Climate Bonds Initiative

Sustainable agriculture

Systems and practices for agricultural transition

DISCUSSION BRIEF

27 September 2022

Defining sustainable agriculture

1. Introduction

Agriculture is a dynamic and complex system, composed of countless particular characteristics that defy standardization and common definitions. For instance, hundreds of cultivated crops and a wide array of systems and practices are employed in different geographical locations with diverse social, environmental and economic landscapes. This scenario requires that any intervention made in the sector should be context-specific.

Agriculture accounts for an estimated 34% of all anthropogenic GHG emissions worldwide (Crippa et al., 2021). In 2019, emissions within the farm gate (crop and livestock production, including on-farm energy use) accounted for 7.2 Gt CO_2 eq. yr^{-1}, while emissions from land-use change accounted for 3.5 Gt CO_2 eq. yr^{-1}. In brief, 65% of all emissions within the agri-food sector are related to primary food production (Tubiello et al., 2022). In addition to the high carbon footprint, traditional agricultural practices are drivers of biodiversity loss and water/soil degradation (Benton et al., 2021; Hunke et al., 2014). At the same time, agriculture is one of the sector most vulnerable to the impacts of climate change (Tao et al., 2011). Recent extreme events have demonstrated how food production systems can be affected by shifting global climate; heat waves in southern Asia have destroying wheat crops and severe drought in southern Brazil has severely damaged the soybean crop.

To reduce the impact of food production on the environment, the sector must shift to a more **sustainable** footing. Generally, 'sustainable' activities are usually understood as those that are capable of meeting the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland report; 1987). However, a standard narrative on what constitutes sustainable agriculture is yet to emerge due to the complexity of the sector. **Production systems** are often referred to as "sustainable", but the absence of agreed definitions mean that the risk of incremental changes to business-as-usual and of greenwashing is substantial.

Moreover, there is an ever-increasing demand that the sustainable performance of agricultural systems should go beyond environmental impact and incorporate **social standards**, such as widespread access to nutritious diets, steady incomes, stable land rights and prioritization of underserved groups. The process of combining environmental guidelines and social standards is an enormous challenge for the definition of sustainable agriculture. Social issues have a horizontal behaviour across the supply chain, and should not only be addressed within the production unit, but also considering and analysing the impacts on upstream and downstream sub-sectors.

Climate Bonds aims to provide clarity to capital markets and institutional investors on the component factors of sustainable agriculture to enable rapid and positive change in investment practices. Considering this challenge, we propose to break down the various named systems (regenerative agriculture, natural agriculture, etc.) into potential sustainable **management practices**, which are to be defined by common characteristics, regardless of the system(s) they may be a part of.

2. Production Systems Linked to Sustainable Agriculture

A large number of systems is reported in literature, but we consider four of the most representative examples that align with the broad concept of sustainable agriculture, although it should be noted that the sustainability of any system is dependent on the actual implementation.

1. **Regenerative agriculture**, a well-established concept that has recently gained a lot of ground. Robert Rodale coined the term in the late 1980s. It consists of a system that aims to restore soil health, reducing but not eliminating synthetic fertilizers and pesticides and ensuring that

agricultural practices positively affect the environment (FOLU, 2019). Regenerative agriculture practices are ultimately linked to shifting the agricultural operations from a source to a sink for carbon, inverting the GHG emissions dynamics correlated to conventional practices (Oberč & Arroyo Schnell, 2020). Despite the broad definition of the regenerative system, the lack of a global consensus on a scope of practices and the exclusive nature of some alternative definitions creates numerous challenges for researchers, producers, regulators, and consumers (Newton et al., 2020).

