ISBN: 978-81-19149-15-5

16. Regenerative Agriculture

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Abstract:

Traditional farming methods may result in soil degradation and decreased output. Regenerative agriculture (RA), according to its proponents, focuses on soil health and carbon sequestration as a solution to these problems. The core tenets of RA are to keep the soil covered, prevent soil disturbance, preserve living roots in the soil year-round, boost species variety, incorporate livestock, and minimize or completely avoid the use of synthetic substances (such as herbicides and fertilizers). The main goals are to regenerate the soil and land and benefit the larger community in terms of the ecology, economy, and social conditions. Despite the supposed advantages of RA, the great majority of producers are hesitant to implement these methods because there is a dearth of scientific evidence supporting the benefits and profitability. We compared the purported advantages and RA-related mechanisms to the best of the available research. According to the literature, specific soil types and climate zones can benefit from agricultural methods like cover crops, residue retention, and limited tillage by increasing soil carbon, crop productivity, and soil health. Overuse of synthetic chemicals may result in ecological deterioration and a loss of biodiversity. Increased soil carbon content and a number of co-benefits can result from combining livestock with agriculture and agroforestry in the same region. The advantages of RA methods, however, may not always be relevant across various agro ecological zones and may differ among various agro ecosystems. In order to increase our understanding of the advantages and mechanisms connected to RA on regional scales, we advise the implementation of rigorous long-term agricultural system studies to compare conventional and RA techniques. This will give farmers and decision-makers access to the data they need to implement RA practices, enjoy their social and economic advantages, and build resilience against climate change..

Keywords:

Regenerative Agriculture, Soil Health, Soil Carbon, Climate Mitigation.

16.1 Introduction:

Regenerative agriculture (RA) is a farming method that makes use of natural processes to boost biological activity, improve soil health, optimize nutrient cycling, restore the functionality of the landscape, produce food and fibre, and maintain or boost farm profitability. In order to increase output and restore the functionality of the landscape, the approach is founded on a set of guiding principles, and practitioners employ a variety of strategies that integrate biological and ecological processes. In order to address these issues, an increasing number of agricultural land managers (hence referred to as farmers) are turning to regenerative agricultural (RA) systems. Robert Rodale was the first to use the phrase *"regenerative agriculture,"* arguing that by using this strategy, a farm system could both restore the natural environment and provide enough food to meet the social and economic requirements of the farmer and their community (Rodale, 1983). Although the precise number of regenerative farmers is unknown, interest in and investment in regenerative agriculture have increased recently. Claims that this form of farm management has a good effect on farmers' social and psychological resources, including their well being and quality of life, have been one of the growth's catalysts. According to recent studies, RA helps farmers adjust to climate change and other problems, which has positive social and psychological effects (Gosnell *et al*., 2020a; Gosnell *et al*., 2019; Sherren *et al*., 2012). The adoption of a socio-ecological systems (SES) approach to manage the farm, a key characteristic of RA, has been suggested as the cause of these advantages. Understanding and regulating the interactions between the environmental, social, and production components of the farm are key to applying SES principles to farm management. This whole-system approach should also be used to guide management decisions (Hruska *et al*., 2017). According to this viewpoint, the social and psychological effects of RA are just as significant as the results based on the landscape. RA is a farming method that integrates farming techniques with the natural processes of the landscape in order to enhance soil quality, boost biodiversity, and foster landscape resilience. Likewise, RA acknowledges that the social aspects of the farm are crucial to its overall operation (Gordon *et al*., 2021; Massy, 2017).

16.1.1 Need of Regenerative Agriculture:

The current intensive agriculture system has led to soil degradation and constant losses. There may not be enough soil to feed the world in next 50 years, according to international scientist. Soil fertility and biodiversity across the globe. Regenerative agriculture improves soil health through practices that increase soil organic matter, biota an biodiversity. It also aims at enhancing water holding capacity and carbon sequestration.

- It facilitates soil aggregation, water infiltration, retention and nutrient cycling.
- Regenerative agriculture also reduces erosion, provides habitat and food for diverse species and is beyond sustainability.

