

Regenerative Agriculture

Farming

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According to our soil scientists, the rate at which soil destruction takes place all over the world as on today, the catastrophic effects of those after 50 years, it is assumed that we will not only suffer serious damage to public health due to degraded food (lack of nutrients and trace minerals) supply, but we will have no longer enough arable top soil to feed ourselves. As per the UN report, without protecting and regenerating soil on our 4 billion acres of cultivated farmland, 8 billion acres of pasture land and 10 billion acres of forest land, it will be impossible to feed the world, keep global warming below 20°C or stop the loss of biodiversity. The regenerative agriculture leads to the development of healthy soil, capable of producing high quality nutrient dense food while simultaneously improving, rather than degrading the land, and ultimately leading to productive farms, healthy community and economies.

Keywords: Agro-ecology, Aquaculture, Biochar, Forestry, No-till, Pasture cropping, Regenerative agriculture

THE concept of regenerative agriculture is to improve the fertility of the soil. Regenerative agriculture leads to the development of healthy soil, capable of producing high quality nutrient dense food while simultaneously improving, rather than degrading the land and ultimately leading to productive farms, healthy community and economies. Application of the regenerative agriculture theme is dynamic and holistic in the sense that, by adopting permaculture and organic farming practices, including conservation tillage, cover crops, crop rotation, composting, mobile animal shelters and pasture cropping, one can, not

only increase food production from farms, but also raise the farmers income and quality of the top soil.

Principles of regenerative agriculture

- Increase soil fertility
- Work with whole systems, not isolated parts
- Progressively improve whole agro-ecosystems (soil, water and biodiversity)
- Connect the farm to its larger agro-ecosystem and bio-region
- Create designs and make holistic decisions that express the value and relationship of farm contributors
- Express the significance of each person, farm and system

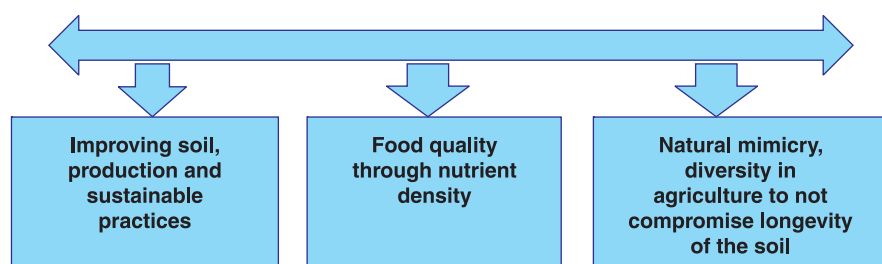
- Make holistic decisions aimed at specific system changes
- Ensure and develop equitable and reciprocal relationships among all stakeholders
- Design for non-linear, multi-capital reciprocity
- Continually grow and evolve individuals, farms and communities to express their potential
- Continuously evolve agro-ecological processes and cultures
- Agriculture influences the world

Benefits of regenerative agriculture

By adopting regenerative agriculture technologies, the following benefits can be achieved, which are significant over sustainable agriculture:

- Feed the world
- Decrease Green house gas emission
- Reverse climate change
- Improve crop yields
- Create drought resistant soil
- Revitalize local economies
- Preserve traditional knowledge

Three key pillars behind regenerative agriculture



- Nurture biodiversity
- Restore grass lands
- Improve nutrition

Regenerative aquaculture

To enhance fish production, everybody is looking for aquaculture farming as one of the alternate methods. Today the world aquaculture production has almost reached the same production figure as that of the total world capture fisheries. Implementation of more efficient and scalable aquaculture has the lowest environmental footprint of all animal protein resources. Multi-trophic aquaculture techniques demonstrate exceptionally useful cycling of waste between organisms and the ability to produce many different food product outputs and minimize waste.

Unlike conventional aquaculture, which often damages wild ecosystems, regenerative aquaculture takes into account the full scope of the impact that farming aquatic species can have. In the oceans, regenerative aquaculture includes shellfish such as oysters, mussels and clams, which filter up to 50 gallons of water a day; and as well the number of useful seaweeds. On land, companies such as Atlantic Sapphire Salmon and many other aquaculture companies are innovating new ways of housing and feeding fish that conserve water and up cycle waste. To encourage regenerative aquaculture, in recent years number of innovative technologies are developed such as the use of biofloc system and bacteriophage therapy to control the spread of diseases.