2. **Ecological intensification** of agricultural activities is a broad concept that may be applied in different regions, contexts, and crops. Countless names have been used to define similar and/or aligned sets of practices and principles, such as **diverse or agroecological systems**. In summary, ecological intensification aims to improve or maintain agricultural yields achieved by conventional practices, but meeting good standards of environmental quality. This goal is attained by optimizing biological processes and using their benefits to overcome challenges such as pests, diseases, and low soil fertility (Oberč & Arroyo Schnell, 2020). In other words, the aim is to embed resilience into the agricultural operation to sustain yields in the face of adversities, based on the postulation that biodiversity and ecosystem services can be used as a replacement for external and artificial inputs (Kleijn et al., 2019). Nevertheless, as discussed for regenerative agriculture, the ecological intensification system faces similar issues related to the lack of a common definition and standard practices, making its widespread adoption a resting challenge.
3. **Sustainable intensification**. This system is linked to the promotion of ever-increasing yields without triggering any adverse environmental impact and eliminating the need to convert additional non-agricultural land. The sustainable intensification concept openly does not highlight or privilege a standard set of practices. Still, it emphasizes the objective of using well-strategized and innovative techniques to enhance the overall efficiency of an agricultural operation (Pretty & Bharucha, 2014). Under this "end rather than means" oriented approach, sustainable intensification systems may take numerous forms depending on where and when it is being employed, making any kind of classification barely impossible, as it may show close similarities with many other described systems, especially with those mentioned above in this document, further falling under the same challenges. However, the use of outcomes as a metric for standardization may be beneficial in the sense that just the endline of an operation is under evaluation, mitigating the complexity of describing all the processes required to achieve said outcome.
4. **Organic agriculture/farming**. This term might be the most widely-known regarding sustainable agriculture. This is because the organic farming movement has successfully built a strong connection between producers and consumers, based on environmental and health benefits linked to the non-use of agrochemicals and other inputs. Even as the principles underpinning the system may seem clear to some, especially consumers, they go deeper into many aspects beyond banning synthetic pesticides and fertilizers, such as maintaining biodiversity, clean energy sources, and animal welfare (Oberč & Arroyo Schnell, 2020). Nevertheless, different practices may be required to achieve these principles depending on where and when the system is being applied, prompting standardization issues as mentioned above. These issues are, in some cases, addressed by regional regulations and standards on produce originating from organic farming operations, much of it answering consumer demand. The most up-to-date data shows that 72 countries have fully implemented national organic agriculture regulations, and 36 have drafted or approved but not fully implemented such rules (FiBL & IFOAM, 2021).

As previously mentioned, the absence of any system in this relatively short list of descriptions is not an attempt to prioritize one concept over another. At this point, it is clear that the list of known systems and variations within systems is extensive and far beyond the capacity of any common standard to classify and regulate. Nonetheless, we must have a proxy guiding the sector towards sustainable approaches. Therefore, we attempt to do so in the next section by identifying the management practices more often related to sustainable agriculture, some of which may very well fit into one or more of the systems previously presented.

3. Management Practices Linked to Sustainable Agriculture

This section aims to summarise the practices more often related to sustainable agricultural operations. It is essential to make clear that the sustainable potential of these practices depends on how and where they are employed. Therefore, regional context must be considered when discussing further standardization, enhancing the complexity of the task. For this reason, all this information is latter summarized in *Table 1*, and for further discussion, practices are broken down in three groups: Always Sustainable, Usually Sustainable (with some caveats) and Sometimes Sustainable (under some conditions) according to their context specific environmental impact. Once again, no preference was given in this selection, and the practices discussed below are up for constant revision and update.

Soil management practices aim to increase soil health and, thus, its capacity to support crops. In this topic, the first set of practices to address is **no/minimum tillage** and **direct seed**. The act of not tilling (not incorporating residues) increases the production and retention of organic matter by the soil, enhancing biological activity and soil fertility, reducing soil erosion, improving water quality and sequestering more carbon (Buffet, 2012). However, no-till practices can be linked to an elevated weed pressure, which should be addressed by means other than increasing the use of herbicides. Additionally, in temperate weather regions, the soil temperature must be closely tracked to ensure these conditions meet crop requirements. No/min-till practices should be accompanied by crop management strategies, such as **crop rotation**, **agroforestry**, **crop-livestock integration**, **intercropping**, **polycultures**, **cover crops,** and **mulching**, aiming to increase the production and distribution of diverse biomass, which is further converted into organic matter. By increasing the content of organic matter, the soil becomes a carbon storage facility, not only reducing emissions by its enhanced capacity of supporting crops without substantial external inputs, but also sequestrating carbon that otherwise would be dispersed in the atmosphere. Finally, crop management must be conceived and applied in coordination with **integrated nutrient management**, which includes compost, organic manure, nitrogen-fixing crops, fertigation, and bio-fertilizers (PGPB and N-fixing microorganisms).

