pagepress

Techno-diversity for carbon farming and climate resilience

Bruno Basso

Department of Earth and Environmental Science and W.K. Kellogg Biological Station, Michigan State University, East Lansing, MI, USA

One size does not fit all in agriculture. What works in one place may not work in another. Land dedicated to agriculture has had the essential role of producing food for all people living on our planet for thousands of years. With the increase in demand for food due to the ongoing global increase in population - this land is continuously being pushed beyond the point where carbon dioxide removed from the atmosphere through the process of photosynthesis, is exceeded by the emissions from the necessary agronomic practices used to obtain ever higher yields (Dusenge *et al*., 2019). Furthermore, excessive use of fertilizers and pesticides has a strong negative impact on the quality of water and the environment (Liu *et al*., 2021). As a consequence of this inappropriate use of resources and the imbalance between carbon dioxide emitted and fixed by plants, the agricultural sector today substantially and negatively contributes to climate change with greenhouse gas (GHG) emissions into the atmosphere accounting for 24% of global anthropogenic activities (Smith and Gregory, 2013).

Reducing the negative impacts of climate change is the biggest challenge of our lifetime. Given our current lifestyles (in most high-income countries), we have less than 7 years to avoid a 1.5 degree warming and 24 years to avoid a 2-degree warming above pre-industrial levels (Warszawski *et al*., 2021). We are already at 1.1 degrees. While it is true that the world has been this warm, and in fact much warmer before, it is the pace of change that will challenge our civilization. If climate change continues to be ineffectively and inappropriately addressed at the highest political level, we can expect to see an increase in the frequency of extreme events; in some cases, a quadrupling of phenomena such as drought, flooding, and forest fires. These worrying forecasts, alongside decreasing food security and reductions in biodiversity, are negatively impacting environmental and economic equity. In short, everyone will be affected, irrespective of social and economic status.

Correspondence: Bruno Basso, Department of Earth and Environmental Science and W.K. Kellogg Biological Station, Michigan State University, 288 Farm Lane, East Lansing 48824-1312 MI, USA.
Tel.: +1.517.353.9009. E-mail: basso@msu.edu

Received for publication: 1 December 2022.
Accepted for publication: 5 December 2022.

Italian Journal of Agronomy 2022; 17:2178
doi:10.4081/ija.2022.2178

The main impacts of agriculture on the climate (global warming) are through GHG emissions of nitrous oxide (N_2O), strongly related to the use of nitrogen fertilizers, methane (CH_4), primarily from the enteric fermentation of animals in livestock farms, and carbon dioxide (CO_2), as a result of tillage activities and land disturbance generated by microbial activity in the soil. Whilst agriculture contributes to climate change, it also suffers its negative effects.

Carbon Farming is considered as a new soil and crop management system; the objective being the net reduction of GHG emissions into the atmosphere and the sequestration of carbon into the soil. The agronomic practices that contribute to the achievement of carbon farming goals are diverse, and their success varies according to many factors including climate, soil type, and landscape. Equally important is the varying and local economic and cultural conditions that help determine the practices that can be adopted; thus, techno-diversity is necessary.

Techno-diversity is a new approach to agricultural activities, based on equity, diversity, inclusion, and justice. Its goal, to unite different stakeholders' visions and directly integrate causality with a systems approach, based on a set of rules open to solutions that would otherwise be impossible to conceive. Techno-diversity does not just mean applying different (often more complex) technologies, but rather integrating techniques resulting from varying stakeholders and actors with different background experiences and potential solutions, to generate flexible and self-adaptive tools (not requiring continual human inputs and corrective measures) in the context of - inevitably - growing complexity. It means considering different levels and sources of knowledge and their derived actions, and then incorporating this understanding into the basis of life itself: unpredictability. A specific vision begins with an assumption, which elicits answers that are somewhat predetermined too often based on personal experiences. We must recognize that 'the best,' solution for a particular scenario will not easily be translatable, or indeed may be appropriate in another context defined by different objectives and questions. Therefore, a new meta vision is required, one that involves the use and integration of different visions, one that is dynamic and responsive to a complex, largely unpredictable reality. The interdisciplinary (not just multidisciplinary), ecological approach that is derived from this new concept vision, is therefore not simply the result of technology born from traditional ecological sciences, but from the integration between all sciences and, more deeply, between diversities, welded by the humanity of the gaze that generates them (Ison, 2018) This humanity has, compared to the rest of reality, nothing less, and only one thing more: the responsibility that derives from awareness and the ability to act by calculation. We need to embrace the natural unpredictability of events, and provide a framework to harness this, while maintaining or possibly increasing positive attributes of the agricultural 'system' (Ison *et al.*, 2021).

