



Review Paper

Principle and prerequisites of regenerative agriculture: a review

Vyta W. Hanifah¹, Vicca Karolinoerita^{2*}, Destika Cahyana³, Budiman Minasny⁴

¹ School of Economics and Public Policy, Faculty of Arts, Business, Law and Economics, University of Adelaide, Australia

² Research Center for Geoinformatics, National Research and Innovation Agency, Indonesia

³ Research Center for Food Crops, National Research and Innovation Agency, Indonesia

⁴ Sydney Institute of Agriculture, The University of Sydney, Australia

*Corresponding author: vicca.karolinoerita@brin.go.id

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Abstract

Regenerative agriculture has recently gained popularity as a promising approach to achieving sustainable agriculture and ensuring food security. This article reviews scientific papers published between 1986 and 2024, as well as popular media, including the documentary "Kiss the Ground," released by Netflix in 2020, which successfully introduced the concept of regenerative agriculture to a broader audience. The article explores the definition, principles, and prerequisites of regenerative agriculture and examines how this concept can be adapted in Indonesia, given the challenges faced by conventional agriculture and the potential for integration with digital technology. This study used 342 papers discussing regenerative agriculture and those related to regenerative agriculture terminology using the virtual tool map, Research Rabbit, and selected 10 most papers relevancies. The review concludes that regenerative agriculture essentially encompasses or aligns with previously established concepts, including agroecology, organic farming, conservation agriculture, climate-smart agriculture, and traditional agricultural systems often associated with environmentally friendly and sustainable practices. In the Indonesian context, farming systems like Subak in Bali, integrated farming in Java, and climate-smart farming in East Nusa Tenggara can be classified as forms of regenerative agriculture. However, the prerequisites for regenerative agriculture to produce commercial-scale yields may vary across different agroecosystems, as each has its specific needs.

Keywords

Agriculture, Agroecosystems, Regenerative, Specific, Sustainable

1. INTRODUCTION

The term "regenerative agriculture" (RA) was introduced among scientists 38 years ago but has only gained significant attention from researchers in the last six years. For 33 years after the first publication by Francis et al. in 1986 titled "The Potential of Regenerative Agriculture in Developing Countries" in the American Journal of Alternative Agriculture, no other journals were published with a specific title including the phrase "regenerative agriculture." It was only since 2018 that dozens of papers were published using this phrase, bringing the term into broader discussion within the scientific community and beyond (Francis et al., 1986; Giller et al., 2021; O'Donoghue et al., 2022). In 1986, Francis et al. identified four main components of a RA system, driven by concerns over the widespread promotion of inorganic fertilizers and synthetic pesticides to meet the growing food needs in the developing world, alongside the increasing reliance on fossil fuels in agriculture. These components encompassed preserving soil fertility, implementing integrated pest management, enhancing plant breeding, and

incorporating agriculture with animal husbandry (Francis et al., 1986).

However, this approach received little attention from policymakers, as the Green Revolution, which relied on inorganic fertilizers and synthetic pesticides, had already shown success in increasing agricultural productivity in countries like the Philippines, Indonesia, and Thailand since the 1960s and 1970s. Indonesia for example, between 1976 and 1984, wetland rough rice yields increased from 2.9 tons to 4.2 tons per hectare (Baharsjah et al., 1989). In national level, paddy production grew from 18 million metric tons in 1969 to 38.1 million in 1984, an increase of 112%. Over the same period, yield growth rose from 2.5 tons per hectare to 4.1 tons, or a 64% rise (Davidson, 2018). Most farmers have been hesitant to adopt regenerative agriculture due to the limited empirical evidence supporting its claimed advantages and profitability. A literature review reveals that the benefits of regenerative agriculture vary greatly across different agroecosystems, and its practices cannot be uniformly applied in various agroecological re-

gions.

