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Regenerative Agriculture: A Primer

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ABSTRACT

Regenerative agriculture (RA) is a conservation and rehabilitation approach to food and farming systems, which is focused on topsoil regeneration, increasing biodiversity, improving water cycle, enhancing ecosystem services, supporting biosequestration, increasing resilience to climate change, and strengthening the health and vitality of farm soil. It is not a specific farm practice but combines a variety of sustainable agriculture techniques. It also involves maximal recycling of farm waste and adding composted material from non-farm sources. Regenerative agriculture on small farms and gardens is based on permaculture, agroecology, agroforestry, restoration agriculture, keyline design, and holistic management. This is also being adopted by large farms, using "no-till" and/or "reduced till" practices.

This paper attempts to look at the benefits, challenges and future uses of regenerative agriculture in boosting food production to meet up with the global demand of food as well as reducing the harmful effects of climate change.

KEYWORDS: *Regenerative agriculture, conservation, rehabilitation, biodiversity, ecosystem, biosequestration, climate change, sustainable agriculture, permaculture, agroecology, agroforestry, keyline design, holistic management, no-till, reduced till, pathogens, crypto-regenerative agriculture, circular economy*

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INTRODUCTION

Regenerative agriculture (RA) helps to improve soil health, may decrease input requirements, and causing the increase in crop yields as soils are more resilient to extreme weather and harbor fewer pests and pathogens [1]. Regenerative agriculture mitigates climate change through carbon dioxide removal from the atmosphere and sequestration – with carbon sequestration to fight climate change [2].

Regenerative agriculture is a conservation and rehabilitation approach to food and farming systems, as shown in Figure 1. This practice focuses on topsoil regeneration, and increasing biodiversity, improving the water cycle, enhancing ecosystem services, supporting biosequestration [3], increasing resilience to climate change, and as well as strengthening the health and vitality of farm soil [4]. This practice combines a variety of sustainable agriculture techniques [5].

HISTORY/METHODS OF REGENERATIVE AGRICULTURE

Regenerative agriculture is based on various agricultural and ecological practices, with particular emphasis on minimal soil disturbance and the practice of composting [4].

The term "regenerative agriculture" was coined by Robert Rodale – the son of J. I. Rodale, one of the pioneers of organic farming in the Unites States in the 1930s, who also established the Rodale Institute, dedicated to researching and promoting regenerative agriculture. Permaculture which is an approach to agriculture mimics the patterns found in nature and used by indigenous peoples around the world, is another movement that is sometimes considered as a form of regenerative agriculture. Sustainable agriculture intersects with many of the principles and methods of regenerative agriculture, though regenerative farming practices aim not to just maintain current levels of land and soil health, as

sustainable agriculture does, but to actively better them [6]. Each approach to regenerative agriculture has slightly different tenets, depending on where in the world it is being employed. The common principles include [6]:

- Minimal tilling of the soil
- Using cover crops
- Planting polycultural crops
- Using organic fertilizers and organic methods of pest control

"No-till farming" is the elimination of the use of machinery and plowing to reduce erosion and help the soil retain moisture, as shown in Figure 2. Carbon which is stored deep in the soil can be released during intensive tilling and become the greenhouse gas carbon dioxide, no-till methods are also an important tool in the fight against anthropogenic global warming. Although labor-intensive, no-till agriculture saves farmers the expense of costly machines and their maintenance.

The planting of nitrogen-fixing cover crops and green manures, like vetch or alfalfa, between cash-crop growing seasons or between the rows of some crops helps to keep the nutrients in the soil as well as avoid erosion.

The planting of more than one crop in the same place known as polyculture, helps to diversify crops and fosters food security, and is more labor-intensive than monoculture as fields are more difficult to sow and harvest mechanically. Polyculture can be fairly self-sustaining, and the diversity of the crops can reduce the vulnerability of farms and ultimately the global food supply to pests and diseases, as shown in Figures 3 and 4. About 75 percent of the world's food comes from only 12 plants and five animals. The overreliance of modern industrial agriculture on so few plants and animals carries a risk that climate change, diseases, or other natural disasters could lead to supply chain interruptions or famines [6].