Carbon Farming fits fully into this context and cannot be faced simply as the contribution of a limited set of actors helping solve climate problems, or a further opportunity for economic exchange on the market. Carbon farming cannot be configured as a specific practice, nor as a sum of practices, but rather as a holistic systems approach conducted with different technologies (techno-diversity) suitable for managing complex space-time interactions. For effective action, the use of appropriate techniques is insufficient. However, the practice of interdisciplinarity, the cross-fertilization of hard sciences and humanities, can generate a culture capable of coordinating and effectively harnessing the complex actions of farmers, industry, citizens in a transactional ecological context for environmental good, through the use of different disciplinary tools, connected and coordinated with each other, such as income support, incentives, active involvement, transparent communication, and integrated supply chains including individual citizens who through their purchasing decisions have immense power but are frequently unaware of it. Research is part of the social context, including the economic one, and it should always be aware of this.

Globally, the top one-meter depth of soil contains around 2 trillion tonnes of soil organic carbon (SOC), a carbon (C) stock approximately three times greater than that held in vegetation and twice that in the atmosphere (Lal, 2004). Returning carbon to the soil has become the cornerstone of healthy soil initiatives. However, doing so by better managing SOC requires farmers to adopt and maintain a suite of regenerative practices that reverse the losses of C due to current conventional agriculture. Incentivizing farmers to use these practices requires low-cost, scalable, high-resolution soil carbon information that can quantify the costs and benefits of a regenerative agricultural transition (Bradford *et al*., 2019).

Regenerative Agriculture is a management system for agricultural production in line with carbon farming. It supports diverse crop rotations, intercropping, reduced or zero tillage, constant soil cover (*e.g*., through the use of cover crops), reduced nitrogen fertilizer inputs, and the sustainable management of livestock. In addition to the reduction of GHG emissions, these practices generate further co-benefits in terms of the sustainability of agricultural activities, such as an increase in biodiversity, a reduction in the contamination of groundwater, rivers, and lakes, an increase in soil organic matter and a reversal of soil degradation, as well as greater efficiency in the use of natural resources (*e.g*., water [rainfall and irrigation] and nutrients) due to an overall improvement in soil health, and greater profits for farmers.

Technology, the daughter of scientific reductionism (which operates by keeping the ways of observing and knowing reality separate) now can and must operate with tools and languages that consider the overall understanding of the system, knowledge of which it is essential to have to make reliable predictions of outcomes. Real, current examples of how this new approach is being implemented is through the use of simulation models of plant growth and the availability of historical remote sensing maps of yield stability (Basso *et al*., 2019; Maestrini and Basso, 2022; Basso and Antle, 2020), which when integrated with real-time satellite observations of the soil, the crops grown, and their management, make it possible to predict and determine the GHG emissions associated with the agronomic practices adopted. These technologically sophisticated systems make carbon farming practically feasible and economically sustainable, due to the ability to simulate the outcomes of potential management actions in advance, measure the outcomes of actual practice, and guide the planning of interventions during crop growth (Jones *et al*., 2017).

There are major barriers to adopting a carbon farming approach. These include the difficulty in correctly determining: i) the carbon sequestration potential in different soils and under different climatic conditions; and ii) the magnitude of the increase in SOC stock due to changes in management practice, when carbon stock prior to the practice change was not determined (*i.e*., additionality); as well as iii) guaranteeing the permanence of carbon in the soil (*e.g*. 100 years); iv) identifying and quantifying possible indirect carbon losses (*i.e*., leakage - reductions in yields that would be compensated for by growing crops in other regions not already cultivated); v) the complexity and difficulty of techniques concerning measurements and the evaluation of uncertainty in simulation models; and vi) the initial cost to adopt management needed to be a carbon farming project. Thanks to the systems approach and the use of the tools mentioned above, the benefits obtained from carbon farming far outweigh the costs generated by the implementation difficulties. A rapid and widespread adoption of carbon farming is possible through economic incentives for farmers and proceeds from carbon credits, together with a reduction in the costs of verifying practice adoption and quantifying carbon in the soil.