Numerous studies generally indicate that specific components of regenerative agriculture (RA) practices, such as reduced tillage, managing crop residues, and using cover crops, can enhance carbon of soil, boost yields of crop, and improve healthy soil in particular climates and types of soil. Conversely, the overuse of synthetic input may result to a decline in species diversity and the degradation of ecosystems. Moreover, incorporating animal husbandry with agriculture and agroforestry within the same environment can boost soil organic matter and offer various other advantages (Giller et al., 2021; Khangura et al., 2023).

The practice of conventional farming often contributes to degradation of soil and reduction of productivity. RA is proposed as a remedy for these issues by prioritizing healthy soil and sequestration of carbon. Key principles of RA include maintaining soil cover, incorporating livestock, enhancing biodiversity, keeping living roots in the soil year-round, and minimizing the use of synthetic chemicals like herbicides and fertilizers. The primary aim is to revitalize soil and land while providing benefit for environmental, economic, and social in broader community.

In recent years, RA has gained considerable momentum within the fields of agriculture, society, and business, evolving into a broader social movement. To guide future practical and academic endeavors, the team have revisited the literature to explore the principles and requirements of this movement, examining it through three phases: early academic, current popular, and current academic.

Overall, several studies indicate that aspects of regenerative agriculture (RA), such as reduced tillage, managing crop residues, and cover cropping, can enhance soil organic matter, boost yields, and improve soil quality in particular climates and soil conditions. Conversely, overuse of synthetic inputs may cause a decline in biodiversity and contribute to ecosystem degradation. Furthermore, combining livestock farming with agriculture and agroforestry within the same environment can enhance soil carbon and offer numerous other advantages (Giller et al., 2021; Khangura et al., 2023).

In recent years, the concept of RA has gained significant traction across agriculture, society, and business, evolving into a broader social movement. To inform future practical and academic efforts in this field, the authors have revisited the literature to examine the principles and prerequisites of this movement through three phases: early academic, current popular, and current academic.

2. METHOD

This review study used 342 papers discussing regenerative agriculture and those related to regenerative agriculture terminology using the virtual tool map, Research Rabbit (Sharma et al., 2022). We explored the citation relationships between papers and explored the chronology of the papers

published to see the development of paper trends related to regenerative agriculture. Next, we selected the 10 most relevant papers that explain the definition, principles, and prerequisites of regenerative agriculture. From the 10 papers, we extracted information in the form of definitions, limitations, and prerequisites of regenerative agriculture using the ChatGPT 4.0 tool which can be customized with prompt engineering (Giray, 2023). This is a guided question such as scenarios, tasks, examples, arrangements, and moderation (STEAM) with output in the form of matrices. Next, the data from ChatGPT was verified manually by checking the paper directly.

3. RESULT AND DISCUSSION

3.1 History of regenerative agriculture

Regenerative agriculture first appeared as a scientific paper title in an article titled “The Potential for Regenerative Agriculture in the Developing World” in the American Journal of Alternative Agriculture in 1986. However, the idea of regenerative agriculture was introduced earlier in an article titled “Breaking New Ground: The Search for a Sustainable Agriculture” in The Futurist journal in 1983 (Francis et al., 1986; Rodale, 1983). Rodale proposed a regenerative agriculture approach to shift farming from a battle against nature—where humans try to dominate it, often causing harm—to an art that encourages nature to provide as many benefits as possible for human use with minimal effort. Meanwhile, Francis outlined four main components of a regenerative agriculture system: preserving soil fertility, implementing pest management strategies, enhancing plant breeding, and combining agriculture with livestock management.

Rodale implicitly considered the regenerative agriculture approach as part of sustainable agriculture, while Francis explicitly treated regenerative agriculture as a distinct term. After this initial introduction, scientific articles titled “regenerative agriculture” seemed to disappear for 33 years, only to resurface in 2018. During that gap, articles did not specifically mention regenerative agriculture but focused on related farming approaches such as no-till, carbon sequestration, soil and water conservation, organic farming, cropping patterns, land cover, environmentally friendly farming, sustainable agriculture, and the integration of livestock with crops. A resurgence of scientific, popular, and even cinematic interest in regenerative agriculture occurred from 2018 onwards. The trend of articles related to regenerative agriculture can be seen in Figure 1.