Regenerative agro-ecology

Agro-ecology shares much in common with other approaches to the sustainable farming. For example, improving soil and plant quality can be done by using available biomass and biodiversity, rather than using the chemical fertilizers and other synthetic compounds. In fact, the agro-ecological farmers seek to improve food yields for balanced nutrition, strengthen fair markets for their produce, enhance healthy ecosystems, and build on ancestral knowledge and customs. The farmers

are guided by the principles of bio and cultural diversity featuring applied research and policies that protect their livelihoods. Worldwide, several public and private agencies are working with farmers to construct sustainable and nutritious food systems based on agro-ecological concept.

According to FAO (2018) there are 10 guiding principles of agro-ecology: diversity, synergies, efficiency, resilience, recycling, co-creation and sharing of knowledge, human and social values, culture and food traditions, responsible governance, circular and solidarity economy. The constant warmth and moisture availability in the humid tropics can support high levels of productivity; however, soil resources are often depleted and limit growth in the humid tropics. Pests, as well as agriculturally desirable plants and livestock thrive in the sub humid and humid tropics. This often limits production of food and other agricultural products. In temperate and drier zones, by contrast, there are cold periods or aridity that can provide a break in the growth of pests. Careful consideration of agro-ecologies, based around gradients of moisture and temperature, along with soil resources, can provide a guide regarding which farming systems or crop combinations will be present. This approach also can provide insights into which types of interventions or technologies might be expected to perform well.

Regenerative agro-forestry

Agroforestry is defined as the intentional integration of trees and shrubs into crop and animal farming systems to create environmental, economic, and social benefits. All these different elements go together and complement each other. When this happens, it leads to enhanced resilience, increased biodiversity and a more productive, profitable, and climate-friendly use of the land and other resources. This integration comes with heaps of ecological and economic benefits and provides us with an alternative way of producing food, timber, biomass, meat, and many other products. Therefore, the agroforestry is seen as a holistic food

production system addressing social, ecological, and economic goals, the regenerative outcomes of which have been recognized and fostered over time.

An agroforestry system may also be a species-rich forest garden consisting of many different vertical layers, maximizing diversity and creating a flourishing flora and fauna. and also contain animals that interact, in one way or another, with the surrounding trees or crops. The three types of agroforestry are (1) Agrisilvicultural systems, (2) Silvopastoral systems and (3) Agrosilvipastoral systems.

Agrisilvicultural systems

In agrisilvicultural systems, crops (agriculture) are combined with trees (silviculture). This could be forest garden in which fruit trees are grown next to shrubs carrying berries and herbs on the ground. It is common on smaller scales, very diverse, and produce loads of edible products on multiple layers and making great use of the available space. It could also be a wheat field that is surrounded by protective hedges or shade trees and produce other goods such as fruit trees or fuel wood. Other examples include alley-cropping (neat rows of different species next to each other) or intercropping (mixed species near each other) with trees.

Silvopastoral systems

The silvopastoral systems integrate trees with either pastures or animals. This combination is often done for yielding additional tree products (e.g. fruits, nuts or biomass), storing O₂ creating better living conditions for animals, or building habitat for other animals (supporting biodiversity). For example, an orchard growing on the pasture lands of chicken, sheep or geese. Silvopastoral systems also encompass projects that grow their own fodder for their animals. For instance, unused spaces can be utilized to grow plants, shrubs or trees producing forage. This decreases costs for buying animal fodder and yields additional benefits for the environment and the soil.

Agrosilvipastoral systems

The third possible system is a

combination of all three components: trees, crops, and animals. The aim is to reap the benefits of this integration. Bees, for instance, can be held for honey production, while pollinating trees and crops. The most common example of this triple combination is a typical home garden involving animals. Another example is the so-called aqua forestry. Here, trees are planted around fishponds, while their leaves are used as fodder for fish. These can be integrated with crop production. Having water in proximity creates another habitat that supports more species.

