towards achieving SDG target 15.3 (UNCCD, 2015). The SDG indicators are reasonable proxies for change in land-based natural capital. They are quantified via associated metrics, which are universally applicable and interpretable, and should ideally be quantifiable with available data sets. Three global indicators were selected to assess the quantity and quality of land-based natural capital and most of the associated ecosystem services: land cover (land cover change), land productivity (net primary productivity, NPP) and carbon stocks (soil organic carbon, SOC).

Desertification is a growing threat in the EU, with significant effects on land use. Human- and climate-related processes affect dry areas leading to problems such as diminished food production, soil infertility, decreases in the land's natural resilience, and reduced water quality (ECA, 2018).

Many Italian regions in the past produced desertification maps with confusing term definition: e.g., "*Risk of desertification*", "*sensibility/sensitivity to desertification*" or "*affected areas*" have interchangeably been used. These scattered regional assessments were not updated regularly. Moreover, they cannot be compared, as different indicators and threshold values were applied to identify the critical areas.Desertification

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assessment is traditionally performed through the integration of key factors involved in the MEDALUS model (MEditerranean Desertification And Land USe) within a GIS. All the indices are grouped into four main quality indices: soil quality, climate quality, vegetation quality, and management quality indices. Other soil threats, like biodiversity decline, are often not taken into account even though they are abundantly present and seriously affect proper soil functioning.

As habitats degrade, they become less able to support biodiversity, with badly degraded habitats typically having a reduced biodiversity, or a biodiversity that is shifted to early successional species, so the loss of biodiversity is considered as a form of land degradation (JRC, 2018).

UNCCD started to “combat desertification” employing integrated strategies focussed on productivity, the rehabilitation, conservation and sustainable management of land (Chasek et al., 2019). Since then, policies, procedures, and programs to address land degradation could not have a clear overarching goal and quantitative, time-bound targets to guide action and make measurable progress (UNCCD, 2016a).

Moreover, the present uncertainty of personnel, technological and financial resources prevents an adequate knowledge on how to monitor and govern processes at the required temporal and spatial scales (Chasek et al., 2019).Therefore, there is an urgency to improve low-cost, robust and effective technical tools.Moreover, further scientific researchis needed, for the development of effective methods to measure the balance between different terrestrial ecosystems' qualities, functions and services (Kust & Cowie, 2017).

Recent synergies between the three Rio Conventions - the United Nations Convention to Combat Desertification (UNCCD), the United Nations Framework Convention on Climate Change (UNFCCC) and the Convention on Biodiversity (CBD) - are focusing more and more on soil processes and ecosystem services provided by soil biota (edaphon) to assess the impact of desertification and the efficacy of the measures undertaken to fight it.

To achieve Land Degradation Neutrality (LDN), the ideal situation should be a holistic approach that incorporates the biosphere, society, and the economy, as well as the driving processes (Keesstra et al., 2018). LDNmeans to assess the amount and quality of land resources necessary to support ecosystem functions and services and enhance food security remain stable or increase within specified temporal and spatial scales and ecosystems (UNCCD, 2015a). To answer this request, we propose an ecosystem approach (IUCN, 2008) to address the present desertification challenge at the landscape/regional scale.Only considering all scientific and technological aspects of land degradation, we can promote the evolution of farming and Natureconservation activities to mitigate and adapt to this problem.

Italy owns an outstanding amount of soil biodiversity, often one order of magnitude richer in species than other Northern Europeor Mediterranean Countries. Within the Mediterranean hotspot of biodiversity, Italy is crowned by 320 Plant Important Areas, 172 Important Bird Areasand over 2500Protected Areas. At least a fifth of its surface (in some Region, even more) is or should be preserved at various levels, although the actual pressures of population, agriculture and industry provide heavy loads to their sustainable management.

Particularly, in Italy soil loss is fast and apparently irreversible, esteemed to overcome a rate of 15hectareslost per day (ISPRA, 2018), and phenomena of mountain and marginal rural areas abandonment often trigger unsustainable conditions for land policies. Another spiny interference is the presence of agricultural practices within protected areas. The National Action Plan to reduce the impact of pesticides implies new paradigm to agricultural patrolling activities, to assess and monitor soil quality, and to soil management in general. Implementation of Common Agricultural Policy reform ledRural Development Programmes to establish a widespread and robust indicator for soil biodiversity. This has been achieved by adoptingQBS index, i.e.Soil Biological Quality Index (Parisi et al. 2005), which aims at assessing mesofauna coenoses quality, measuring their specific adaptations to soil.

Crucial roles for soil-provided ecosystem services are performed in the soil foodweb by mesofauna, litter shredders and detritivorous elements in a rich (where natural) community of predators, detritivores and decomposers (Lavelle & Spain, 2001). This key element is central to microorganisms and macrofauna, linked to the peculiarity of local conditions and can be assumed as proxy indicator of both soil biodiversity and soil quality (Parisi et al., 2005; Menta et al., 2018; SISS, 2019).