3.2 Principles and Prerequisites of Regenerative Agriculture

In recent years, the term “regenerative agriculture” has again attracted public attention, focusing on key themes such as soil health, biodiversity, and socio-economic disparities. However, there are various definitions and components related to regenerative agriculture, so this article

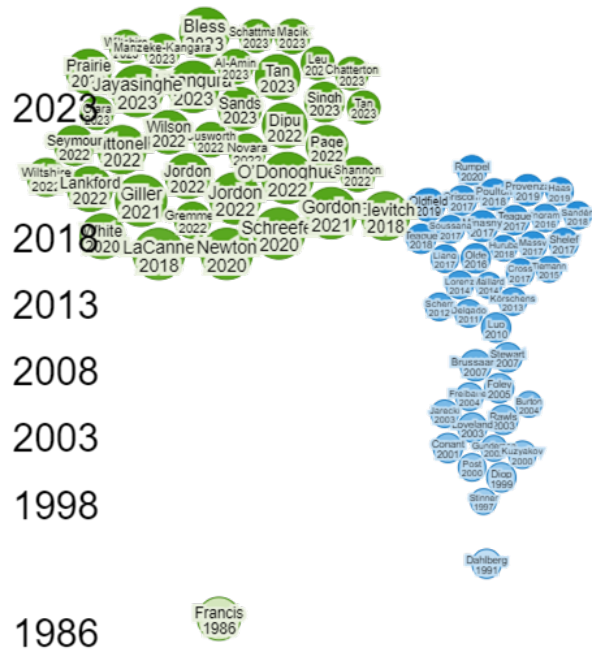


Figure 1. Chronology of regenerative agriculture articles from 1986 to 2024 (green indicates articles using the term 'regenerative agriculture' and blue indicates articles related to regenerative agriculture)

attempts to extract principles that might help establish a common consensus. The author compares early literature on regenerative agriculture, its initial rise, and the most recent trends. The definitions, limitations, and prerequisites of regenerative agriculture are presented in Table 1.

Based on Table 1, the initial concept of regenerative agriculture is to restore highly degraded land resources, maintain soil quality, and even enhance them by building better soil quality so that soil productivity, including its economic value, can be sustained (Rodale, 1983). This approach serves as an alternative to conventional agriculture, which tends to harm the environment, and as a more progressive effort than sustainable agriculture, which is often seen as too slow in boosting soil productivity and its benefits for humans. Sustainable agriculture, as an alternative approach, along with terms like organic agriculture, agroecology, and climate-smart agriculture, faces challenges in delivering both high productivity and significant economic impact. In this context, RA is expected to serve as an alternative to conventional agriculture, which damages the environment, and to restore the degraded environment more quickly than sustainable agriculture.

Recently, the promotion of RA is supported by civil society organizations, NGOs, and many large multinational food companies (Giller et al., 2021). The concept also gained public attention through the popular American documentary "Kiss the Ground," released in 2020 and broadcast on

various platforms (O'Donoghue et al., 2022). Common practices promoted under RA include restoring plant biomass, cover cropping, and minimal tillage, which are central to the canon of "good agricultural practices."

Despite the perceived benefits of RA, most farmers are hesitant to adopt the practice due to the lack of empirical evidence supporting its claimed advantages (Burns, 2021). Reviews of the literature suggest that practices such as reduced tillage, managing crop residues, and using cover crops can increase soil carbon levels, boost crop yields, and enhance soil health in specific climate zones and soil types (Khangura et al., 2023). Soil health is the capacity of soil to function as a vital living system to sustain biological productivity, maintain environmental quality, and promote plant, animal, and human health (Larkin, 2015). Conversely, the excessive use of synthetic chemicals can result in biodiversity loss and ecosystem damage. Integrating livestock with agriculture and agroforestry within a single landscape can improve soil carbon and offer additional benefits. However, the benefits of RA practices may differ across various agroecosystems, thus a universal method may not be applicable across different agroecological contexts.