Biochar and Terra preta

Biochar and terra preta are important components of regenerative agriculture. Biochar is nothing but charcoal that is produced by thermal decomposition (pyrolysis) of biomass. It is a stable solid that is rich in carbon and can endure in soil for thousands of years. Biochar is being investigated as a means of carbon sequestration, and it may be a means to mitigate global warming and climate change. It results from processes related to pyrogenic carbon capture and storage. Biochar increase soil fertility of acidic soils (low pH soils), increase agricultural productivity, and provide protection against some foliar and soil-borne diseases.

The use of charcoal/biochar for soil amendment is well known and there are several publications to support this. At that time, the term *agrishar* was variously used to specify, the application of charcoal in agriculture and the term biochar was officially adopted at an international scientific conference in Birmingham, England, in 2009. Since that time, academic research on biochar has exploded, and lot of research investigation is being emphasized to find out its possible role in regenerative agriculture. In 2017, the number of scientific papers published on studies of biochar exceeded the papers on compost, and the pace of research has only accelerated internationally.

Terra Preta is actually fertile black soil and these soils are many hundreds years old, and have

remained remarkably fertile in many tropical areas in spite of different weather conditions. It has been reported that these soils were artificially cultivated by an age old civilization that practiced agriculture. These soils were seemingly permanently fertile, which double the crop yields compared to surrounding soils and holding about three times as much phosphorus and nitrogen, while consisting of about 9% carbon. Regeneration of terra preta from forest litter suggests that the microbiome of terra preta may have as much of an influence as added charcoal, imparting the character of the underlying material on organic material that decays upon it. Terra preta has even been found to promote mycorrhiza and host higher populations of diazotrophs (nitrogen-fixing bacteria). It has been reported that the compost and soil are home to tens of thousands of species of microbes, and biochar likely also exerts selection pressures on these microbes that result in significantly different proportions of various species, resulting in a significantly different microbiome from the surrounding soil. This altered microbiome that colonizes and decomposes the new forest residue landing upon it, transforming it into regenerated terra preta populated with the same microbiome.

Compost and compost tea

Composting is nothing but decomposing organic solid wastes in the presence of air. It can therefore be used to recycle organic material. The process involves decomposition of organic material into humus like material, known as compost, which is a good fertilizer for plants. Composting requires three components: human management, aerobic conditions, and development of internal biological heat. The most efficient composting occurs with an optimal carbon: nitrogen ratio of about 25:1. Compost has several advantages over using synthetic fertilizers and other organic materials. Composting makes plant nutrients available over a longer period of time particularly nitrogen, phosphorus and potash (NPK). The advantage of

compost is most apparent with nitrogen. Composting mineralizes complex nitrogen, slowly putting it into a form that is available to higher plants. Mineralized nitrogen is released as nitrate more slowly compared to soluble and volatile forms. Research has shown that compost can activate minerals that are ordinarily unavailable, such as rock, phosphorus, can be activated by composting

Compost tea describes many different preparations made using compost as a starting material and producing a liquid extract of the original compost. There are probably many recipes for compost tea and a focus on its use for more specific applications. For example, when making compost tea to combat plant pathogens, the trend is to have as much microbial diversity as possible. When making a tea to supplement plant nutrients, many producers are fortifying the tea with supplements either during production or as a post-production addition. Compost tea is a readily available form of compost that will impact the plant more quickly than compost mixed into the soil (Fig. 1). Compost quality issues, including maturity and microorganism content, become very important for making effective compost tea. The transformation of compost into compost tea cannot improve on the original quality of the compost. Good compost has the potential to make good compost tea, if made properly; poor compost will always make poor compost tea. Many imperfections in the starting compost, such as high salt concentrations, high levels of anaerobic microorganisms and the presence of pathogens may actually be amplified in the final compost tea. It is critical, therefore, to use only the highest quality compost available. Compost that is rich in microbial numbers and diversity can result in compost tea with these same qualities. Even so, the typical representation of microorganisms in compost tea differs from the original compost. Some types of microorganisms like to live attached to particulate matter and a compost tea made using a fine mesh strainer

popular for tea destined for drip irrigation does not let a sufficient amount of particulate matter through to support these microorganisms. The beneficial fungi and antinomycetes prominent in good compost may be poorly represented in the compost tea simply due to the necessity of straining out the material to which they would attach due to the demands of the irrigation

system equipment. It is imperative to note that compost tea microbiology is most impacted by oxygen availability, nutrient availability and initial microbiology of the compost used to make the tea. Compost tea does not typically improve with time. For best results, it should be used as soon as possible and should store in shaded area with agitation and ventilation to the tank. Compost teas are applied either to the soil or to the plant foliage. Those applied to the soil will move into the root zone and affect the rhizosphere of the plant. The plant as well as the microorganisms in the soil will use nutrients carried in the tea area. The microbes in the compost tea may have a lot of competition with other soil microorganisms, but have the opportunity to become a part of the soil and rhizosphere microbial ecology.