16.1.2 Principles of Regenerative agriculture:

Five principles that guide the approach are as follows:

- Minimize soil disturbance
- Keep the soil covered year-round
- Keep live plants and roots in the soil for as long as possible
- Incorporate biodiversity
- Integrate animals.

Advocates and practitioners of RA claim that these techniques will reduce greenhouse gas emissions, stop soil erosion and depletion, actively build soil, provide adequate crop nutrients with minimal outside inputs, produce healthy, high-yielding crops with few weeds and pests, improve human health, and more.

Figure 16.1: Regenerative Agriculture

- To boost productivity and restore the function of the landscape, RA practitioners employ a variety of approaches that mix biological and ecological systems. The main objective is to benefit from natural processes, which can be achieved by doing the following actions: through the photosynthesis of plants with large biomass, soil carbon is captured.
- Improving symbiotic soil micro biota plant interactions.
- Using biological systems to enhance soil structure and water retention.
- Including livestock, with an anticipated positive impact on ecosystem services.

There is no one method that works for all situations; rather, these techniques must be adapted to the particular farming and environmental conditions in which they are used. When adopting a RA system, it is necessary to take into account variables like precipitation, temperature, soil type, farm enterprise mix, markets, and human preferences.

Moreover, RA is neither an organic farming practise nor a strict agricultural technique. Instead, it is founded on fundamental ideas that let people use different methods on their properties in order to get the results they want. Several of the methods employed by RA farmers are well-known "good farming" methods also employed by conventional farmers. Several RA practices are also used in other types of sustainable agriculture, including climate smart agriculture, organic farming, low-input farming, conservation agriculture and carbon farming.

16.2 Benefits of Regenerative Agriculture:

The ability of soil to continue functioning as an essential living system within ecological and land-use boundaries, supporting biological productivity, maintaining air and water quality, and promoting plant, animal, and human health, has been described as soil health (Doran *et al.*, 2013 and 2014).

The ability of the soil to support the productivity, variety, and environmental services of terrestrial ecosystems is how the International Technical Panel on Soils (ITPS) has recently defined soil health (ITPS 2020).

The desirable physical, chemical, biological, and biological (microbial diversity, N mineralization, and soil respiration) characteristics of healthy soil include its desirable physical properties (texture, water holding capacity), pH, and soil organic matter (SOM), which support healthy, productive crops.

It is believed that soil is a living, dynamic ecosystem that is home to a variety of micro- and macro-biota that control its characteristics. The capacity of soil to retain its functions has been weakened by the intensification of agriculture using contemporary technologies, impacting long-term production and leading to a loss of ecosystem services (Tilman *et a*l.,2001; Bender *et al*., 2016 and Wagg *et a*l., 2016). The main goal of RA is to improve soil health by increasing organic matter and enhancing its fertility and productivity.

16.2.1 Increased Soil Carbon:

Soil can hold three times as much carbon as the atmosphere, it is regarded as an active storage pool for the gas (Reeves *et al*., 1997). The loss of soil organic carbon is one of the main causes of soil degradation (SOC). It has been demonstrated that SOC enhances the soil's structure, fertility, availability of nutrients, aeration, water infiltration, and water-holding capacity (Robertson *et al.*,2015).

It has recently been discussed as a strategy for reducing climate change (Chabbi *et al*., 2015). A major problem for decreased agricultural production is the depletion of SOC supplies in terrestrial ecosystems. It is advised to use management techniques that raise SOC to maximize agricultural production. Maize and wheat yields have been demonstrated to rise when SOC is increased by up to 2%, and this may lessen the need for N fertilizer (Oldfield *et al*., 2019 and Kane *et al*., 2021). Although regional climate and management techniques have an impact on soil carbon build-up (Hoyle *et al.*, 2016), events including deforestation, fire, land use conversion, and erosion are thought to result in a loss of SOC.

Land cultivation, in particular, alters the soil's physical qualities and nutrient availability by removing topsoil, destroying the structure of the soil aggregates, and exposing SOC to oxidation.