As a concept, RA represents a significant effort to protect our planet from degradation. However, to achieve food sovereignty in developing countries, we recommend conducting rigorous, long-term trials comparing conventional and RA practices. These long-term trials will build a robust knowledge base about the advantages and mechanisms related to RA on a regional level. This information will enable farmers and policymakers to make informed choices about adopting RA practices, aiming to achieve social and economic gains while strengthening resilience to climate change. Recent reviews have underscored important aspects of regenerative agriculture—such as soil health, biodiversity, and socioeconomic inequalities—but have yet to offer a comprehensive definition based on practices and outcomes.

It is similar with researcher from University of Sydney that proposed the Farm scape Function framework for monitoring the impacts of changes in agricultural resources over time, alongside mechanisms to facilitate continued data-driven innovation. These tools, together with the movement's objectives, frame RA as a state of practice rather than a distinct farming method. Enhancing agricultural output and improving incomes for farming families are primary objectives of rural development in developing countries (O'Donoghue et al., 2022).

However, we acknowledge that most conventional agriculture strategies are realistic for wealthy farmers and large-scale operations, but they are unrealistic for small farmers due to their limited resources. Transitioning from fundamental food cultivation in diverse cropping systems to specialized monocropping for export markets is notably challenging. Conventional agriculture, dependent on petroleum-based inputs, requires valuable foreign currency and fre-

Table 1. Principles and prerequisites of regenerative agriculture from various literature

Year	Author(s)	Title	Publisher	Proposed and Concluded definition	Limitation	Prerequisite
1983	Robert Rodale	Breaking new ground: the search for a sustainable agriculture	The Futurist	Regenerative agriculture is sustainable approach that enhances land and soil productivity, maintains economic and biological stability, minimizes environmental impact, produces biocide-free food, and promotes the involvement of more people while reducing dependence on non-renewable resources.	Just seeding an idea that continues a terminology proposed by Gabel (1978)	Growth productivity all components
1986	Francis, C. A., Harwood, R. R., Parr, J. F.	The Potential for Regenerative Agriculture in the Developing World	American Journal of Alternative Agriculture	Regenerative agriculture is characterized by successive cycles of change in crop and livestock production environments, emphasizing the use of local resources, minimizing outside inputs, and enhancing biological activity and ecological balance within farming systems.	Focuses primarily on environmental aspects; lacks comprehensive socio-economic strategies.	Efficient use of local resources, integration of cropping and animal systems, and fostering biological activity and ecological balance.
2017	Rhodes (2017)	The Imperative for Regenerative Agriculture	Science Progress	Regenerative agriculture restores soil health and biodiversity, and even builds new soil by prioritizing ecosystem balance and reducing reliance on synthetic inputs.	Lacks clarity on economic scalability for large commercial farms.	Soil health restoration, biodiversity enhancement, and reduction of synthetic input reliance.
2020	Schreefel et al. (2020)	Regenerative Agriculture – The Soil is the Base	Global Food Security	A farming approach that starts with soil conservation to rehabilitate and enrich various ecosystem services, including resource provision, environmental regulation, and ecosystem support.	Lacks a comprehensive socio-economic framework; focuses primarily on environmental dimensions.	Emphasis on soil health improvement, resource management, biodiversity, water availability, and ecosystem services.
2020	Newton et al. (2020)	What Is Regenerative Agriculture? A Review of Scholar and Practitioner Definitions Based on Processes and Outcomes	Frontiers in Sustainable Food Systems	An alternative of producing food that aims to achieve overall beneficial environmental or social effects through processes like cover cropping, reducing tillage, and integrating livestock, as well as outcomes like improving soil health and increasing biodiversity.	No legal or regulatory definition; wide variance in definitions leading to confusion among stakeholders.	Focus on reducing tillage, using cover crops, integrating livestock, and improving ecosystem services like soil health and carbon sequestration.