Planned and holistic managed grazing

Holistic Planned Grazing is a planning process for dealing simply with the great complexity of integrating livestock production with crop, wildlife and forest production while working to ensure continued land regeneration, animal health and welfare, and profitability. In this holistic management tools, three actions of living organisms are important i.e. grazing, animal impact and rest from both are those which we use within holistic planned grazing. There are four management principles in this tool which help us make decisions when using these tools; population management/stocking rate, time, stock density and herd effect. Demarcating land into divisions – commonly called pastures or paddocks – is also very important



Fig. 1. Compost tea preparation

for planning in advance but these paddocks need not be fenced, rather they can be managed through herding or the use of attractants/deterrents and even technology. By taking the entire Holistic Context into consideration during planning, one can build a clear picture of where livestock need to be and when. The land has to be subdivided into grazing divisions (i.e. pastures, paddocks) to gain control over livestock movements. The divisions are first planned on a map and then on the ground demarcated by fences, natural barriers, or for herders by blazed trees or natural features. In creating their grazing plans, one has to decide how long the animals will stay together in one place, where they will move next, and when they will come back?

The planning steps address these questions:

- What landscape to create?
- Will livestock be used to regenerate cropland soils through animal impact?
- What other wildlife, forestry, or other land uses will livestock be used to enhance?
- How much total forage will the land under management have to supply in the current planning period?
- How much forage will an average hectare/acre of land have to supply?
- How long will standing forage at the end of the growing season last in a nutritious state?
- How long will livestock spend in each grazing division, and when will they return?
- Where and when will you need to concentrate livestock to maintain healthy grassland, reduce weeds or woody vegetation, or prevent soil erosion?

Rotational, rational and holistic planned grazing

There are many number of rotational grazing systems that involve the division of large grazing areas into smaller ones, and the rotation of livestock through them. Grazing rotations may appear to work fairly well in perennially humid environments, where livestock are mainly run on planted and fertilized pastures and the

variables are fewer. Animal performance and forage production are generally not as high as they could be, and very dry or very wet years can cause real problems. While it served reasonably well in the more humid environments, it generally leads to decreased production over time. Holistic planned grazing is generally more dynamic, gives greater weight toward real-time feedback and new information, and is designed to give the tools necessary to manage complex systems.

No-Till farming

Modern day agriculture has progressed and developed greatly in recent past. One of the most important advancements the agricultural society has seen is the plow. Plowing the agriculture land is an old and conventional method since ancient times. The primary purpose of plowing is to turn over the upper layer of the soil, bringing fresh nutrients to the surface of a field, while burying weeds and the remainder of any prior crop, and allowing them to decompose and act as an organic fertilizer. It also aerates the soil and helps it to hold moisture better by being under constant cover. In modern use, a plowed field is typically left to dry out, and it is then turned over again before planting. The effects of this process are impacting everything from the air we breathe to the vast erosion of soil. In order to reduce these effects, the method of no-till planting was developed. The notion of no-till farming has been around since the 1960s, when it was introduced to help reduce erosion of the valuable topsoil from farmland. Since then, the realization of other benefits such as reduced need for

irrigation, less labour for farmers, and increased soil quality. In recent years, awareness in no-till has increased due to concern with soil conservation. No-till farming, as its name indicates, does away with the plowing of soil between crops as a result dead crops are left on top of the soil, where they decompose slowly.

No-till farming actually limits the amount of anthropogenic involvement, which can contribute to the soil degradation by exposing the upper soil horizon, re-introducing noxious weeds to germination, allowing for leaching and erosion of topsoil. This method also helps in keeping higher organic matter in the soil, and retains higher amounts of moisture, so that intact and healthy soil provides better conditions for agricultural crops to perform well year after year.

