SOIL, FERTILIZERS AND COMBATING CLIMATE CHANGE

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WHAT DO WE KNOW ABOUT SOIL?

We need soil, to keep ourselves alive, on the earth! Soil is a stomach of the plants, as the digestive system is for humans (Patrick Holden, 2015[1]). The fertility of soil is directly connected to the percentage of organic matter and humus in the soil.

Organic matter contributes to soil fertility, structure, and moisture retention. It serves as a source of energy and nutrients for soil microorganisms. Decomposed organic matter is often referred to as humified or stabilized organic matter.

Humus contributes to soil fertility by holding onto essential nutrients, making them available to plants. Humus also helps buffer soil pH and promotes beneficial microbial activity.

Organic matter and humus are the key to healthy soil.

The organic matter in soil serves several important functions[2], including nutrient cycling, water retention, soil structure, carbon storage.

Soil organic matter contains around 60% carbon. It is the defining factor in soil's influence on the global carbon cycle, which makes soil the second largest active store of carbon (40 000 billion tons) after the oceans (European Commission, 2011[3]). There is more carbon stored in soil than in the atmosphere.

WHAT ARE WE DOING TO EARTH'S SOIL?

The agriculture uses fertilizers. Synthetic fertilizers make up 74% of petrochemical industry production (+ other plastics), and they emit 2.6 gigatons of carbon per year (manure has its share as well), which is more than global aviation and shipping combined (Gao & Cabrera Serrenho, 2023[4]). Over 100 million hectares (about two siz-

1 Holden, P. (2015). Soil is the stomach of the plant - sustainable food trust, Sustainable Food Trust - A global voice for sustainable food and health. Available at: ***https://sustainablefoodtrust.org/news-views/soil-stomach-plant/#:~:text=The%20layer%20of%20healthy%20topsoil,forms%20that%20plants%20can%20absorb.*** (Accessed: 18 November 2023).

2 EIP-AGRI. (2016). EIP-AGRI Brochure Soil organic matter. Available at: ***https://ec.europa.eu/eip/agriculture/sites/default/files/eip-agri_brochure_soil_organic_matter_matters_2016_en_web.pdf***. (Accessed: 18 November 2023).

3 European Commission. (2011). SOIL-the hidden part of the climate cycle. Publications Office of the European Union. ISBN: 978-92-79-19269-2 doi:10.2779/30669.

4 Gao, Y. and Cabrera Serrenho, A., (2023). Greenhouse gas emissions from nitrogen fertilizers could be reduced by up to one-fifth of current levels by 2050 with combined interventions. Nature food, 4(2), pp.170-178.

es of Greenland) of healthy and productive land, is degraded each year, from 2015 to 2019 (UN Division for Sustainable Development Goals No:15). Usage of synthetic fertilizers is changing the soil, the gut of plants and the normal carbon cycle. We, humans, striving to produce more food, use more fertilizers, spoil the soil's organic and humus matter and we put agriculture on a carbon positive list.

CURRENT SITUATION IN NORTH MACEDONIA

In the pursuit of sustainable development, the role of environmental stewardship and responsible resource management stands paramount. Recognizing that sustainable development is intricately tied to the well-being of the environment and its ecosystems, this exploration aims to shed light on the impacts of fertilizer usage on soil health and, consequently, its implications for achieving the Sustainable Development Goals (SDGs) in North Macedonia[5].

As the country grapples with the impacts of climate change, including shifts in precipitation patterns and temperature, the need for resilient ecosystems becomes increasingly apparent. Focusing on soil health, a vital component of terrestrial ecosystems addressed in SDG 15, is integral to both climate action and land conservation efforts. Sustainable land management practices not only enhance soil fertility and productivity but also contribute to climate resilience by sequestering carbon and mitigating the effects of extreme weather events. By aligning climate action with the preservation of terrestrial life, North Macedonia can forge a path toward a more sustainable future, where soil health becomes a milestone in achieving both SDG 13 and SDG 15.