In the United States, carbon farming continues to expand with carbon credit market transactions as an inset, *i.e*. within the agricultural product supply chain, and as an offset between different societal sectors (*e.g*., finance, transportation, energy). These transactions undergo an ever-increasing scrutiny by consumers and communities who rightly demand greater transparency in the manufacture of products derived from agriculture and greater environmental protection. The growing attention to environmental sustainability generated by carbon farming is now also evident in the financial markets where investors in 'sustainable investing' and 'ethical finance' (investments in the sustainability of companies and countries) can obtain greater economic returns from investments in companies that use carbon-based fossil fuels.

Carbon farming will undoubtedly help shape the future of agriculture and the sectors that rely on and are associated with it (environment, agri-food, finance, and tourism), and by extension the future of our planet. Carbon farming can be a winning scenario on many fronts; it enables resilience in agricultural systems, allowing them to better adapt to the deleterious effects of climate change and mitigate the contribution of agriculture to these negative impacts. However, it is foolish to think that we can solve the problem solely by relying on silver bullet technologies. The human mind is the greatest asset that the planet has. Just as the dashboard of an aircraft is complicated, the climate crisis is a complex issue because it involves human decision making. The initial complexity evolves into new complexity that cannot be analysed using the same tools. A technology that may work in one place and in one time period, may very well fall flat in another location and time if communities are not engaged and have no feeling of ownership of the solution. The writer Kim Stanley Robinson in his book *The Ministry for the Future*, posed the question: Does technology drive history? We make tools and they have allowed us to cope with the world. But it is the mind the driving force in history, it is the social engineering and systems architecture that drive history. We need to accept that we live in chaos, and we need to learn to cope with it. The Sustainability revolution needed to protect our planet is among the largest investment opportunities in history, and we will succeed.

References

Basso B, Shuai G, Zhang J, Robertson GP. 2019. Yield stability analysis reveals sources of large-scale nitrogen loss from the US Midwest. Sci. Rep. 9:5774.

Basso B, Antle J. 2020. Digital agriculture to design sustainable agricultural systems. Nat. Sustain. 3-4:254-6.

Bradford MA, Carey CJ, Atwood L, Bossio D, Fenichel EP, Gennet S, Fargione J, Fisher JRB, Fuller E, Kane DA, Lehmann J, Oldfield EE, Ordway EM, Rudek J, Sanderman J, Wood SA. 2019. Soil carbon science for policy and practice. Nat. Sustain. 2:1070-2.

Dusenge ME, Galvao Duarte A, Way DA. 2019. Plant carbon metabolism and climate change: elevated CO2 and temperature impacts on photosynthesis, photorespiration and respiration. N. Phytol. 221:32-49.

Ison RL, Collins KB, Iaquinto BL. 2021. Designing an inquiry-based learning system: Innovating in research praxis to transform science-policy-practice relations for sustainable development. 2021. Syst. Res. Behav. Sci. 38:610-24.

Ison RL, 2018. Governing the human-environment relationship: systemic practice. Curr. Opin. Environ. Sustain. 33:114-23.

Lal R. Soil carbon sequestration impacts on global climate change and food security. Science. 304:1623-7.

Liu L, Zheng X, Wei X, Kai Z, Xu Y, 2021. Excessive application of chemical fertilizer and organophosphorus pesticides induced total phosphorus loss from planting causing surface water eutrophication. Sci. Rep. 11:23015.

Jones JW, Antle JM, Basso B, Boote KJ, Conant RT, Foster I, Godfray HCJ, Herrero M, Howitt RE, Janssen S, Keating BA, Munoz-Carpena R, Porter CH, Rosenzweig C, Wheeler TR, 2017. Brief history of agricultural systems modeling. Agric. Syst. 155:240-54.

Maestrini B, Basso B, 2021. Subfield crop yields and temporal stability in thousands of US Midwest fields. Precis. Agric. [Epub ahead of print].

Sanderman J, Hengl T, Fiske GJ, 2017. Soil carbon debt of 12,000 years of human land use. Proc. Natl. Acad. Sci. 114:9575-80.

Smith P, Gregory P, 2013. Climate change and sustainable food production. Proc. Nutr. Soc. 72:21-8.

Warszawski L, Kriegler E, Lenton TM, Gaffney G, Jacob D, Klingenfeld D, Koide R, Mañez Costa M, Messner D, Nakicenovic N, Schellnhuber HJ, Schlosser P, Takeuchi K, Van Der Leeuw S, Whiteman G, Rockström J, 2021. All options, not silver bullets, needed to limit global warming to 1.5°C: a scenario appraisal. Environ. Res. Lett. 16:064037.

Zomer RJ, Bossio DA, Sommer R, Verchot LV, 2017. Global sequestration potential of increased organic carbon in cropland soils. Sci. Rep. 7:15554.