2. Methodology

The scientific conceptual framework for LDN is designed to be applicable to all land uses (i.e., production, conservation and soil loss), as well as practices introduced to manage land resources, and all types of land degradation, across the wide variety of countries' circumstances, to implement in a harmonised fashion (Chasek et al., 2019).

The complex causes of soil degradation point toward an ecosystem approach to be implemented.Assessing soil degradation by means of soil biological monitoring techniques offers a chance to fully integrate activities related to environmental protection and natural resource management, and to address the complementary nature of the three Rio Conventions at all levels.

Biological processes are key factors to monitor effective soil degradation and desertification intensification, though seldom soil monitoring programmes have used soil biological assays to assess these calamities.

At a landscape/regional scale, we propose to use an integrated method, with GIS system and a geolocalized database. To strengthen statistical analyses, the first step is to upscale the soil types in higher group. To identify these groups, parental material, texture, pH, salt content and organic carbon content are considered. Within each group, applying GIS and NDVI desertification model, we are going to identify three different stages: a normal condition, a transition condition, and a desertification condition.

In each different condition, at least five sites should be identified, within which three different soil samples of 1 dm^3 each (Parisi et al., 2005) should be collected. The samples must be placed for 7-15 days,depending on local conditions, in a Berlese-Tullgren modified extractor for mesofauna extraction and identification.

Multivariate analyses based on the minimum statistical difference,allow to identify the mesofauna type of community for eachsoil group even underdifferent conditions. The QBS indexis based on scoring the morphological adaptations of edaphic microarthropods, their richness and distribution, to assess the degree of specialisation and resistance of soil communities. It reckons differences among taxonomical units, without counting specimens and identifying soil fauna only at high taxonomical level.

An easy-to-apply, simple-to-learn monitoring protocol provided a steady base for further investigation on degraded areas and processes, under different land use and land cover situation, and in different soil types (Menta et al., 2018).

3. Results and Conclusion

Desertification and land degradation are complex phenomena affected by many interdependent factors, and there is no scientific consensus as to how to assess these factors (ECA, 2018). Any effort to address it requires careful assessment of reliable, precise, timely and cost-effective indicators, considering all the environmental, social and economic points of view. A system should be able to determine how the ecosystem behaves under overwhelming waves of stressors, where are the weak points of the ecological community, and determine which pathways are increasing and which are not, and how(Bünemann et al, 2018). An ideal solution to soil degradation monitoring is considering the whole community of detritivores, at least assessing more levels (e.g.: rhizosphere: microbes, fungi, protists, nematodes… porosphere: detritivores, coprophylous, pollenivorous, microphytophagous, invertebrates … drilosphere: earthworms, molluscs and macroarthropods) and eventually relating their quality with soil threats.

With this approach, a model to assess land degradation changes, desertification and loss of biodiversity in a similar climatic region with similar soil group should be accomplished. However, a first step of analysis could be the correlation betweensoil and mesofauna communities as limits of this method could be for each specific region incomplete soil datasets and the accuracy of soil maps.A potential of this method is his application at different scales of analysis, from farm to macro region scale, based upon affordable, shared datasets in a geodatabase.Further insights could be gained analysing each soil community sample in relationship with the corresponding soil group.

Soil biodiversity, in its essence, function and services,is the common element addressingthe hardest challenges derived by desertification, global climate change and loss of biodiversity phenomena, and can be considered also a tool to solve several monitoring and assessment problems and drive societal changes.

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4. References

Akhtar-Schuster M, Stringer L C, Erlewein A, Metternicht G, Minelli S, Safriel U, Sommer S (2017). Unpacking the concept of land degradation neutrality and addressing its operation through the Rio conventions. *J. Environ. Manage*. 195 (Part 1): 4–15. https://doi.org/10.1016/j.jenvman.2016.09.044. http://www.sciencedirect.com/science/article/pii/S030147971630706X.

Bünemann E K, Bongiorno G, Bai Z, Creamer R E, De Deyn G, de Goede R, Fleskens L, Geissen V, Kuyper T W, Mäder P, Pulleman M, Sukkel W, van Groenigen J W, Brussaard L (2018). Soil quality – A critical review. *Soil Biology and Biochemistry* 120: 105–125.

Chasek P S, Akhtar-Schuster M, Orr B J, Safriel U, Luise A, Ratsimba H R (2019). Land degradation neutrality: The science-policy interface from the UNCCD to national implementation. *Environmental Science & Policy* 92: 182-190.

Cowie A L, Orr B J, Castillo Sanchez V M, Chasek P, Crossman N D, Erlewein A, Louwagie G, Maron M, Metternicht G I, Minelli S, Tengberg A E, Walter S, Welton S (2018). Land in balance: the scientific conceptual framework for land degradation neutrality. *Environ. Sci. Policy* 79: 25–35. https://doi.org/10.1016/j.envsci.2017.10.011.

