# Scientific Literature Review of Regenerative Agriculture Definitions, Practices, and Outcomes

Prepared by the Natural Resources Defense Council for the CDFA Science Advisory Panel

*12/22/2022*

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## NRDC's Recommended Definition of Regenerative Agriculture

From our analysis of the peer and non-peer reviewed literature, we recommend the California Department of Food and Agriculture adopt the following definition of regenerative agriculture:

*Regenerative agriculture is a system of crop and/or livestock production based in Indigenous knowledge that recognizes that natural ecosystems are complex networks that support farms and societies in multiple ways[1]. Through the lens of soil conservation, regenerative agriculture actively seeks to restore and improve the numerous[2] provisioning, supporting, regulating, and cultural[3] ecosystem services that society depends on [4] while operating within the natural resource constraints of a specific area. These ecosystem services include[5] human health—particularly farmworker health and safety, nutrient cycling, erosion prevention, biodiversity, and water filtration, and cultural services such as social connection and spiritual traditions that lead to social outcomes such as farmer wellbeing and farmer innovation. Both individual practices and groups of agricultural practices (including/such as organic farming) are regenerative if they help restore and improve ecosystem services without having negative impacts on human health.*

We provide a more thorough list of examples of regenerative practices below.

We recommend this definition because it makes use of an existing, internationally recognized framework[2] for categorizing the numerous services that natural ecosystems provide to both farms and societies and our recommended definition also incorporates the main points gleaned from a review of the literature:

1) That regenerative farming is context-dependent,
2) It acknowledges the complexity and interconnected nature of natural ecosystems,
3) It works to improve or regenerate natural ecosystems' ability to provide vital services, and
4) It incorporates improvements to social and economic aspects of farm production.

Cultural services are rarely included in discussions of ecosystem services, partly because they are considered "intangible" or "invisible" compared to other, more material services[6]. However, it is difficult to discuss regenerative agriculture without acknowledging that it is driven and defined by the "intangible" benefits experienced by farmers that practice it, such as improved relationships among farming communities, surrounding neighbors, and consumers[7].

Both explicit definitions stated in Schreefel et. al and O'Donoghue et. al acknowledge that one of the goals of regenerative agriculture is to improve societal conditions related to food production, whether that be "human endeavor" or "the social and economic dimensions" of food production. It is increasingly clear that obstacles to the adoption of soil health practices are not only based on the practices themselves, but on farmer perspectives, education and noneconomic motives[8,9,10] and that for farming systems to be sustainable in the long term, they need to include space for farmer innovation[23,24], and positive impacts on farmer well-being[11]. The importance of these non-economic motives is core to the understanding of regenerative agriculture and necessitates their inclusion in the definition. Thankfully, the advances made in measuring the non-economic value of cultural ecosystem services in the last few decades[12] have increased their practical feasibility.

# Regenerative Agriculture Definitions in the Scientific Literature

Literature review for this topic began with Web of Knowledge and Google Scholar searches for the terms "regenerative agriculture" + "meta-analysis", "review", and "practices". Four primary reviews/meta-analyses were identified, and the sources cited in these papers were used for further analysis.

These four papers provide an overview of regenerative agriculture (RA) through the meta-analysis of both peer-reviewed and grey (potentially non-peer-reviewed) literature: Giller et. al 2021[13], Newton et. al 2020[14], Schreefel et. al 2020[15], and O'Donoghue et. al 2022[16].

Of these 4, the O'Donoghue et. al peer-reviewed meta-analysis is the most recent and attempts to include all sources cited in the Giller, Newton and Schreefel et. al reviews as well as several (assumed) non-peer reviewed reports and white papers. This paper better articulates the origins of, and intentions behind regenerative agriculture.

The O'Donoghue et. al 2022 paper defines Regenerative Agriculture as:

> "Any system of crop and/or livestock production that, through natural complexity and with respect to its contextual capacity, increases the quality of the product and the availability of the resources agriculture depends upon; soil, water, biota, renewable energy and human endeavor."

Schreefel et. al 2020 defines Regenerative Agriculture as:

> "An approach to farming that uses soil conservation as the entry point to regenerate and contribute to multiple provisioning, regulating, and supporting services, with the objective that this will enhance not only the environmental, but also the social and economic dimensions of sustainable food production."

While the Newton et. al and Giller et. al papers do not provide explicit definitions; they do identify themes common to Regenerative Agriculture:

> Giller et. al highlights "the most commonly occurring themes associated with Regenerative Agriculture are improvements to soil health, the broader environment, human health and economic prosperity" while "the two challenges most frequently linked to Regenerative Agriculture are: 1. Restoration of soil health, including the capture of carbon (C) to mitigate climate change 2. Reversal of biodiversity loss".

Newton et. al highlights the tension between process- and outcome- based definitions of RA, noting that numerous studies use one or the other. They note that drawbacks exist to defining regenerative agriculture solely in terms of practices or outcomes, noting that the most popular systems seek to incorporate elements of both. They also note that certification and payments for soil carbon storage are moving towards an outcome-focused approach[17].