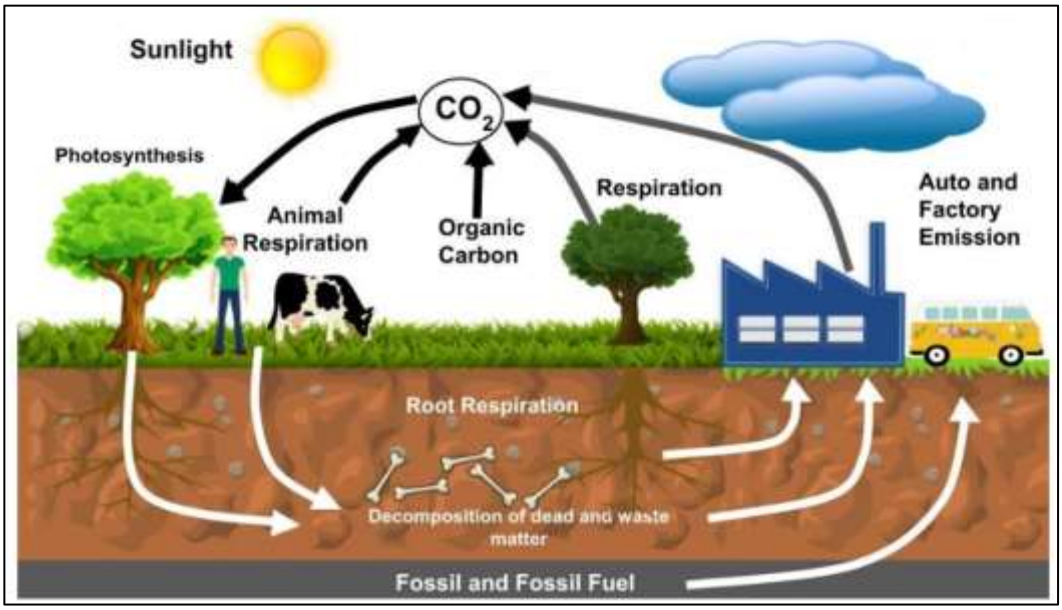

Figure 16.1: Increased Soil Carbon

Several cropping practices implemented to maintain or increase SOC are discussed below:

A. Minimum / No Tillage:

To reduce soil disturbance, RA farmers priorities minimal or no tillage. The purpose of the approach, in addition to reducing soil disturbance, is to promote the growth of fungal hyphae, which will improve nitrogen cycling in the soil. Carbon dioxide (CO2) fluxes to the atmosphere and water resources are caused by soil disturbance brought on by intensive tillage (Sapkota *et al.*, 2015).

In some nations, minimal or no tillage is commonly used not simply to reduce costs but also to benefit areas at risk of soil and water erosion. In addition to these advantages, some professionals think that using conservation tillage techniques can boost carbon sequestration, reducing the effects of global warming (Yang *et al.*, 2013).

Significant soil degradation and atmospheric carbon dioxide emissions result from tillage and ploughing. Moreover, it may cause the soil to become bare or compacted, which is not ideal for beneficial soil microbes. No-till/minimum tillage, on the other hand, enhances soil aggregation, water infiltration and retention, and carbon sequestration when used in conjunction with other regeneration techniques. By enhancing root zones and yields, intermediate ripping can also improve soil health and carbon sequestration in some soils by breaking up hard pans.

