



Regenerative Agriculture

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The term regenerative agriculture is defined by the University of Notre Dame as methods of food production that aim to rehabilitate and create a more robust and resilient system that lessens or improves agriculture's environmental impacts. However, it should be noted that the term "regenerative agriculture" does not have a legal or regulated definition. Hence discovering its implied meaning can vary from process-based definitions to outcome-based definitions or a combination of both. Outcome-based definitions focus on any given process that yields certain agricultural outcomes such as carbon sequestration, soil health improvement, increase in biodiversity, and a decrease in greenhouse gas emissions, among others. Thus, allowing for a more open-minded approach to processes that may lead to the desired outcome (Newton et al. 2020). Process-based definitions are more concerned with the methods employed whilst developing food production. Meaning the inclusion or exclusion of one or more agricultural principles and/or methods (e.g., the integration of crops and animals, no-till practices, cover crops rotations, etc.) as a way to determine what is considered regenerative agriculture (Newton, et al. 2020). In contrast to its counterpart, process-based definitions concentrate on the techniques themselves and may encourage an open-minded observation of their results. Others define regenerative agriculture on a combination-basis of process and outcome. This may be based on a belief that defined processes will always lead to defined outcomes; or that regenerative agriculture only exists when defined processes lead to defined outcomes (Newton, et al. 2020).

So what are some of the practices that are considered regenerative?

No-till Agricultural Practices

Also known as conservation tillage, no-till practices are farming techniques that minimize or eliminate the conventional practice of plowing or tilling the soil before planting crops. Instead of disturbing the soil through intensive tillage, no-till practices aim to maintain the soil's integrity and reduce soil erosion. This preservation of soils structure can have multiple environmental benefits such as:

Soil Conservation

By minimizing or eliminating tillage, the soil structure remains intact, preventing erosion caused by wind and water. This lack of erosion then allows for proper soil functionally preventing gasses to escape soil, thus, promoting carbon sequestration.



Increased Organic Matter

The accumulation of organic matter such as leaves, stems, and roots, among others, can aid soil fertility, improve water retention, and promote soil biota health and abundance.

Energy and Cost Savings

No-Till practices can lead to reduced fuel consumption and lower labor requirements compared to traditional tillage methods. Since there is no need for extensive plowing and seedbed preparation, farmers can save on fuel costs and reduce the wear and tear on machinery. This can be particularly advantageous for large-scale farming operations.

It's important to note that the adoption of non-till practices may require adjustments in crop management techniques, such as modified planting equipment and weed control strategies. Additionally, the effectiveness of non-till practices can vary depending on soil type, climate conditions, and the specific crop being grown. However, when implemented correctly, non-till agricultural practices offer numerous benefits, including improved soil health, water conservation, and reduced environmental impact.

Nutrient Management & Fertilizer Diversifications

Nutrient Management

Nutrient management in agriculture refers to the practice of efficiently and effectively managing the application, use, and cycling of nutrients in agricultural systems. It involves optimizing the availability and utilization of essential nutrients, such as nitrogen, phosphorus, potassium, and other micronutrients, to promote healthy plant growth while minimizing environmental impacts.

Proper nutrient management is essential for achieving optimal crop yields, maintaining soil fertility, and minimizing negative environmental consequences such as nutrient runoff, groundwater contamination, and air pollution. It involves various strategies and practices that aim to balance nutrient inputs with crop nutrient requirements, taking into account soil conditions, crop types, and specific regional factors.

Here are some key components and approaches involved in nutrient management in agriculture:

Soil testing

Soil analysis is conducted to determine the nutrient content and pH level of the soil. This information helps farmers identify nutrient deficiencies or excesses and guides them in making informed decisions about fertilizer application.



Nutrient planning

Based on soil test results, crop nutrient requirements, and yield goals, nutrient management plans are developed. These plans outline the appropriate types, amounts, and timing of fertilizer application to meet the crop's nutritional needs.

Fertilizer application

Precision application techniques, such as variable-rate fertilization and site-specific nutrient management, can help optimize fertilizer use and minimize wastage.

