

Natural Forest Regeneration and Tree Planting Complexity: An Enigma of Climate Mitigation in the World of Technology

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Abstract

Given the severity and implication of prolonged palpability epitomized by Climate change, discussion and negotiation between parties and policy applications for mitigations employed is not 100% solution. The mitigation of carbon emission through tree planting alone is inadequate. There's need for knowledge on the type of trees, where to plant them, and their impact on the biosphere. Previous study shows that uncensored tree planting programs causes riparian land to dry up. This study lingers on achieving climate change mitigation through afforestation, algae, and technology. It adopts three hypotheses; the first, there's nothing like global warming or climate change occurring, Secondly, global warming and climate change occurs as natural and cyclic events not related to human activity, Thirdly, global warming and climate change are outcome of mans' activities. This is a desk top study, the findings indicate that trees are important factors in conserving atmosphere with a balanced biosphere, but not solutions to climate crisis. Thus, certain types of trees cause problems for other plants and animals in their symbiotic nature. Scientists shows that Algae consumes 400x more CO2 hence, investing in them is efficient. Additionally, investing in technology like carbon engineering, direct air capture, and geological sequestration are effective in reducing greenhouse gas emissions from the atmosphere and revolutionize the energy sector. In conclusion, embracing technology and change of human consumer behavior should be the way to go in the contemporary world to mitigate climate issues.

Keywords: Natural Forest Regeneration, Tree Planting Complexity, Climate Mitigation, Greenhouse Gas, Carbon Capture, Fossil Fuels, Carbon Storage and Sequestration

Introduction

Globally, governments are investing billions of dollars and putting more emphasis in tree planting yearly yet, without increasing forest cover. Different organizations, governments, and even individuals invest so much in planting trees but are not sure what happens after that¹. This is a fundamental fact of shifting the discussion from tree planting to tree growing in restoring this project. There's a need to consider the right time for planting which type of trees, where to plant them, who will take care of the growing seedlings into mature trees, the monitoring of this growth, and a balanced environmental and economic needs of the surrounding people where trees are planted². Engaging local community in this process is indispensable to its success, meeting these targets can almost be impossible if small farmers and communities are not factored in the whole process (Balongo and James, 2022).

According to IPCC, (2018) it estimated that close to 1.0°C. of global warming above pre-industrial levels have been caused by activities of man. As we approach 2030 and 2052, the estimate on global warming is approximated to be 1.5°C. if the activities continue to increase at the current rate³. Trees are important in nature conservancy as they have a lot of benefits such as providing clean air, storing carbon, preventing soil erosion, providing shelter and homes, shades and reducing energy costs plus providing a sense of well-being for man. In their effort to combat climate change, conservationists are working extremely, for instance, in the year 2020 the World Economic Forum (WEF) launched a movement of growing 1 trillion trees globally, an initiative towards restoration, growing, and conserving trees around the world by the year 2030⁴.

There's no doubt that planting trees is not only good for our environment but also quite important for our physical and mental health. Yet, planting of these trees is more complex than it may appear. Tree planting program to mitigate climate change initiative as a low-cost strategy with mutual benefits is a concept of United Nations Sustainable Development Goals (UN-SDG).

For many years, the United Nations Convention to Combat Desertification (UNCCD) through its many programs on reforestation and afforestation schemes in effort to climate change mitigation, laid down numerous initiatives both regional and national. Such schemes include China's forest rehabilitation program and African Great wall initiative which were aimed at combating poverty, desertification through creation of over 780 million hectares of land across the Sahel region through the Horn of Africa and the Southern part of Africa⁵. These was aimed at halting land degradation, restoring over 10 million hectares of land by 2030, in 2019 for instance, FAO initiated a plan to restore cities through (Great Green Wall-GGW) a reversal of environmental pressure that could be caused by expansion of urban or are city-based. where

¹<https://www.sciencenews.org/article/planting-trees-climate-change-carbon-capture-deforestation>