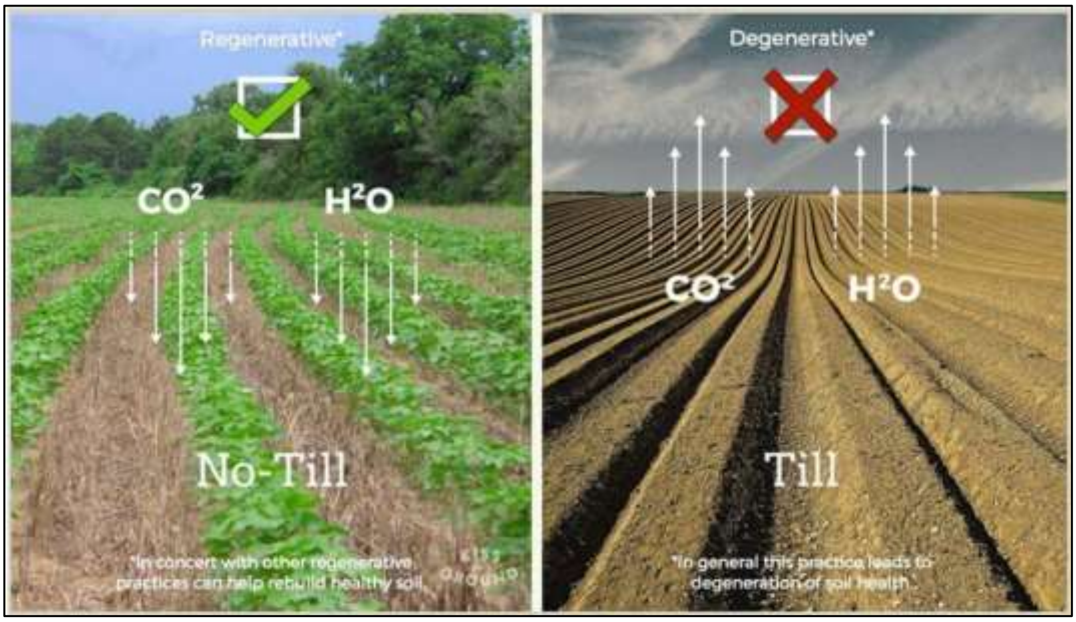

Figure 16.3: Minimum / No Tillage

The most effective management technique for raising SOC stocks in croplands is minimal tillage combined with residue retention in a double-cropping system. In addition to supporting more biologically active and productive soil, increasing SOC stock or concentration in the topsoil also fosters resilience to severe weather.

The increased C stock under no tillage versus high tillage in the upper soil (0–30 cm) was estimated by Haddaway *et al*., (2017) based on a global met analysis to be roughly 4.6 Mg/ha (0.78–8.43 Mg/ha, 95% CI) over approximately 10 years, while no influence was found in the complete soil profile (Deen *et al*., 2003).

In contrast, continuous cropping with zero tillage in a warm, semi-arid temperate or subtropical climate was shown to have negligible SOC accumulation; nevertheless, slow SOC accumulation was discovered to be possible with the rotational addition of perennial pastures (Chan *et al*., 2003 and Young *et al.*, 2009).

The ability to increase SOC through conservation tillage depends on a number of variables, including rainfall, soil depth, crop output, retention of stubble, and decomposition rate. No-till (NT) farming has been promoted as a means of enhancing soil biological characteristics. When Martinez *et al.* (2013) evaluated specific soil characteristics in irrigated Mediterranean no-till and conventional tillage (CT) systems, they found that soil chemical fertility increased under NT, with greater levels of N, P, and K. No-till produced higher carbon dioxide storage than traditional tillage. Under NT as opposed to CT, increased SOC led to higher biological activity. While no-till is good for soil quality, its importance in reducing climate change is substantially overstated, according to Powson *et al*., (2014), who also advocated the improved productive capability of NT soil in terms of soil chemical characteristics.

B. Cover Crop:

Maintaining soil cover and living roots in the soil throughout the year is a requirement of the second and third RA principles. Including cover crops in the farming system is one strategy. In order to cover the soil and maintain living plants there during non-cash cropping seasons, cover crops are often grown in between primary crops. This is done by either planting cover crops after harvest or by under-seeding cash crops—usually grains—with perennial crops that will grow and sustain soil cover throughout the following season. Single species or mixtures of multiple species can be used as cover crops. Notwithstanding how simple it is to manage a single species of cover crop, a combination of species may offer all the advantages of each species in the mix (Finney *et al.*, 2017). Legumes are among the multi-species cover crops that are believed to enhance ecosystem processes such biological nitrogen fixation, microbial variety, decrease of compaction, attraction of beneficial insects, weed suppression, regulation of soil temperature, and increased water infiltration.