Timing and placement

Nutrient application is timed to coincide with the crop's growth stages and nutrient uptake patterns. This ensures that nutrients are available when the plants need them most. Precision placement techniques, such as banding or side-dressing, can be employed to target fertilizer application near the root zone for better nutrient uptake.

Crop rotation and diversification

Rotating crops and introducing diverse plant species can help break pest and disease cycles, improve soil health, and enhance nutrient cycling. Different crops have varying nutrient requirements and abilities to utilize different nutrient sources, which can be strategically managed through crop rotation.

Monitoring and evaluation

Regular monitoring of soil nutrient levels, plant tissue analysis, and crop performance provides feedback on nutrient management practices. This feedback allows farmers to adjust their nutrient management plans and make improvements for future seasons.

Diversifying Nutrients

Balancing nutrient inputs from various sources helps minimize nutrient imbalances and potential environmental risks. To do so, farmers consider different nutrient sources, including synthetic fertilizers, organic amendments (e.g., manure, compost), cover crops, and crop residues, to meet the nutrient requirements of crops.

Some of the most common alternative to synthetic fertilizers include:

Manure

The application of manure on soils has been found to offer several benefits for soil health, including increased levels of macro and micronutrients, as well as organic matter (Urrea, Alkorta, and Garbisu, 2019). Additionally, manure can contribute to improved soil structure by reducing bulk density and increasing soil porosity, enhancing water filtration and overall stability (Urrea,



Alkorta, and Garbisu, 2019). Moreover, the application of manure has been shown to stimulate soil fungal and microbial activity, supporting biodiversity and biomass (Ding et al., 2015).

However, it should be noted that excessive manure application can result in similar adverse environmental impacts as synthetic fertilizers if applied improperly such as nutrient leaching (van Es, Sogbedji, and Schindelbeck, 2006), and greenhouse gasses emission (VanderZaag, Jayasundara, and Wagner-Riddle, 2011). To mitigate these effects, proper nutrient management procedures should be employed to address leaching concerns. Additionally, strategies including livestock dietary measures, manure treatment, and the use of nitrification inhibitors can help mitigate greenhouse gas emissions (VanderZaag, Jayasundara, and Wagner-Riddle, 2011).

Cover crops

The inclusion of cover crops in agricultural systems, particularly legumes, has been found to have several positive effects on soil fertility and microbial biomass by promoting nitrogen fixation (Shah and Rashid, 2010). Legumes accomplish this through a symbiotic relationship with rhizobia bacteria, housed within nodules on their roots, which produce ammonia that can be utilized by other bacteria and plants (Clúa et al., 2018).

Furthermore, legume cover crops offer weed management benefits by outcompeting weeds through their competitive advantage, thereby inhibiting seed germination and the emergence of weed seedlings (Kocira et al., 2020). Additionally, legume cover crops contribute to the reduction of soil compaction and erosion, while enhancing structural and hydraulic properties and increasing organic matter content (Kocira et al., 2020 and Harper, 1992).

It is important to note, however, that the growth of legumes can result in soil acidification due to an excess uptake of cations over anions. This leads to the release of H_3O^+ ions into the rhizosphere, resulting in a decrease in soil pH (HAYNES, 1983). Therefore, it is crucial to regularly monitor soil pH levels when utilizing legumes for nitrogen fixation.

Other types of cover crops may include grasses which can aid in collecting loose nitrogen in soil to prevent leaching, while producing high amounts of organic matter to nourish soil.

Brassica cover crops which include plants such as radishes, turnips, and mustards, can also act as nitrogen scavengers but are more commonly used for their weeds and pest management qualities. Concerning weed management, brassica cover crops exhibit allelopathic properties, releasing compounds that inhibit the germination and growth of weeds (Haramoto and Gallandt, 2004). This reduces weed competition, minimizing the need for herbicides or manual weed control. Furthermore, Some brassica cover crops, such as mustard, can exhibit biofumigation properties (Haramoto and Gallandt, 2004). When incorporated into the soil, these cover crops release compounds that have natural pesticidal properties, suppressing soil-borne pathogens, nematodes, and pests, which can contribute to effective pest and disease management in the field. It should be noted the application of brassica cover crops will likely not be sufficient to fully



control weeds, pests and diseases and should be applied along other complementary management practices.