Pasture cropping

Pasture cropping is a farmer-initiated land management system that integrates cropping with pasture production, and allows grain growing to function as part of a truly perennial agriculture. In the system, annual winter growing cereal crops are directly sowed into living summer growing perennial pasture grasses as the pasture sward enters the dormant phase of its growth cycle, allowing year-round growth and eliminating fallow and bare ground. This cereal production for grain and fodder is integrated with an intensive time controlled grazing system. There are important sustainability benefits of maintaining more perennial plants across agricultural landscapes, and the low input costs and flexible nature of the system make it attractive to producers. Pasture cropping has already captured the imagination of the permaculture community because of its potential to make grain cropping compatible with permanent, regenerative agriculture. With this technology, not only is soil disturbance low, but perennial plants are maintained, inter-cropped with the annual grain crop. Pasture cropping in suitable agro-ecological conditions has the potential to reduce and even reverse the environmental impacts associated with grain production by increasing soil organic

carbon, increasing agro-biodiversity and improving hydrology. Pasture cropping, applied as a general term referring to the planting of annual crops into a living perennial pasture, includes a wide variation of techniques around preparing for planting, timing of planting, herbicide and fertilizer types and applications, and grazing management. It includes techniques that apply herbicides prior to sowing to reduce competition from annual weeds, as well as the 'advance sowing' or 'no kill' approach, where crops are planted 'dry' before the autumn break with no herbicides used. The latter approach relies on the crop having more vigorous growth than germinating annual weeds.

Here are some reasons why pasture cropping is important:

- High crop yields
- Sustained high pasture and animal production from cropped land
- Increased fodder for livestock
- High rates of carbon bio-sequestration
- Marked improvement in the water-holding capacity of the soils
- Improved nutrient cycling
- Improvements in biodiversity and resilience, even under drought stress
- Significantly reduced input costs and risks
- Improved economic return from the vertical stacking of enterprises
- Improved happiness quotient on the farm.

The main obstacle in operation of pasture cropping is climate—grass species need a true dormant season for the technique to work properly, a condition that is unusual in tropical and sub-tropical environments. Another obstacle can be the land's lack of perennial grasses due to overgrazing, drought, or a combination of both. This can be overcome, however, by re-sowing grass species and then encouraging their growth through pasture cropping, which stimulates plant vigor and seed recruitment once grasses take hold.

Perennial crops

Perennial crops unlike annual crops – do not need to be replanted each year. After harvest, they automatically grow back. By eliminating replanting, perennial cropping can reduce topsoil losses due to erosion, increase

biological carbon sequestration due to reduced soil-disturbing tillage, and greatly reduce waterway pollution through agricultural runoff due to less nitrogen input. Perennial crops such as oil palm (*Elaeis guineensis*) and coconut (*Cocos nucifera*) have played and will continue to play important roles in the agriculture of the humid and semi humid tropics where they are cultivated on a large scale in both plantations and smallholdings for food and nonfood industrial purposes. Perennial crops are typically considered as those that are more permanent, requiring a number of growth cycles before fruit is produced. One of the characteristics of these plants is their requirement for winter chilling before flowering the next spring. There is evidence that with warming winter temperatures some perennial crops may not have their chilling hour requirement satisfied, which will limit flowering and formation of fruit. An additional concern is that warm winters may promote early bud and flower development and late season frost events will damage these flowers and fruit or nut formation. Perennial crops are valued for a combination of their total production and the quality of the harvested product, for example, size of a peach or apricot, the red blush on an apple, oil content of olives, or the quality of wine produced from a particular vineyard. By nature, perennial crop production is long-term and climate change will create interesting problems for production. It provides an excellent example to show how climate stress impacts growth throughout and across the years.

Perennial crops are particularly vulnerable to climate given their exposure to fluctuating weather conditions throughout the year. Key climate-influenced vulnerabilities include winter chill fulfillment, springtime freeze risk, pollination, heat stress, and disease and insect pest pressure. Other contributions to vulnerability include changes in consumer demand, competing land uses, and competition with other production regions. Assessment of the impact of climate on perennial crop production need to move

beyond the local–regional scale, and recognize that perennial crops constitute an international market system with multiple production regions that differ in terms of climate vulnerability.