A widespread adoption of cover crops might cut agricultural GHG emissions by 10%, which is comparable to employing no-till or other cropping strategies, in addition to boosting soil fertility and assisting in carbon sequestration (Kaye *et al*., 2017). A major advantage of cover crops is increased microbial biomass, which is achieved by increasing the amount of SOM in the soil (McDaniel *et al.*, 2014). Yet, a large increase in soil carbon may not occur for several years. Ghimire *et al.* (2018) and Poeplau *et al*., (2015)). In diverse agroclimatic areas throughout the world, a range of cover crop reactions to SOC accumulation have been documented. The application of cover crops six times in eight years in a temperate humid region of North America was demonstrated to improve SOC surface storage, but profitability depended on the sort of production system employed (Chahal *et al*., 2020).

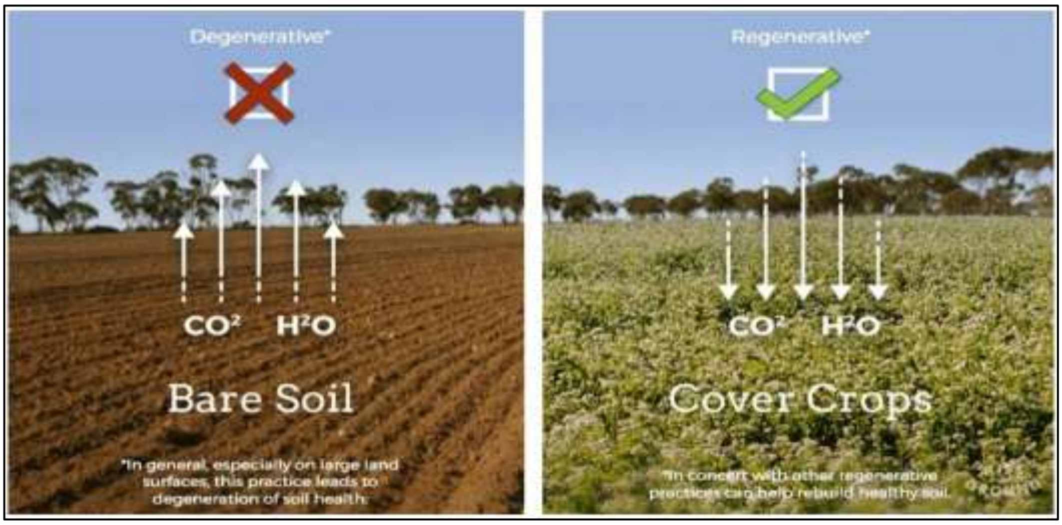

Figure 16.4: Cover Crop

The texture of the soil has been connected to soil carbon accumulation with cover crops, with clay soils with cover crops having a higher likelihood of increasing soil carbon. According to studies conducted in Argentina, cover crops planted on both fine- and coarsetextured soils increase soil carbon uptake (Alvarez *et al*., 2017). Although cover crops can aid eroded soils with low carbon content in accumulating more carbon (Hassink et al., 1997; Berhe *et al.,* 2007), the advantages of no tillage are more apparent because the pace of residue decomposition is slower than with conventional tillage (Olson *et al.,* 2014).

C. Stubble Retention:

After harvest, leaving the stubble on the land offers many benefits, such as reducing soil erosion and water runoff, replenishing the soil's nutrients, and improving carbon input and water infiltration (Packer *et al.,* 1992). In general, when used in conjunction with other management techniques, stubble retention has a stronger effect on C build-up (Saffigna *et al.,* 1989) Plant diversity affects the breakdown and transformation of above- and below-ground plant litters, which in turn affects the creation and accumulation of SOC (Cotrufo *et al.,* 2015). Moreover, the quality of the residual C intake influences how much carbon is sequestered (C:N ratio).Higher C:N ratio manure decomposes more slowly, adding more C to the soil, and vice versa. Burning stubble reduces SOM, damages physical, chemical, and biological qualities, and produces greenhouse gas emissions (Pandey *et al.,* 2019). Using waste as a surface mulch is an additional method of enhancing soil biodiversity and SOC (Tomar *et al*., 1992). Depending on the kind of soil, adding stubble might have a significant or insignificant impact on carbon sequestration potential. Compared to sandy soils, clay soils with integrated stubble sequester more carbon. Several studies have discovered that crop production and SOC stocks considerably increased when no tillage was combined with stubble retention (Xia *et al*., 2018 and Shi *et al*., 2022).