North Macedonia holds an SDG index ranking[6] of 60 among the 166 countries assessed. The indicators reveal a stagnant rate for SDG 13 and a moderately improving rate for SDG 15.

Under SDG 13, the target (No.13.2) is to integrate climate change measures into national policies, strategies, and planning, as indicated by No. 13.2.2), which measures total greenhouse gas emissions per year. In alignment with SDG 15 from the United

5 Voluntary National Review 2020 Republic of North Macedonia. (n.d). Division for Sustainable Development Goals (DSDG) in the United Nations Department of Economic and Social Affairs (UNDESA). Available at: ***https://sustainabledevelopment.un.org/memberstates/macedonia*** (Accessed: 28 November 2023).

6 Rankings-The overall performance of all 193 UN Member States. (n.d). Sustainable Development Solutions Network a global initiative for the United Nations. Available at: ***https://dashboards.sdgindex.org/rankings***.(Accessed: 28 November 2023).

Nations Division for Sustainable Development[7], target 15.3 strives to restore degraded land and soil, ultimately working towards achieving a land degradation-neutral world by 2030. This objective is measured by Indicator 15.3.1, assessing the proportion of land that is degraded relative to the total land area. But, according to the UNECE Roadmap[8] for North Macedonia the green growth indicators are not being produced in the country and there is no monitoring of progress towards the global Sustainable Development Goals or their environmental dimension.

No national environmental information system was developed and established in accordance with the provisions of the Law on Environment and the 2005 governmental Strategy for Environmental Data Management.

Recommendation from the UNECE Roadmap are toward detailed actions of preparation of integrated Report on Environmental Indicators and State of Environment Report. Report[9] is done but soil indicators are not included. In addition, the Law on Climate Action was announced in the last three years – but it is still not done.

The validity of the National Strategy for Sustainable Development[10] of North Macedonia was extended until 2030. Outcomes from this Strategy are that the UN in North Macedonia will help country meet its climate change challenges and will work towards integration with global value chains in order to enhance agricultural productivity by implementing sustainable practices, which will lead to creation of awareness about carbon footprints and support industries and the private sector (including SMEs) in adopting resource-efficient and cleaner technologies.

Moreover, a strategic target could involve the establishment of a carbon market, particularly designed to assess, and recognize companies, including those involved in the production of organic fertilizers, that attain carbon negativity. This initiative not only provides a measurable framework for evaluating environmental contributions but also introduces a financial mechanism, fostering incentives for businesses to actively engage in sustainable practices, ultimately contributing to a greener and more carbon-neutral economy.

7 Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss. (n.d.). United Nation Division for Sustainable Development. Available at: ***https://sdgs.un.org/goals/goal15*** (Accessed: 18 November 2023).

8 United Nations Economic Commission for Europe. (2019). Roadmap for the implementation of the recommendations from the third EPR of North Macedonia. Available at: ***https://unece.org/sites/default/files/2021-01/Roadmap%20North%20Macedonia%20-%203rd%20EPR.pdf***. (Accessed: 26 November 2023).

9 Ministry of environment and physical planning. (2022). Quality of the environment in the Republic of North Macedonia Annual Report. Available at: ***https://www.moepp.gov.mk/wp-content/uploads/2023/07/VkupenGodisen2022_Final.pdf.*** (Accessed: 26 November 2023).

10 Sustainable development cooperation Framework 2021-2025. (2020). Government of the Republic of North Macedonia and United Nations North Macedonia. Available at: ***https://www.undp.org/sites/g/files/zskgke326/files/2022-11/un-sdcf-mk_english_signed_0.pdf.*** (Accessed: 25 November 2023).

WHAT CAN BE DONE?

According the Enhanced Nationally Determined Contribution[11] the target level for 2030 is 82% reduction in net GHG emissions compared to 1990 levels (imported electricity not included). Agriculture field should produce 29% reduction (including **soil organic matters** as a default emission factors to be solved). Time frame of implementation is by 2030, with a single-year target delivery.