As with organic farming, regenerative agriculture does not rely on chemical pesticides or synthetic fertilizers. Instead, pests and weeds are managed by using crop rotation to disrupt pest cycle, biological control to combat insect pests, and rotational animal grazing to control weeds. Livestock can eat cover crops and produce natural nutrient-rich fertilizer, and while crop residues can be composted and returned to the soil. Livestock such as cows, goats, sheep, chickens, and pigs, are known as walking bioreactors, transforming plant material into rich organic matter through manure production – with the range of benefits, this can be integrated into crop production. Soil health is improved when crops are kept in the ground year-round. Regenerative agriculture farmers plant a different crop immediately after harvest, that is, often by alternating cash crops and cover crops. The green cover shades the soil and the roots dig into it, increasing moisture [7].

Optimizing the application of biological and chemical inputs can be achieved through precision agriculture (PA), which is the science of improving crop yields and assisting management decisions using high technology sensor and analysis tools [8]. Data-driven precision farming is an important part of regenerative agriculture. In this case, farmers make use of digital tools such as soil-scanning sensors, to create detailed field maps and tailored applications of crop protection products and fertilizers. This leads to using only the optimal amount and the right type of product needed for a productive crop.

GOALS OF REGENERATIVE AGRICULTURE

The goals of regenerative agriculture are to [7]:

- Produce enough nutritious food for the world population
- Mitigate climate change by sequestering carbon in soil and reducing greenhouse gas emissions
- Restore threatened biodiversity and enhance natural habitats
- Prevent further deforestation and grassland conversion by increasing productivity on existing farmland
- Enhance farmer livelihoods

THE REVERSAL OF CLIMATE CHANGE BY REGENERATIVE AGRICULTURE: IS IT POSSIBLE?

According to the Intergovernmental Panel on Climate Change (IPCC), it is believed that about 22% of anthropogenic greenhouse gases come from agriculture, forestry, and other land uses [7]. Another model also has estimated that agricultural land use has contributed significantly to the loss of carbon from the soil over 12,000 years – 133 Pg C from the top 2 meters of soil, or 8% of total global carbon soil stocks [7]. Soils act as one of the Earth's most important carbon sinks, that holds more carbon than all of the world's vegetation plus our atmosphere combined. Soils can sequester significant amounts of carbon each year, by the use of practices that maximize carbon inputs to soils like the planting of cover crops, coupled with minimal carbon losses such as no-till. With this, RA has the potential to transform agriculture from a source of greenhouse gases towards net carbon drawdown [7]. Therefore, the changes in farm practices could sequester nearly a billion tons of carbon dioxide around the world every year [7].

CAN REGENERATIVE AGRICULTURE FEED THE WORLD?

Currently, 7.9 billion of the world population is being fed by the modern form of agriculture. However, the global population is projected to reach 9.7 billion in 2050, with agriculture facing increasing challenges from degraded land, unprecedented weather extremes, new pests and blights migrating from other parts of the world, and the diminishing water resources. The keyline design can be used as a landscaping technique of maximizing the beneficial use of water resources of a tract of land [8].

- According to research, the building of soil organic matter through RA practices can help improve yields. The organic matter will retain more water and nutrients, such that during long periods of drought, crops can survive for longer periods in the soil that retains moisture.
- Studies of high-tech row crop farming in the US which applied RA practices maintained similar yields versus conventional practices. A study in Kenya also found that the use of regenerative practices in maize, sorghum, and beans increased yields significantly (up to 200%). While another study in the US also found out that as soil organic matter concentrations increase, so do yields.
- Yields will not always increase the moment regenerative practices are introduced. As with any monumental shift, farmers may need a transition period.
- Crops grown in biologically active, healthy soil are richer in nutrients. This has huge implications for growing global population.

RA can as well restore lost biodiversity which are below and above the ground. When all the principles and practices of regenerative agriculture are put in place, these will help to nourish our biodiversity, via repopulating the surrounding ecosystem with beneficial fungi, insects, mammals, and birds [7].

EFFECT OF REGENERATIVE AGRICULTURE

The interest in regenerative agriculture is now growing across the entire food value chain. This is in response to growing food insecurity cum increasing threats from climate change, and while seeing agriculture is an integral part of the solution. Food – and other products – that are more friendly to the environment are also a big trend among consumers in the US and other countries, especially among Millennials.

Large food value chain companies are committing to source ingredients produced through regenerative practices such as Nestle, and PepsiCo – committed to sourcing their key ingredients through RA methods by 2030, and with others like Cargill, General Mills, McCain and Walmart; and with many partnerships being formed to help farmers adopt regenerative agriculture [7]. The benefits of RA would be for farmers, the environment, and consumers alike.