Figure 16.5: Stubble Retention

While the retention of stubble has been recommended to improve soil health, it can be harmful in terms of transmitting illnesses that affect crop productivity and are carried by stubble. However, by using integrated disease management strategies, the adverse effects can be reduced.

D. Crop Rotation:

Crop rotation, also known as diversification, is a centuries-old practice that improves yield and profit by providing nutritional benefits and breaking the pest–disease–weed cycle. However, crop rotation as a practice reverted to monoculture in the middle of the last century due to a heavy reliance on inorganic fertilizers and pesticides, improved crop varieties, and, in some cases, economic considerations. All of these eventually resulted in land degradation and the loss of SOM (Di Bene *et al.*, 2016).

Figure 16.5: Crop Rotation

Crop rotation is becoming increasingly recognized for its potential to improve soil quality (Jarecki *et al.*, 2003) roping practices that include rotating with high-residue-producing crops, as well as maintaining surface residue cover and reducing tillage, can significantly increase SOC and N (Havlin *et al*., 1990). Crop rotation, however, had no impact on SOC in WA's fertile soil. Pulse crops greatly aid in biological nitrogen fixation, which raises SOC. However, because certain pulse crops produce substantially smaller biomass and residual inputs than others, the yield advantage of rotating wheat and pulse crops depends more on the kind of pulse crop in rotation than SOC.

E. Well Managed Grazing Practice:

Despite the fact that livestock farming is commonly held responsible for helping to increase methane emissions, integrating animals is another common RA technique that helps to improve soil health and diversify revenue sources. Rotational grazing is preferred to continuous grazing to raise SOC and enhance soil health. They promote greater plant development, increased soil carbon deposits, and overall pasture and grazing area productivity. They also increase soil fertility, insect and plant biodiversity, and soil carbon sequestration. These actions enhance the availability of micro nutrients and enhance dietary omega balances, which benefits not only the environment but also the health of the animal and human consumers. Restricted animal feeding methods and feed lots greatly contribute to-

- Un-healthy monoculture production systems,
- low nutrient density forage,
- increased water pollution,
- antibiotic use and resistance
- CO_2 and methane emissions

Figure 16.5: Well Managed Grazing Practice

All of which work together to create flawed food production systems that harm the environment. Rotational grazing, which entails moving cattle through pastures on a regular basis to improve the health of the soil, plants, and animals, is a key component of the numerous methods used to raise organic livestock. In order to meet the demands of the animals and maintain their health without the use of antibiotics or hormones, animal welfare is of the utmost significance.

16.2.2 Pest, Pathogen, and Weed Control / Suppression:

Worldwide, crop viruses, pests, and weeds result in considerable productivity and monetary losses. Climate change is predicted to make some illnesses and pests more prevalent and severe, especially those that like warmer climes. Plant immune responses are influenced by factors such as increased temperature, CO2, humidity, and nutritional condition. Monoculture is one agricultural method that encourages pests and disease. Integrated disease and pest management is commonly advised to reduce ensuing losses.

One of the suggested methods is the use of fungicides and insecticides for conventional plant disease and pest control, however this method has a number of drawbacks. Pesticide resistance has emerged as a result of pesticide usage in recent years, along with pollution and detrimental impacts on soil micro biota. As a result, experts from all around the world are interested in creating disease management strategies that are sustainable and safe for the environment.

Many bacteria and fungi found in soil have been identified as pest and disease suppressors. Via a number of processes, including competition, hyper parasitism, and antibiosis, microbial biological control agents shield crops from diseases. It has been observed that a number of helpful soil bacteria, fungi, viruses, and micro fauna are possible candidates for biological control and the restoration of ecological balance (Ruiu *et al*., 2018).

In WA farming systems, weeds are a major issue, and chemical weed management is widely employed. Without the rapid development of innovative non-chemical techniques, weed management in no-till and other regenerative farming approaches will be very challenging. In addition to being expensive, chemical weed management poses significant problems with weed species creating resistant populations. The future of long-term weed control is integrated weed management (IWM), which incorporates physical, cultural, genetic, biological, and chemical techniques. Another strategy to lessen the use of weedicides is allopathy. Weed seed banks can be diminished by soil microbes such nematodes, bacteria, viruses, and fungi. The majority of microorganisms used for weed control are diseases that are common to both crop plants and weeds, which is a significant disadvantage.