Continuing our run across sustainable practices, the centre of attention will now be on how to deal (sustainably) with one of the most prominent threats to agriculture production through a joint strategy defined as an **integrated pest, diseases, and weed management**. One of the backbones of this approach is the intensively discussed practice of **biological control**, which can potentially be applied to managing all harmful organisms in an agricultural operation (pests, disease, and weeds). Biocontrol is the act of combating said pestilential organisms using other living agents. However, recently, the use of nature-based substances (non-living, e.g., isolated metabolites) is to be considered under the same umbrella, now renamed **bioprotection** (Stenberg et al., 2021). The benefits are numerous; to emphasize the reduction/extinction of agrochemicals as a management practice and the potential of creating long-term resilient environments.

Many sustainable agriculture systems focus on enhancing production efficiency, meaning that bigger yields are contemplated while using fewer resources. Some systems have in-scope practices related to **precision agriculture/farming to enforce this objective**. Those practices aim at using the necessary number of resources, and nothing more than that, to ensure the highest possible yield. This goal is achieved by applying technologies of near-real-time observations, which enables agricultural management decisions to be tailored in time and space, always following the actual necessities of the system (Finger et al., 2019). Some practical examples of precision agriculture practices are predictive models of plant diseases and pests, precision planting/fertilizing technologies, irrigation control, remote crop-scouting, interpretative yield maps, and many other technologies being developed and tested by the numerous dedicated companies in the field.

Another set of practices that trigger discussions in the sector is the vast group of **plant breeding** approaches, especially regarding genetically modified organisms or GMOs. Traditional plant breeding, based on selecting and/or crossing genotypes to accumulate desired characteristics in one individual plant, has been around for millennia and has acted on building the genetics of all cultivated crops nowadays. These techniques have shown incredible potential in increasing plant production efficiency and resilience by adding traits such as disease resistance, drought tolerance, and yield performance, thus enhancing the sustainable capacity of agricultural systems (Borlaug, 1983). However, the use of genetic engineering techniques for the same purpose has been criticized by some authors, and no conclusion was reached on the alignment or not to sustainable agricultural standards. The actual landscape reflects many developments in the plant genetic transformation field, with new techniques (CRISPR) and potential new traits, which may be of good use for a more sustainable sector, even though some concerns still have to be addressed.

Finally, two sustainable practices have an important influence on the livestock production sector. The first one is **rotational grazing**, which promotes the grazing of different paddocks at a time while the remainder of the pasture grows and recovers, resulting in higher biomass production and elevated animal conversion ratio (Undersander et al., 2002). In addition, some emphasis must be given to **silvopastoralism**, which embodies the combination of forage grasses and forestry species, like trees and shrubs, improving animal nutrition and generating benefits such as enhanced soil fertility/productivity and higher sequestration of carbon (Murgueitio et al., 2011).

The list of practices highlighted above is a collection of activities that when properly applied may translate into environmental benefits, such as the mitigation of GHGs emission, protection of biodiversity and increased climate resilience. Nonetheless, it is essential to mention that the **social impacts** related to the employment of these practices must be subject of an assessment prior to labelling any of them as sustainable. For such label to be given, it is expected that said practice impose no significant harm (do no significant harm - DNSH) to any social aspect of concern, and preferably increase the social performance of the agroecosystem into consideration. The DNSH and increase in social performance must also be subject of evaluation across the supply chain, ensuring that no additional issues will arise either upstream or downstream.

Unsustainable Practices:

Some practices may never be considered sustainable and should be permanently restricted. These practices are primarily linked to uncontrolled deforestation, the conversion of other high-carbon stocks such as peatlands and permanent pasture and endangerment of other ecosystems, particularly the rampant clearing of protected areas for crops and pastures, use of illegal chemicals and unimpeded application of potentially dangerous substances. The employment of these practices by any production system, even those mentioned above, is a red flag to indicate the unconformity with any sustainable standard. In addition, practices that inflict any type of significant social harm should receive the label of unsustainable regardless of their eventual environmental benefits.