URGENT TRANSITION TO REGENERATIVE AGRICULTURE

In order to quickly transit to RA, there is the need to accelerate the widespread adoption of regenerative agricultural practices, greater investment, with the working together of the farmers, policymakers and agricultural companies. Farmers carry a heavy burden of costs – seeds, equipment, overheads, for example – and take much of the risk of growing food crops despite the uncertainty about weather, water and market prices. Changing farm practices brings greater costs at the start. The transition must not be left to the farmers alone, therefore, the governments need to support them by rethinking existing farming policies to make RA economically attractive. Subsidies can be restructured to incentivize farmers to phase out soil-degrading practices in favor of approaches that build healthy, and fertile soil while sequestering carbon. The private sector as well has a great role to play in this regard through partnerships and collaborations [7, 10].

It is noteworthy, that Asia (consisting of 48 countries), which is the largest continent in the world by both land and population, with the majority of human population of about 4.7 billion people, constituting roughly 60% of the world's population is currently adopting regenerative agriculture, as shown in Figure 5. Both Singapore and the United Arab Emirates are in Asia; but we can see that in Singapore for instance, Nestle is advancing regenerative farming practices with the aims to conserve and restore farmland and its ecosystems. This further aims to maintain, sustain, improve and restore what has been degraded over the past so as to ensure sustainable food production. This will involve Nestle working with their food system partners, which will include networking with more than 500,000 farmers and 150,000 suppliers in order to advance regenerative farming practices [11, 12].

FOOD WASTE

Food waste has serious economic, social and environmental consequences. In terms of economics, it represents a loss of investment and resources for producers, retailers, and consumers. Socially, it exacerbates food insecurity and hunger, particularly in regions with limited access to food. Environmentally, decomposing food generates

methane, a potent global greenhouse gas emission (GHG) [13].

Smallholder farmers often lack market intelligence, such as real-time information on demand, pricing, and consumer preferences – leading to oversupply as farmers struggle to align their production with market needs [14]. Consequently, a significant portion of the food produced by smallholders goes to waste, reducing environmental sustainability. This therefore calls for dynamic and responsive systems to address waste-reduction challenges and increase efficiency in agri-food supply chains [15].

The intersection of cryptocurrency and agriculture as of recent years has given rise to a revolutionary concept known as Crypto-Regenerative Agriculture, as shown in Figures 6 and 7. It is worth to note that each bitcoin transaction generates carbon emissions roughly equivalent to driving a gasoline-powered car between 1,600 and 2600 kilometres [16]. Gaining popularity now is the concept of circular economy as this can help to minimize carbon emissions, by tackling global changes such as climate change, biodiversity loss, waste, and pollution by the use of the three principles for the transformation to a circular economy which are: designing out waste and pollution, keeping products and materials in use, and regenerating natural systems, as shown in Figures 8 and 9. Crypto-regenerative agriculture is the financing of sustainable farming practices through the use of cryptocurrencies, presenting a transformative model for the agricultural sector, and providing a decentralized and transparent financial framework. My NEO Group is said to be a pioneer in crafting state-of-the-art FinTech and crypto solutions. With over 200 specialists from 12 diverse nations, the group offers expertise in various financial domains, including trading, blockchain, and comprehensive fund management [17].

CONCLUSION

The widespread adoption of regenerative agriculture will definitely be important to effectively and systematically address some of today's most pressing challenges such as climate change, food security and nutrition, water and soil quality, biodiversity and sustainable livelihoods. This will as well assist in achieving some of the 2030 Agenda for Sustainable Development goals adopted by all United Nations Member States in 2015 (i. e the 17 SDGs), most especially in the areas of zero hunger, good health and well-being, clean water and sanitation, among several others.

More information about sustainable agriculture can be found in the book [18] and the following related journals:

- The Journal in Sustainability Begins with Education
- Journal of Agriculture Environment & Food Security

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Figure 1. Regenerative agriculture

Source:https://www.google.com/search?sca_esv=332c1457e26e21ac&sxsrf=ADLYWIJinIo6HtZ11PY-ZYv_MDEDtIxHGw:1732260628415&q=images+on+regenerative+agriculture+by+wikipedia&udm=2&fbs=AEQNm0Aa4sjWe7Rqy32pFwRj0UkWd8nbOJfsBGGB5IQQO6L3JyJJclJuzBPl12qJyPx7ESJehObpS5jg6J88CCM-RK72qUv4GOvBp3LxAsC-35pUAVd1mVJIz_kJEl7OpW0Y42rOM96fEVibRmxJCzmEqh53sBnJMLdHFyYMnh1J8SLKdTBIS0c&sa=X&ved=2ahUKEwjK4ajbteJAxVgUkEAHfoFQQQtKgLegQIExAB&biw=1034&bih=539&dpr=1#vhid=Xv-x2Fj9u_oNIM&vssid=mosaic