Summary

Overall, nutrient management in agriculture aims to optimize nutrient use efficiency, minimize environmental impacts, and sustainably support crop production. It involves a combination of scientific knowledge, best management practices, and site-specific considerations to ensure the responsible and effective use of nutrients in agricultural systems. It should also be mentioned that greatest success has been found when combining the aforementioned practices.

Increasing Biodiversity

As modern agriculture became more and more specialized, farmers began to rely on what is known as monocropping. Monocropping refers to the practice of cultivating a single crop or species over a large area. Although this practice can help farmers increase profits by producing bigger yields of a single crop that may be best suited to a certain type of soil or climate. Additionally farmers can concentrate their efforts on learning about a single crop and purchase a single type of equipment. However, monocropping can leave farmers in a very vulnerable place. When a single crop is grown extensively, pests and diseases can easily spread across the entire area, causing significant damage. Monocultures lack the natural checks and balances that diverse ecosystems provide, making them more susceptible to outbreaks and requiring increased use of pesticides and other chemical interventions. Which in turn further reduces biodiversity, as they can affect other non-harmful organisms. In short, these monocropping can lead to a dependence on chemicals, reduce crop resiliency, and expose farmers to economic vulnerability.

To avoid these consequences, regenerative farmers maintain and promote biodiversity as a core aspect of regenerative agriculture. Diverse plant species, including cover crops and native vegetation, are cultivated to provide habitat for beneficial insects, birds, and other wildlife. Enhancing biodiversity helps support natural pest control, pollination, and overall ecological balance. This can be achieved through techniques such as:

Intercropping

Intercropping involves growing crops with different growth habits, resource requirements, or ecological characteristics in a mutually beneficial arrangement. In intercropping, the crops are strategically selected to complement each other, optimize resource utilization, and enhance overall productivity.



Integration of Livestock

Well-managed grazing practices can mimic natural grazing patterns, improve soil fertility through nutrient cycling, enhance plant growth, and promote ecosystem health. Livestock can also contribute to the diversification of farm income streams through the production of meat, milk, eggs, and other animal products.

Crop Rotation

Implementing crop rotation involves growing different crops in a specific sequence over time. This practice helps break pest and disease cycles, improves soil health, and diversifies the habitat for beneficial organisms. Rotating between different plant families and incorporating cover crops can enhance biodiversity and ecosystem services.

Agroforestry

Agroforestry combines the cultivation of trees or woody perennials with agricultural crops or livestock. Planting trees in agricultural landscapes provides habitat for birds, insects, and other wildlife. It also helps improve soil structure, nutrient cycling, water retention, and carbon sequestration.

Habitat Creation

Setting aside areas within farmland for wildlife habitat can support biodiversity. These habitats can include native grasslands, wetlands, hedgerows, or wildflower strips. They provide shelter, food, and nesting sites for a wide range of organisms, including pollinators, birds, and beneficial insects.

Integrated Pest Management (IPM)

Implementing IPM strategies reduces the reliance on chemical pesticides and promotes natural pest control methods. By utilizing techniques such as crop monitoring, biological control (e.g., using beneficial insects), cultural practices, and targeted pesticide use, farmers can preserve beneficial insect populations and maintain a balance between pests and their natural enemies.

Conclusion

Overall, the goal of regenerative agriculture is to create sustainable and resilient food systems that restore and enhance the health and vitality of ecosystems. It aims to go beyond sustainable practices by actively improving the health of the soil, biodiversity, and ecosystem functions while also ensuring the long-term viability of agricultural production. By adopting methods which closely mimic natural processes, sustainable and regenerative food systems aim to promote ecological health, support farmer livelihoods, produce nutritious food, and ensure the long-term viability of agricultural production. By adopting regenerative practices, farmers and stakeholders can contribute to environmental stewardship, food security, and the well-being of present and future generations.



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