"What we need: Deep, rapid and sustained Green House Gases emission reductions by 43% by 2030 and net zero by 2050" (UN Division for Sustainable Development Goals No:13[12])

EU regulation dictates reduction of all nitrogen inputs and soil nitrogen supply, but also a maximum amount of livestock manure to be applied, corresponding to 170 kg nitrogen/ha/year (European Nitrates Directive 91/676/EEC[13]). All Member States are required to adopt measures to reduce nitrogen pollution, closed periods when manure and chemical fertilizers cannot be disposed of, and limitations on manure storage and fertilizer application (Kryda, 2014[14]).

European Commission gives a direction to EU members (including North Macedonia as aspiring country), for reaping the benefits of healthy soils for people, food, nature, and climate and made healthy soil until year 2050 (EU Soil Strategy for 2030, Brussels, 17.11.202)

The 3rd Environmental Performance Review of North Macedonia[15] clearly stated that the country did not perform soil monitoring systematically (source available only for heavy metals pollution in the Skopje area).

Actions proposed by United Nations Economic Commission for Europe UNECE[16] are in the direction of preparation of national strategy and action plan on environmental monitoring, legislation specifically addressed to climate change (or an overall strategic document setting climate change priorities) and integration of climate change issues into primary, secondary, and tertiary education curricula.

11 Enhanced Nationally Determined Contribution- Submission by the Republic of North Macedonia. Ministry of environment and physical planning of R.N Macedonia. Available at: ***https://unfccc.int/sites/default/files/NDC/2022-06/Macedonian%20enhanced%20NDC%20%28002%29.pdf*** (Accessed: 29 November 2023).

12 Take urgent action to combat climate change and its impacts. (n.d.). Division for Sustainable Development Goals. Available at: ***https://sdgs.un.org/goals/goal13***. (Accessed: 18 November 2023).

13 European Nitrates Directive 91/676/EEC. (1991). Available at: ***http://data.europa.eu/eli/dir/1991/676/2008-12-11***. (Accessed: 18 November 2023).

14 Kryda, M. (2014). Factory farming makes Baltic Sea one of the world's most polluted. ARC2020. Available at: ***https://www.arc2020.eu/factory-farming-made-the-baltic-sea-one-of-the-worlds-most-polluted-seas/***. (Accessed: 18 November 2023).

15 United Nations Economic Commission for Europe. (2019). 3rd Environmental Performance Review of North Macedonia. United Nations, Geneva.

16 United Nations Economic Commission for Europe. (2019). 3rd Environmental Performance Review of North Macedonia. United Nations, Geneva.

What direct actions can restore the carbon in the soil?

Carbon restoration in the soil is a multifaceted process that involves integration of various sustainable agricultural and land management practices in order to enhance soil health, carbon restoration in the soil and mitigate the impacts of climate change. For example, leaving crop residues on the field after harvest instead of burning them helps retain organic matter or/and manure management as composting manure and organic materials before applying them to the soil.

SOLUTION

Vermicompost Fertilizers

Composting (or casting[17]) manure offers several benefits, both for agricultural practices and environmental sustainability. One of the benefits is **pathogen reduction** (sterilization) of raw manure for reducing the risk of diseases in crops and animals.

Composting stabilizes and transforms the nutrients in manure into a more plant-friendly form which allow **nutrient enrichment** gradually over time, providing a sustained and steady supply of nitrogen, phosphorus, potassium, and other essential elements for plant growth.

Using this kind of inputs (fertilizers) **adds organic matter to the soil**, enhancing its structure and water retention capacity contributing to overall soil health. **Microbial activity** by microorganisms introduced during composting can further enhance soil microbial activity, fostering a healthy soil ecosystem. Composting manure helps **sequestering[18] carbon in the soil**, contributing to the mitigation of greenhouse gas emissions. The stable organic matter created through composting acts as a carbon sink, promoting soil carbon storage.