	No Till / Min Till	Set Aside / Biological buffer zones	Cover Crops	Perennial crops	Intercropping / Mixed Cropping / Polyculture	Mulch (biological)	Compost (soil conditioner)	Manure use as fertiliser	Silvopasture	Rotational Grazing	Agroforestry	Minimal chemical Use	Integrated Pest management	Integrated Nutrient management	Pollinator Promotion	Precision Agriculture Technology	Crop Rotation	Fertigation	Nitrogen Fixation	Ionising Radiation	GMOs	Livestock Production (Intensive - feedlots)	Livestock Production (extensive - grazing)
Always Sustainable		X										X	X	X	X				X				
Usually Sustainable (with some caveats	X		X	X	X	X	X	X	X	X	X					X	X				X		X
Sometimes Sustainable (under some conditions)																		X		X		X	
Social DNSH and improvement (assessment necessary)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table 1. List of production practices and their alignment to sustainable agricultural production. This list is not based on preferences and reflects frequently debated concepts in the sector. There are numerous additional sustainable practices not showcased in this section. Additionally, the classification of practices is subject to regional influences.

4. Conclusion

Agriculture is a dynamic and complex sector, making it challenging to reach any kind of standardization, especially regarding sustainability. One potential approach to overcome some of the issues related to standardization and consensus in the sector is to focus on the study and description of practices, labelling the ones more often aligned with a credible sustainable transition and giving preference to systems contemplating similar practices. However, there are many gaps in evaluating these practices, considering that their sustainable potential varies from place to place and the assessment of their social impacts demands a horizontal approach. Therefore, it is essential to foster the debate around this issue and further reach a guideline on **identifying and measuring sustainability in the agricultural sector**. It is also indispensable to discuss the transition timeline in the sector, being attentive to how to set **phase-out** dates to certain **practices** in conformity with regional and social aspects, such as the region's stage of development and the operation's size.

References

1. Benton, T.G.; Bieg, C.; Harwatt, H.; Pudasaini, R.; Wellesley, L. (2021). Food system impacts biodiversity loss: three levers for food system transformation in support of nature. Energy, Environment and Resources Programme, Chatham House. Available at: https://www.chathamhouse.org/2021/02/food-system-impacts-biodiversity-loss

2. Borlaug, N.E. (1983). Contributions of conventional plant breeding to food production. Science, 219, n.4585, 689-693. Available at: https://www.science.org/doi/10.1126/science.219.4585.689

3. Brundtland, G. (1987). Report of the World Commission on Environment and Development: Our Common Future. United Nations General Assembly document A/42/427. Available at: https://www.are.admin.ch/are/en/home/media/publications/sustainable-development/brundtland-report.html

4. Buffet, H.G. (2012). Reaping the benefits of no-tillage farming. Nature, 484, 455. Available at: https://www.nature.com/articles/484455a

5. Crippa, M., Solazzo, E., Guizzardi, D., Monforti-Ferrario, F., Tubiello, F.N. and Leip, A. (2021) Food systems are responsible for a third of global anthropogenic GHG emissions. Nature Food, 2, 198–209. Available at: https://ecbpi.eu/wp-content/uploads/2021/03/Nature-food-systems-GHG-emissions-march-2021.pdf

6. FiBL & IFOAM (2021). The World of Organic Agriculture: Statistics and emerging trends 2021. Available at: https://www.fao.org/family-farming/detail/en/c/1378841/#:~:text=Statistics%20and%20Emerging%20Trends,106%20billion%20euros%20in%202019.

7. Finger, R.; Swinton, S.M.; Benni, N.E.; Walter, A. (2019). Precision farming is at the nexus of agricultural production and the environment. Annual Review of Resource Economics, 11, 313-335. Available at: https://www.annualreviews.org/doi/full/10.1146/annurev-resource-100518-093929#_i2

8. Hunke, P.; Mueller, E.N.; Schröder, B.; Zeilhofer, P. (2015). The Brazilian Cerrado assesses water and soil degradation in catchments under intensive agricultural use. Ecohydrology, 8, n. 6, 1154-1180. Available at: https://onlinelibrary.wiley.com/doi/abs/10.1002/eco.1573