Year	Author(s)	Title	Publisher	Proposed and Concluded definition	Limitation	Prerequisite
2021	Giller, K.E., Hijbeek, R., Andersson, J.A., and Sumberg, J.	Regenerative Agriculture: An Agronomic Perspective	Outlook on Agriculture	A set of farming practices that involves the rehabilitation of soil health, including the capture of carbon to mitigate climate change and the reversal of biodiversity loss.	Limited focus on economic sustainability and social equity.	Requires adoption of ecosystem-based practices and soil health improvements.
2021	Burns, E. A.	Regenerative agriculture: farmer motivation, environment and climate improvement	Policy Quarterly	Regenerative agriculture is a social movement in farming that embraces an ecological, whole-systems approach to land management.	There are no guarantees that all farmers will be able to successfully transition to and survive under regenerative farming practices.	Motivating benefits that drive farmers to adopt the practices.
2022	O'Donoghue, T., Minasny, B., McBratney, A.	Regenerative Agriculture and Its Potential to Improve Farmscape Function	Sustainability	An approach that rebuilds agricultural resources like soil, water, biota, and energy while aiming for a sustainable agriculture through ecosystem function improvement.	Lack of clear, universally agreed-upon definitions or outcomes; difficulty in measuring performance.	Focus on soil health, water management, biodiversity, energy reduction, and holistic farming practices.
2023	Khangura, R., Ferris, D., Wagg, C., and Bowyer, J.	Regenerative Agriculture—A Literature Review on the Practices and Mechanisms Used to Improve Soil Health	Sustainability	An approach to enhance soil health and carbon storage by keeping the soil covered, minimizing disturbance, preserving living roots, increasing diversity, and integrating livestock.	Lacks empirical evidence on the long-term benefits and profitability across diverse agroecosystems.	Requires minimum soil disturbance, crop diversity, soil cover, and integration of livestock into farming systems.
2023	Bless, A., Davila, F., and Plant, R. (Bless et al., 2023)	A genealogy of sustainable agriculture narratives: implications for the transformative potential of regenerative agriculture	Agriculture and Human Values	A narrative to gained prominence as a response to the challenges faced by the agri-food system, particularly those exacerbated by industrial agriculture.	Risky in inhibiting deeper transformations due to insufficient attention to power and equity issues within the agri-food system.	A collective approach to integrating with broader sustainable practices to address social-ecological challenges.

quently uses excessive chemical fertilizers and pesticides. This results in higher production costs, adverse effects on farm families, and environmental harm. Dependence on export-oriented crops and global markets can be financially

burdensome, especially for smallholder farmers.

On the other hand, the general practices of RA, when applied without considering local contexts, can lead to misunderstandings. Practices like no-till, no-pesticide use, or no

external nutrient inputs are unlikely to produce high yields in all locations. The growing interest in RA reflects a reframing of the debate between modern agriculture, which relies on synthetic inorganic fertilizers and pesticides, and traditional agriculture, which avoids these inputs altogether (Giller et al., 2021).

Scientific evidence from many universities and research institutions has proven that the combination of inorganic and organic fertilizers, for example, produces the best productivity. Agricultural practices without inorganic fertilizers can only achieve high productivity on fertile soils or with very large inputs of organic fertilizers, which are often impractical and uneconomical in real-world scenarios due to the difficulty of providing them. This situation tends to confuse the public rather than clarify the debate. More importantly, it diverts attention from more fundamental challenges. However, this idea is not easy to realize because, in practice, the term RA often refers to only a small part of the complex components involved in land management.