Carbonization of soil is a complex and dynamic process influenced by multiple factors. Naturally made microbial, worm composting fertilizers can heal the soil. Those fertilizers (known as biohumus) are not made in laboratories. They are made on the field, as a product of vermicompost farming. The "Californian red worms"[19] use manure as a food. Worms process manure within a period of one year and deliver biohumus. Biohumus is a solid fertilizer[20] rich in all organogenic elements, microelements, and bioactive microorganisms. Biohumus as a fertilizer, is applied directly

17 Casting is a process in which Californian red worms treat/use, as food, the manure originating from cows/ horses/ sheep. Composting is a process in which worms are feed with food leftovers or plant residues.

18 Carbon Sequestration -process of capturing and storing atmospheric carbon dioxide.

19 Eisenia fetida (Latin Binomial name)- species of earthworm adapted to decaying organic material.

20 It can be used for any kind of plants (organic / conventional agriculture).

to/above the root. Application of solid Biohumus for certain plants can be difficult. But innovative liquid form[21] can be applied by: drip irrigation system, foliar irrigation, with sprinklers, atomizers (using tractor) or by airplane/ drone spraying. Process for obtaining Orgalife liquid fertilizer is patented[22] under the patent number MK/P/2020/107 (Trade mark/ registration number: 31392[23])

Fertilizer's microbes and their value proposition

Microbes are a crucial component of the vermicompost fertilizers. The high number of microorganisms and their ferments revive the soil, increase soil fertility and can retain carbon back into the soil. Microorganisms representing integral parts of this fertilizer are in direct connection with fertilization restructuring as well. Due to their metabolism, microorganisms are able to endure the most extreme soil existence conditions, resulting in their long-term presence in soil. Those microbes are actually "soil microbes".

In liquid fertilizer[24] microbiological analysis[25] shows different types of soil microbes such as Nitrogen fixator, Cellulolytic bacteria, Nitrificator and Denitrificator bacteria. Also includes aerobic, heterotrophic and mesophilic bacteria, and yeasts + molds.

Microorganisms from worm fertilizer (Orgalife) stimulate the following processes: Nitrogen fixation[26] of molecular nitrogen from the air, the circulation of phosphorus[27], potassium synthesis[28] and Humification[29].

The Humification is the process by which organic matter in the soil is transformed into humus, a more stable and resistant form of organic material.

Humus is resistant to further decomposition and provides long-term storage of carbon in the soil. Microorganisms, particularly bacteria and fungi, play a crucial role in decomposing the complex organic compounds present in the organic materi-

21 Orgalife: liquid organic Microbiological Fertilizer, Biostimulator and Soil improver, ***www.organikanova.com***

22 Technological procedure for obtaining liquid fertilizer and soil improver from California worms. (2023). State office of industrial property- R. of N. Macedonia. Available at: ***http://www.ippo.gov.mk/Search/PatentSearchDetails.aspx?nr=107&series=2020*** (Accessed: 18 November 2023).

23 Orgalife- Trade Mark. (2019). State office of industrial property- R. of N. Macedonia. Available at: ***http://www.ippo.gov.mk/Search/TradeMarkSearchDetails.aspx?nr=869&series=2019*** (Accessed: 18 November 2023).

24 Orgalife. (n.d.). Organika Nova. Available on: ***www.organikanova.com***. (Accessed: 18 November 2023).

25 Microbial analysis Available at: ***http://organikanova.com/wp-content/uploads/2018/02/MIKROB.-2017-ORGALI-EN.pdf***

26 Nitrogen fixation of molecular nitrogen from the ai. Organika Nova. Available at: http://organikanova.com/nitrogen-fixation-of-molecular-nitrogen-from-the-air/ (Accessed: 18 November 2023).

27 The circulation of phosphorus. (n.d.). Organika Nova. Available at: ***http://organikanova.com/the-circulation-of-phosphorus/*** (Accessed: 18 November 2023).

28 Potassium synthesis. (n.d.). Organika Nova. Available at: ***http://organikanova.com/potassium-synthesis/*** (Accessed: 18 November 2023).