# Regenerative Agriculture Practices

There are several farming practices that fall under the regenerative agriculture umbrella, and growers may utilize different combinations of practices depending on their topography, geography, soil type, climate, and natural resource availabilities and constraints. Based on our analysis of the peer and non-peer reviewed literature regenerative agriculture practices include but are not limited to reducing the use of tillage while simultaneously reducing synthetic pesticides, fertilizers, and other inputs; planting hedgerows, diversified cropping systems, and regionally adapted cultivars; composting; cover cropping; as well as managed grazing practices for beef and dairy production.

Newton et. al 2020 (Table 1) is the only meta-analysis that explicitly identifies practices that are regenerative based on their analysis of the literature. The 5 most common practices cited in journal articles (n=229) include:

1. "Use no or low external inputs; maximize on-farm inputs" (26.4%)
2. "Integrate livestock" (19.0%)
3. "Use no synthetic pesticides" (12.4%)"
4. "Use no synthetic fertilizers (12.4%)"
5. "Reduce tillage" (11.6%)

The 5 most common practices cited in practitioner websites (n=25) include:

1. "Reduce tillage" (40.9%),
2. "Integrate livestock" (40.9%),
3. "Use cover crops" (36.4%),
4. "Use crop rotations" (31.8%), and
5. "Use no or low external inputs; maximize on-farm inputs" (31.8%).

Giller et. al 2021 (Table 1) also outlines a similar list of practices and further suggests a list of questions to guide growers in determining which practices can and should be adopted for their unique context:

1. "What is the problem to which Regenerative Agriculture is meant to be the solution?
2. What is to be regenerated?
3. What agronomic mechanism will enable or facilitate this regeneration?
4. Can this mechanism be integrated into an agronomic practice that is likely to be economically and socially viable in the specific context?
5. What political, social and/or economic forces will drive use of the new agronomic practice?"

Practices suggested in additional papers include agroforestry[18], the use of compost, and more diversified crop rotations[19].

# Regenerative Agriculture Outcomes

The 5 most sought-after outcomes of regenerative agriculture from practitioner websites and journal articles outlined in Newton et. al 2020 were:

1. "Improve soil health and fertility" (40.5% of journals, 86.4% of websites),
2. "Increase carbon sequestration" (17.4% of journals, 63.6% of websites),
3. "Increase biodiversity" (21.5% of journals, 45.5% of websites),
4. "Improve water health" (14.9% of journals, 45.5% of websites) and
5. "Improve the soil and/or economic wellbeing of communities" (17.4% of journals, 40.9% of websites).

Schreefel et. al's research echoed the outcomes listed by Newton et. al and models a transition plan for a regenerative farm whose goals are to: "enhance and improve soil health", "alleviate climate change", "improve nutrient cycling", "improve water quality and availability", "improve economic prosperity" and "improve human health" (which includes measures of farmer and farm laborer wellbeing).[20,21]

The explicit inclusion of regenerative agriculture's positive impact on social outcomes is a recurring theme in the literature and plays a role in setting regenerative agriculture apart from other farming systems[16]. Measuring the social impact of regenerative agriculture has been done using several methods, including discourse analyses[22], wellbeing measures[11], and measures of farmer innovation[23,24]. These social analyses are in addition to more traditional measurements of soil indicators under regenerative systems (RA here being defined on a paper-by-paper basis)[25,26, 27,34].

# Non-Journal Articles and Grey Literature on Regenerative Agriculture

One important observation is that the peer-reviewed meta-analyses cite many non-peer-reviewed articles because many of the initial concepts and philosophies that define regenerative agriculture were first outlined in non-academic reports. Some of the most widely cited are the 2016 "Levels of Regenerative Agriculture" report by Soloviev and Landau[28] and the Rodale Institute's "Regenerative Organic Agriculture and Climate Change" report[29]. Many recent reports on regenerative agriculture have come out of Australia and New Zealand, including the 2021 report "Regenerative Agriculture in Aotearoa New Zealand– Research pathways to build science-based evidence and national narratives"[30] and "An Analysis and Overview of Regenerative Agriculture" by Merfield (2019)[31].

In the United States, reports that attempt to outline and define regenerative agriculture include the Natural Resource Defense Council's 2022 report on "Regenerative Agriculture: Farm Policy for the 21st Century"[7], and the Rodale Institute's 2020 report on "Regenerative Agriculture and the Soil Carbon Solution"[32]. Other reports include a 2017 collaboration between The Carbon Underground and the Regenerative Agriculture Initiative at Chico State[33] that defines regenerative agriculture as "a holistic land management practice that leverages the power of photosynthesis in plants to close the carbon cycle, and build soil health, crop resilience and nutrient density."

## Conclusion

The 113 farmers interviewed for the NRDC's "Regenerative Agriculture" report affirmed the findings from this literature review: regenerative agriculture is an emergent farming system where desired outcomes guide what practices to use. The farmers interviewed for NRDC's report shared countless stories of the social and cultural benefits of transitioning to regenerative agriculture, and the literature reviewed echoes the need to capture these social and cultural outcomes in any definition. While more long-term, geographically diverse research is needed to quantify its benefits, farmers and ranchers that ascribe to a regenerative philosophy are already innovating and experimenting with how to tailor their farming systems to the conditions they live in.

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