This explains why almost all papers related to regenerative agriculture have not yet demonstrated its large-scale agricultural application or its economic impacts compared to conventional agriculture. As a result, the term RA, in fact, has become synonymous with various alternative systems that have developed or are newly emerging, such as organic agriculture, climate-smart agriculture, agroecological agriculture, and good agricultural practices. A study in Australia comparing two groups of farmers who applied RA practices and those who did not found that the perceptions or farmers' knowledge are critical drivers of best-practice implementation (Alexanderson et al., 2023).

Thus, RA cannot be applied with a one-size-fits-all approach. Traditional Indonesian agricultural systems, such as the Subak system in Bali, already embody environmentally friendly principles. Subak is a traditional irrigation system used by farmers in Bali to manage water sustainably. This system not only involves efficient water management techniques but also includes social and cultural aspects that support cooperation among farmers and the wise use of resources. Subak maintains a balance between human needs and environmental sustainability, making it a real example of successful regenerative agriculture in Indonesia. Therefore, adaptation to local conditions is necessary.

Agricultural production systems can be improved to better utilize on-farm resources. Enhancements in nitrogen fixation, increased organic matter production, integrated pest control, genetic resilience to pests and stress, and elevated biological activity all enhance resource efficiency. Employing suitable information and management practices to reduce reliance on expensive inputs. At the farm level, integrating crop planting with livestock operations can create highly organized and efficient systems.

Such approaches can assist national agricultural planners aiming to enhance self-sufficiency in agricultural in-

puts and the supply of essential food products. This entails a practical focus on educating local development specialists, intensifying research on crops grown with limited resources, and offering appropriate information, incentives, and technology to both large and small-scale farmers. A well-structured national plan should encompass a variety of food production methods and alternatives for farmers with differing resource levels.

The consistent goals from early proponents to the present include the restoration or renewal of agricultural resources, including soil, water, ecosystems, communities, and energy, as essential measures for achieving sustainable agriculture. These goals align with the international push to improve ecosystem function. Unconfirmed definitions, objectives for adaptive design, and developing consumer and ecosystem service markets offer potential pathways to achieving these goals.

Regenerative agriculture can also synergize with digital agriculture, leading to the concept of Digital Regenerative Agriculture. This approach prioritizes environmental performance to increase agricultural productivity and improve farmer welfare with the support of digital technology. Consumers can also access information on how food products are produced in an environmentally friendly manner (O'Donoghue et al., 2022).

The concept of regenerative agriculture is a social movement that represents a significant effort to protect our planet from degradation. However, to achieve food sovereignty in developing countries, multi-location and long-term trials comparing conventional and regenerative agriculture (RA) practices are necessary to build a robust knowledge base about the benefits and mechanisms associated with RA at a national scale. This evidence will enable farmers and policymakers to make informed decisions regarding the adoption of RA practices, thus attaining social and economic advantages and building resilience to climate change. Recent reviews have emphasized important aspects of regenerative agriculture, such as soil health, biodiversity, and socioeconomic inequalities, but have not yet offered a thorough definition grounded in practices and outcomes. Soil health is the capacity of soil to sustain a vital living system in the soil to support plant, vegetation, and human (Larkin, 2015).

4. CONCLUSION

The concept of regenerative agriculture is a social movement that represents a significant effort to protect our planet from degradation. However, to achieve food sovereignty in developing countries, multi-location and long-term trials comparing conventional and regenerative agriculture (RA) practices are necessary to build a robust knowledge base about the benefits and mechanisms associated with RA at a national scale. This evidence will enable farmers and policymakers to make informed decisions regarding

the adoption of RA practices, thus attaining social and economic advantages and building resilience to climate change. Recent reviews have emphasized important aspects of regenerative agriculture, such as soil health, biodiversity, and socioeconomic inequalities, but have not yet offered a thorough definition grounded in practices and outcomes. Its adaptive principles and respect for local diversity make it relevant in various contexts, including Indonesia. Integration with digital technology can further strengthen this concept, benefiting not only the environment but also farmer welfare and overall food security.

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