29 Decomposition of organic matter. (n.d.). Organika Nova. Available at: ***http://organikanova.com/the-rapid-decomposition-of-organic-matter/***. (Accessed: 18 November 2023).

al, where complex organic materials are transformed into humus. This decomposition is part of the natural breakdown of organic matter.

All those processes occur in their balanced form. When using "microbial fertilizer", there is no extra depositing of certain elements (such as when applying chemical fertilizers) since those are natural physiological soil processes resulting from existing and evolution processes of soil microorganisms. Humification process can be accelerated by vermicomposting.

This specifies the so-called balance or equilibrium level for importing and exporting natural nutrients in and out of the soil. It is sufficient for correct yields and preserving the natural fertility of soil to the level it used to have in the past.

In the end of their life cycle, microbes themselves contribute to the organic matter pool in the soil (formation of microbial biomass). As microbes decompose organic matter, they incorporate some of the carbon into their own biomass. Microorganisms in the soil multiply by dividing. A single bacterial cell could give rise to a large population, often referred to as exponential or logarithmic growth (Hagen, 2010[30]). When bacteria die, their biomass becomes part of the soil, leaving behind a huge[31] amount of organic matter.

Foundation of vermicomposting farms (for production of microbial fertilizer) can be crucial for manure displacement action (unsustainable industrial livestock production is the major contribution in overall pollution). North Macedonia does not have a strategy for manure (pollution) displacement.

By clear strategy and spreading the know-how of vermicompost farming, each of the livestock farms can be potential vermicompost farm, as a side activity. Organika Nova provides, free of charge, know-how for establishing and running the vermicomposting farm (brochure: Manual for raising Californian red worms[32]). The farmers, with no extra efforts and in addition to livestock farm activities, can run vermicomposting farm and produce biohumus fertilizer. The Government should recognize the potential of healing the soil by vermicompost farming and usage of vermicompost fertilizers. This can be incorporated into the subsidizing of startups but also in subsidizing the "market placement" and usage of the fertilizer as a domestic product. With this action, in addition to environmental sustainability (healing the soil/ replacing the soils' carbon reservoir), economic benefits for the rural parts can be in accordance with the "leave no one behind" strategy).

Industrialization is going forward fast. The food production as well.

30 Hagen, S.J., (2010). Exponential growth of bacteria: Constant multiplication through division. American Journal of Physics, 78(12), pp.1290-1296.

31 The specific quantity of dead bacterial body left in soil can vary because it is part of a broader cycle of organic matter turnover and decomposition in the soil ecosystem.

32 Manual for raising Californian red worms. (n.d.). Organika Nova. Available at: ***http://organikanova.com/wp-content/uploads/2023/08/Oganika_ENG_A4prirachnikPRINT.pdf***. (Accessed: 18 November 2023).

CONCLUSION AND RECOMMENDATIONS

The imperative to prioritize soil health and responsible fertilizer use is inseparable from the global effort to combat climate change under the umbrella of the Sustainable Development Goals (SDGs). It is crucial to recognize the interconnectivity of these elements and underscore the need for comprehensive policies and initiatives. The success of these endeavors hinges on addressing the diverse needs of various communities, ensuring that advancements in soil management and fertilizer practices are inclusive and benefit all. For instance, policies should consider the challenges faced by smaller farmers, aiming to provide them with the necessary resources and knowledge for sustainable practices. Simultaneously, initiatives should strive to enhance food accessibility for marginalized communities, fostering a future where no one is left behind in our collective pursuit of a healthier, more sustainable planet.

At the policy level, it is imperative to implement financial instruments that support grassroots initiatives. Furthermore, the inclusion of soil indicators is essential. The development and production of green growth indicators within the country, along with a systematic monitoring of progress towards global Sustainable Development Goals, particularly in their environmental dimension, should be prioritized. Additionally, the adoption of the Climate Action Law is crucial to solidify these efforts.