Figure 2. No-till farming

Source:https://www.google.com/search?sca_esv=332c1457e26e21ac&sxsrf=ADLYWIJinIo6HtZ11PY-ZYv_MDEDtIxHGw:1732260628415&q=images+on+regenerative+agriculture+by+wikipedia&udm=2&fbs=AEQNm0Aa4sjWe7Rqy32pFwRj0UkWd8nbOJfsBGGB5IQQO6L3JyJJclJuzBPl12qJyPx7ESJehObpS5jg6J88CCM-RK72qUv4GOvBp3LxAsC-35pUAVd1mVJIz_kJEl7OpW0Y42rOM96fEVibRmxJCzmEqh53sBnJMLdHFyYMnh1J8SLKdTBIS0c&sa=X&ved=2ahUKEwjK4ajbteJAxVgUkEAHfoFQQQtKgLegQIExAB&biw=1034&bih=539&dpr=1#vhid=2mHqtVF68-WTSM&vssid=mosaic

Figure 3. Sustainable agriculture

Source:https://www.google.com/search?sca_esv=332c1457e26e21ac&sxsrf=ADLYWIJinIo6HtZ11PY-ZYv_MDEDtIxHGw:1732260628415&q=images+on+regenerative+agriculture+by+wikipedia&udm=2&fbs=AEQNm0Aa4sjWe7Rqy32pFwRj0UkWd8nbOJfsBGGB5IQQO6L3JyJJclJuzBPl12qJyPx7ESJehObpS5jg6J88CCM-RK72qUv4GOvBp3LxAsC-35pUAVd1mVJIz_kJEl7OpW0Y42rOM96fEVibRmxJCzmEqh53sBnJMLdHFyYMnh1J8SLKdTBIS0c&sa=X&ved=2ahUKEwjK4ajbteJAxVgUkEAHfoFQQQtKgLegQIExAB&biw=1034&bih=539&dpr=1#vhid=ZfQrmWedNP8cDM&vssid=mosaic

Figure 4. Agroforestry

Source:https://www.google.com/search?sca_esv=332c1457e26e21ac&sxsrf=ADLYWIJinIo6HtZ11PY-ZYv_MDEDtIxHGw:1732260628415&q=images+on+regenerative+agriculture+by+wikipedia&udm=2&fbs=AEQNm0Aa4sjWe7Rqy32pFwRj0UkWd8nbOJfsBGGB5IQQO6L3JyJJclJuzBPl12qJyPx7ESJehObpS5jg6J88CCM-RK72qUv4GOvBp3LxAsC-35pUAVd1mVJIz_kJEl7OpW0Y42rOM96fEVibRmxJCzmEqh53sBnJMLdHFyYMnh1J8SLKdTBIS0c&sa=X&ved=2ahUKEwjK4ajbteJAxVgUkEAHfoFQQQtKgLegQIExAB&biw=1034&bih=539&dpr=1#vhid=fIUVvGEKvHi1SM&vssid=mosaic

Figure 5. Asia

Source:https://www.google.com/search?q=image+of+map+of+48+asian+countries+by+wikipedia&sca_esv=48b03a8d7cbf7ae6&udm=2&biw=1036&bih=539&sxsrf=ADLYWIJSbZnFGFN3AU2_EFMvYWVgAfqVKQ%3A1733701689280&ei=OTBWZ83jEPGThbIPnd6IyQI&ved=0ahUKEwiN5NeKrpmKAxXxSUEAHR0vIikQ4dUDCBA&oq=image+of+map+of+48+asian+countries+by+wikipedia&gs_lp=EgNpbWciL2ltYWdlIG9mIG1hcCBvZiA0OCBhc2lhbiBjb3VudHJpZXMgYnkgd2lraXBlZGlhSPOEAVCjD1jKPXABeACQAQCYAdABoAHbBKoBBTAuMS4yuAEMyAEAAEBmAIBoALgAcICBBAjGCeYAwCIBgGSBwMyLTGgB4ID&sclient=img#vhid=z1Kymw88Y-IQFM&vssid=mosaic