9. Kleijn, D.; Bommarco, R.; Fijen, T.P.M.; Garibaldi, L.A.; Potts, S.G.; van der Putten, W.H. (2019). Ecological Intensification: Bridging the gap between science and practice. Trends in Ecology & Evolution, 34, n.2, 154-166. Available at: https://www.cell.com/trends/ecology-evolution/fulltext/S0169-5347(18)30273-8?_returnURL=https%3A%2F%2Flinkinghub.elsevier.com%2Fretrieve%2Fpii%2FS0169534718302738%3Fshowall%3Dtrue

10. Murgueitio, E.; Calle, Z.; Uribe, F.; Calle, A.; Solorio, B. (2011) Native trees and shrubs for the productive rehabilitation of tropical cattle ranching lands. Forest Ecology and Management, 261, 1654-1663. Available at: https://www.academia.edu/22566303/Native_trees_and_shrubs_for_the_productive_rehabilitation_of_tropical_cattle_ranching_lands

11. Newton, P.; Civita, N.; Frankel-Goldwater, L.; Bartel, K.; Johns, C. (2020). What Is Regenerative Agriculture? A review of scholar and practitioner definitions based on processes and outcomes. Frontiers in Sustainable Food Systems, 4:5777723. Available at: https://www.frontiersin.org/articles/10.3389/fsufs.2020.577723/full

12. Oberč, B.P. & Arroyo Schnell, A. (2020). Approaches to sustainable agriculture. Exploring the pathways towards the future of farming. Brussels, Belgium: IUCN EURO. Available at: https://doi.org/10.2305/IUCN.CH.2020.07.en

13. Pretty, J.; Bharucha, Z.P. (2014). Sustainable intensification in agricultural systems. Annals of Botany, 114, 1571-1596. Available at: https://academic.oup.com/aob/article/114/8/1571/210078

14. Stenberg, J.A.; Sundh, I.; Becher, P.G.; Björkman, C.; Dubey, M.; Egan, P.A.; Friberg, H.; Gil, J.F.; Jensen, D.F.; Jonsson, M.; Karlsson, M.; Khalil, S.; Ninkovic, V.; Rehermann, G.; Vetukuri, R.R.; Viketoft, M. (2021). When is it biological control? A framework of definitions, mechanisms, and classifications. Journal of Pest Science, 94, 665-676. Available at: https://link.springer.com/article/10.1007/s10340-021-01354-7

15. Tao, S.; Xu, Y.; Liu, K.; Pan, J.; Gou, S. (2011). Research progress in agricultural vulnerability to climate change. Advances in Climate Change Research, 2, n.4, 203-210. Available at: https://www.sciencedirect.com/science/article/pii/S1674927811500504#:~:text=Agricultural%20vulnerability%20to%20climate%20change%20is%20the%20function%20of%20characteristics,or%20unable%20to%20cope%20with

16. The Food and Land Use Coalition (FOLU) (2019). Growing Better: Ten Critical Transitions to Transform Food and Land Use. The Global Consultation Report of the Food and Land Use Coalition. FOLU. Available at: https://www.foodandlandusecoalition.org/wpcontent/uploads/2019/09/FOLU-GrowingBette

17. Tubiello, F.N.; Karl, K.; Flammini, A.; Gütschow, J.; Obli-Laryea, G.; Conchedda, G.; Pan, X.; Qi, S.Y.; Heiðarsdóttir, H.H.; Wanner, N.; Quadrelli, R.; Souza, L.R.; Benoit, P.; Hayek, M.; Sandalow, D.; Contreras, E.M.; Rosenzweig, C.; Moncayo, J.R.; Conforti, P.; Torero, M. (2022). Pre- and post-production processes increasingly dominate greenhouse gas emissions from agri-food systems. Earth Syst. Sci. Data, 14, 1795–1809. Available at: https://essd.copernicus.org/articles/14/1795/2022/essd-14-1795-2022-discussion.html

18. Undersander, D.; Albert, B.; Cosgrove, D.; Johnson, D.; Peterson, Paul. (2002). Pasture for profit: A guide to rotational grazing. The University of Wisconsin-Extension. Available at: https://www.clfdccd.com/uploads/2/2/1/7/22174852/pastures_for_profit_guide_to_rotational_grazing.pdf