Cowie, A., Schneider, U.A., Montanarella, L., 2007. Potential synergies between existing multilateral environmental agreements in the implementation of land use, land-use change and forestry activities. *Environ. Sci. Policy* 10: 335–352.

ECA (2018) *Combating desertification in the EU: a growing threat in need of more action.* Special Report 33/2018.

Imbrenda V, Coluzzi R, D'Emilio M G, Lanfredi M & Simoniello T (2013). Estimating vegetation vulnerability to detect areas prone to land degradation in the Mediterranean basin. *Geophysical Research Abstracts*. Vol. 15, EGU2013-13652, 2013. EGU General Assembly 2013.

ISPRA (2018) *Rapporto sul consumo di suolo*. Manuali e Linee Guida, MLG 218/2018.

Keesstra S, Mol G, de Leeuw J, Okx J, Molenaar C, de Cleen M & Visser S (2018). Soil-Related Sustainable Development Goals: Four Concepts to Make Land Degradation Neutrality and Restoration Work. *Land* 7: 133.

Kosmas C, Ferrara A, Briasouli H, Imeson A (1999). Methodology for Mapping Environmentally Sensitive Areas (ESAs) to Desertification. In: Kosmas C, Kirkby M, Geeson N (Eds.) *The Medalus Project Mediterranean Desertification and Land Use. Manual on Key Indicators of Desertification and Mapping Environmentally Sensitive Areas to Desertification.* EU, Brussels: 31-47.

Kust G, Andreeva O & Cowie A L, (2017). Land degradation neutrality: concept development, practical application and assessment. *J Environ Manage* 195: 16-24.

Lavelle P & Spain A (2001). *Soil Ecology*. Kluwer Academic Publishers, New York, Boston, Dordrecht, London, Moscow.

Menta C, Conti F D, Pinto S, Bodini A (2018). Soil Biological Quality index (QBS-ar): 15 years of application at global scale. *Ecological Indicators* 85: 773–780.

Orr B J, Cowie A L, Castillo Sanchez V M, Chasek P, Crossman N D, Erlewein A, Louwagie G, Maron M, Metternicht G I, Minelli S, Tengberg A E, Walter S, Welton S (2017). *Scientific Conceptual Framework for Land Degradation Neutrality. A Report of the Science-Policy Interface*. United Nations Convention to Combat Desertification (UNCCD), Bonn, Germany.

Parisi V, Menta C, Gardi C, Jacomini C & Mozzanica E (2005). Microarthropod communities as a tool to assess soil quality and biodiversity: a new approach in Italy. *Agriculture, Ecosystems and Environment* 105: 323–333.

Internet Sources

FAO (2013). Classifications and standards. Retrieved on April, 12, 2011 from http://www.fao.org/economic/ess/ess-standards/en/

IPBES (2019).Web conference: Land Degradation and Restoration: Knowledge Gaps and Needs. 14 January – 4 February 2019. Retrieved on May 14, 2019 from: https://www.ipbes.net/sites/default/files/em_2018_28_land_degradation_and_restoration_knowledge_gaps_needs_20181204.pdf.

Italian Ministry of Environment, Land and Sea, UNCCD, 2015. *Towards Achieving Land Degradation Neutrality: Turning the Concept Into Practice. Italy Summary Report*. Accessed on May14, 2019. Retrieved from: https://knowledge.unccd.int/sites/default/files/inline-files/italy-ldn-country-report-updated-version.pdf.

Shepherd G (2008). The ecosystem approach: five steps to implementation. Accessed on May14, 2019. Retrieved from:https://www.iucn.org/content/ecosystem-approach-five-steps-implementation.

SISS - Italian Society of Soil Science (2019). *Third National Workshop on QBS-ar Index. QBS-ar Working Group Final Report*. https://scienzadelsuolo.org/

UNCCD (2015a). *Integration of the Sustainable Development Goals and Targets into the implementation of the United Nations Convention to Combat Desertification and the İntergovernmental Working Group Report on Land Degradation Neutrality*. Decision 3/COP.12, Ankara,Oct. 12-23 2015. ICCD/COP(12)/20/Add.1.https://www2.unccd.int/sites/default/files/sessions/documents/ICCD_COP12_20_Add.1/20add1eng.pdf

UNCCD (2015b). SDG Indicator 15.3.1. Retrieved on May, 14, 2019 from https://knowledge.unccd.int/topics/sustainable-development-goals-sdgs/sdg-indicator-1531.

UNCCD, 2016a. *Achieving Land Degradation Neutrality at the Country Level: Building Blocks for LDN Target Setting*. UNCCD, Bonn. https://www2.unccd.int/publications/achieving-land-degradation-neutrality-country-level-building-blocksldn-target-setting.

JRC (2018). *World Atlas of Desertification*, https://wad.jrc.ec.europa.eu.