Figure 6. Environmental impact of bitcoin

Source:https://www.google.com/search?sca_esv=93cc6a6cdbe51fb9&sxsrf=ADLYWILNWA2BS9m4vfsNO5LbM8qypp9e1A:1733576969892&q=images+on+cryptoregenerative+agriculture+by+wikipedia&udm=2&fbs=AEQNm0Aa4sjWe7Rqy32pFwRj0UkWd8nbOJfsBGGB5IQQO6L3JzWreY9LW7LdGrLDAFqYDH32tgteNhtZOxnGezgnEGc8k4dQgIn4td5_IKOvJAVYNMpBG_vzv09_z3ozdsV1574v_l4gmjMdaDFLpg9ELpUCM3lLnYw1mpVTSmqh03mtH24pA&sa=X&ved=2ahUKEwiWsy73ZWKAxVtKvsDHZ2UDhwQtKgLegQIGBAB&biw=1036&bih=539&dpr=1#vhid=kXm_VYtRhRkhZM&vssid=mosaic

Figure 7. Tap tin: Cryptocurrency Mining Farm.jpg

Source:https://www.google.com/search?sca_esv=93cc6a6cdbe51fb9&sxsrf=ADLYWIJ5B3jn0WrV-sR2_FEowQGSDecJjg:1733577419581&q=images+on+cryptoregenerative+agriculture+by+wikipedia&udm=2&fbs=AEQNm0Aa4sjWe7Rqy32pFwRj0UkWd8nbOJfsBGGB5IQQO6L3JzWreY9LW7LdGrLDAFqYDH32tgteNhtZOxnGezgnEGc8k4dQgIn4td5_IKOvJAVYNMpBG_vzv09_z3ozdsV1574v_l4gmjMdaDFLpg9ELpUCM3lLnYw1mpVTSmqh03mtH24pA&sa=X&ved=2ahUKEwislaOS35WKAxUAaEEAHYCMAUIQtKgLegQIGBAB&biw=1036&bih=539&dpr=1#vhid=VX3WOw4EejH2cM&vssid=mosaic

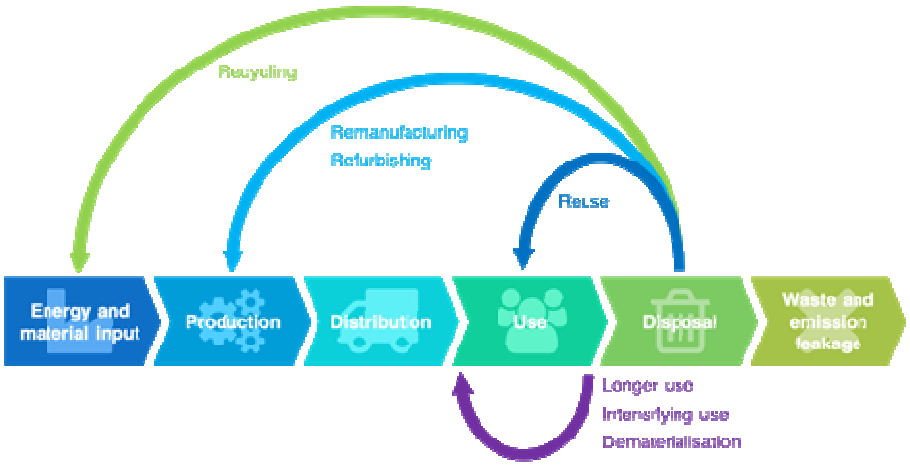

Figure 8. Circular economy

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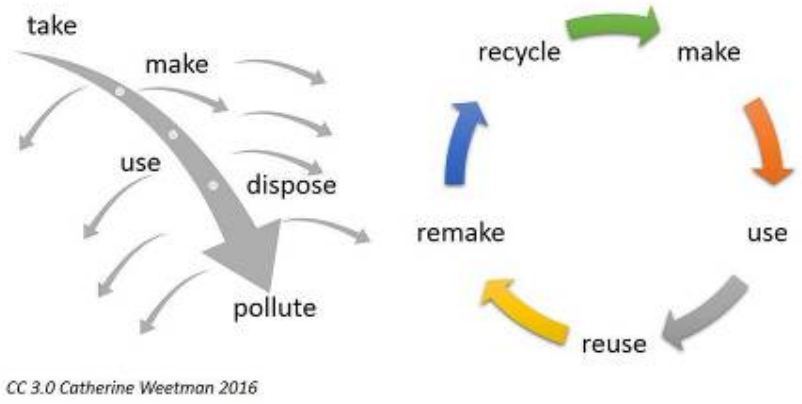

Figure 9. Linear vs Circular economy

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