Equipment necessary for regenerative agriculture

Regenerative agriculture takes a less industrial approach to growing food than most forms of modern farming. It focuses on regenerating healthy soil that can nurture better crops and be more resilient in the face of climate change. While many people equate regenerative agriculture with sustainable and organic growing practices, it tends to go above and beyond growing without chemicals or large amounts of energy. Still, regenerative agriculture operations require some equipment. Some farms are only a few acres, while others may be thousands. Some essential equipment items for farmers in regenerative agriculture are described below.

Smart irrigation

Regenerative agriculture is about supporting soil with higher nutrient levels, water retention abilities, and overall resilience against drought and other natural events. Farmers growing vegetable and fruit crops may require ground irrigation, also known as drip tape, to effectively water their plants. But irrigation practices can be wasteful, and sometimes farmers end up ineffectively using water resources. By incorporating new technology involving timers and sensors, farmers can be more efficient in their energy usage. Smart irrigation is an excellent tool to ensure irrigated crops are getting the right amount of moisture without wasting resources.

Manure spreader

Regenerative agriculture operations often have different income streams and markets. While industrial agriculture often focuses on producing only one crop, many regenerative farmers understand a healthy ecosystem consists of various processes, and it is more effective to cultivate different crops in one area.

Instead of a field of soybean, regenerative farms may raise livestock in one field, vegetables in another, and have fruit trees in a third. Manure is an incredibly nutrient-dense and efficient way to restore minerals to the soil before or after planting annual crops. If the farm uses rotational grazing, they most likely have a manure spreader attachment to distribute manure elsewhere on the farm.

No-Till drill

Tilling is the process of digging up and turning the soil to plant a new crop. Most industrial agriculture uses tilling to sow annual crops, and while it makes things easy, it is terrible for the soil. Tilling disturbs the health of the soil's microbiome, contributes to greenhouse gas emissions, and removes stored carbon from the soil. Using a no-till drill, regenerative farmers can plant traditional crops like grains and cover crops without tilling the soil first.

Post-Hole digger

There are several types of regenerative agriculture, and agroforestry is one of the most popular. Agroforestry is the process of integrating tree crops with other farming operations, using nut and fruit trees to restore previously degraded soil. Many regenerative farms plant fruit and nut orchards and run livestock in between, so the trees benefit from the nutrient exchange, and the livestock clear out any potential pests on the ground. However, planting young seedlings can be very time-consuming. Investing in a post-hole digger is a worthwhile investment for a regenerative farmer, streamlining the planting process.

Bioreactor

Compost is vital to healthy soil, especially when growing annual crops. Most regenerative farmers rely on the compost they generate, though more extensive operations may buy in large amounts when necessary. One innovative technology transforming regenerative agriculture is the availability of compost bioreactors, which allow farmers to convert their waste into nutrients

more effectively. Bioreactors are especially helpful on farms with livestock operations, ensuring nothing goes to waste.

Green tools

Regenerative agriculture is all about the earth, and keeping the soil healthy involves some special tools and equipment. Unlike more industrialized agricultural operations, many regenerative farms operate without a traditional tractor or other expensive equipment. However, a few tools are vital for regenerative farmers. Smart irrigation, a manure spreader, no-till drill, post-hole digger, and bioreactor are just a few pieces of equipment necessary for regenerative agriculture.

Conclusion

Regenerative agriculture farming comprises varieties of techniques that helps in rebuilding of soil and, in the process, sequester carbon also. Typically, it uses cover crops and perennials so that bare soil is never exposed, and grazes animals in ways that mimic animals in nature. It also offers ecological benefits far beyond carbon storage: it stops soil erosion, remineralises soil, protects the purity of groundwater and reduces damaging pesticide and fertilizer runoff. However, all these methods are slow and may be expensive and we not sure whether we will be able to feed the population at the rate it is growing. This requires re-examination and revalidation and if necessary further research plans need to be formulated to develop cost effective regenerative agricultural tools. While comprehensive statistics are hard to come by, there are several scientific studies, where it was reported that the yields from regenerative agriculture tools often exceed conventional yields. Likewise, since these tools build soil, crowd out weeds and retain moisture, fertilizer and herbicide inputs can be reduced or eliminated entirely, resulting in higher profits to the farmers.

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