16.2.3 Climate Mitigation:

Reduced greenhouse gas emissions are one of the additional benefits of RA, claim RA practitioners. Methane and nitrous oxide from enteric fermentation of livestock/animals and crops, respectively, account for 14.6% of Australia's yearly GHG emissions. A reduction in SOC caused by rising temperatures and probable soil erosion can lower agricultural output by 10% to 20% (Delgado *et al*.,2011).

SOC sequestration in soil through photosynthesis is responsible for agricultural practices' potential to reduce climate change. Croplands, grazing/range lands, degraded/deserted lands, and irrigated soils have the largest sequestration capacity, with the potential to offset fossil fuel emissions by 5-15% annually. Management techniques including the use of perennial forage crops, the elimination of bare fallows, the cultivation of bio fuel crops, enhanced nutrient management, reduced tillage, and the production of high residues all help to increase C sequestration in soil (Paustial *et al.*,1997).

A global shift to RA:

- **Feed the globe:** With less than 25% of the world's acreage, small farmers currently feed the world.
- **Reduce GHG emissions:** A new food system might be a major factor in climate change solutions. In the existing industrial food system, 44 to 57% of all greenhouse gas emissions occur.

- **Reverse climate change:** Simply said, reducing emissions alone is insufficient. Fortunately, by increasing soil carbon stores, we can actually slow down climate change.
- **Improve yields:** In cases of extreme weather and climate change, yields on organic farms are significantly higher than conventional farms.
- **Create drought-resistant soil:** The addition of organic matter to the soil increases the water holding capacity of the soil. Regenerative organic agriculture builds soil organic matter.

Regenerative agriculture in India:

The Bharatiya Prakritik Krishi Paddhati Programme (BPKP), a centrally financed programme known as Paramparagat Krishi Vikas Yojana, promotes natural farming in India (PKVY). BPKP seeks to advance conventional indigenous ways of life that reduce the demand for foreign inputs. Several high-level debates on natural farming techniques with foreign specialists were hosted by NITI Aayog in association with the Ministries of Agriculture and Farmers Welfare. Regenerative agriculture is already used by an estimated 2.5 million farmers in India. In the next five years, it's anticipated that 20 lakh hectares will be dedicated to organic farming of any kind, including natural farming, with 12 lakh of those hectares falling under the BPKP. It is thought to be a profitable farming technique with the potential to boost employment and rural development.

16.3 Conclusion:

By growing organic matter, a farmer who employs regenerative techniques and doesn't disrupt the soil lessens the effects of climate change. Also, a soil's ability to retain water increases with the amount of organic matter present. Adopting regenerative agriculture practices enables farmers to take long-term action by taking part in a larger solution to the crisis through carbon sequestration, in addition to assisting them in coping with the immediate effects of climate change by making their farms more resilient and adaptable to what is happening around them.

In response to the problems caused by climate change and increased input costs, RA is becoming more popular. It is suggested that adopting climate smart agriculture practices, such as RA, will lessen the effects of extreme weather events and fight GHG emissions.

The main objective of RA is to restore soil health in order to rejuvenate degraded land and deliver environmental, economic, and social advantages to a larger community. RA is not a wholly new farming system; rather, it includes aspects from proven sustainable agricultural systems. SOM and SOC are important factors in soil biodiversity because they control a variety of biological processes in the soil. Even a little drop in SOC can have negative effects on soil health by hindering ecosystem operations. Management strategies have a significant impact on microbial community development, which in turn affects ecosystem services. It is commonly known that intensively treated soils experience a loss of soil biodiversity. Due to the naturally low SOC of agricultural soils in Western Australia, there is currently a significant risk to soil biodiversity. The literature demonstrates that microbial biomass, activity, and soil functions are increased by sustainable management approaches.

The literature indicates that there is potential for carbon sequestration and enrichment of below-ground biodiversity by changing agronomic techniques, notwithstanding the major difficulties in generating SOC in WA dry lands, particularly in regions with restricted water supply.

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