² <https://www.worldagroforestry.org/publication/tree-planting-tree-growing-rethinking-ecosystem-restoration-through-trees>

³https://unfoundation.org/blog/post/intergovernmental-panel-climate-change-30-years-informing-global-climate-action/?gclid=Cj0KQCQiAi8KfBhCuARIsADp-A5718HkERGxJiwnUWRVEctSRXJ6VzjB9ibOi9fOYs0fGrXsUaJRihuwaAg_8EALw_wcB

⁴<https://www.weforum.org/agenda/2020/01/one-trillion-trees-world-economic-forum-launches-plan-to-help-nature-and-the-climate/>

⁵<https://rapidtransition.org/stories/solving-the-tree-planting-puzzle-natural-forest-regeneration-for-rapid-transition-and-community-empowerment/>

over 500,000 hectares of land forests were to be planted or protected both across Sahel and Central Asia. The aim of this project was to help reduce CO₂ from the atmosphere⁶ every year by between 0.5 Gigatons.

Despite all these preparations for planting trees, scientists are urging caution of the kind of massive tree projects which must address such issues like political, social, economic and scientific concerns because poorly designed projects may have more harm than good. Such activities may result in wasting huge amount of money plus the socio-political and public goodwill (Fleischman, *et al*, 2021). Much focus is placed on the number of seedlings planted yet, in the long run, very little time is spent on keeping the seedlings alive or even initiating a working program with local communities.

Still, not much is placed on the type of tree forest sequester, there's too much talk on tree planting yet no other forms of carbon-storing ecosystem⁷. Tree planting not only increases carbon storage, but some types of trees also accelerate biodiversity loss. Greenhouse gases are gases that trap or have capacity to trap heat in the earth's atmosphere in regulating temperature. The gases are methane, carbon dioxide, chlorofluorocarbons, nitrous oxide and water vapor. The heat trapped by these gases contributes towards changing of climate. the changes in climate result into the polar glacier and ice sheets in the region to melt, and the unending raising of the sea levels affecting the currents in the oceanic region.

The mitigation for these is to prevent the additional combustion and emission of fossil fuel into the atmosphere as a greenhouse gas⁸. The reduction could involve the use of sustainable sources of energy that are non-fossil products. It also requires the capture technology in reducing carbon from the atmosphere and stored into the tissues of plants, kept underground with technology known as geological repositories and solid concrete or carbon to keep it from mixing with the atmosphere (Soeder, 2021).

Research Problem

Since time immemorial, trees have helped man achieve immeasurable lifesaving activities. Trees can be said to be unsung heroes when it comes to fighting climate change by pulling carbon from the atmosphere and helping human beings and ecosystem to adapt the unpredictable weather conditions. Trees have uncountable benefits to man and other animals as they provide food, help in reducing temperature, and slowing down flood waters during rainy season. The only challenge is planting the right tree species in a particular biome as some tree species can't grow in one unit with others. Therefore, priority areas for planting trees like dryland, tropical forests, mangroves, and other biomes has to be degraded as deforested ecosystems with particular species of trees that can grow together. Alien invasive trees tend to undermine the resilience of natural habitats making them exposed to climate change vulnerability. Hence, since the alien tree species tend to outgrow other species, it becomes challenging for them to grow in the same ecosystem.

Consequently, it's necessary that the expert (arboriculturist) in their work of carrying out research for proper biomes of the right tree species to advise where and when those trees should be planted. This is because

⁶ <https://www.fao.org/news/story/en/item/452701/icode/>

⁷ <https://www.sciencenews.org/article/planting-trees-climate-change-carbon-capture-deforestation>.

⁸ https://www.sciopen.com/article/10.46690/ager.2021.03.04?issn=2207-9963&utm_source=TrendMD&utm_medium=cpc&utm_campaign=Advances_in_Geo-Energy_Research_TrendMD_1

trees just like any living organism, loses water in extreme heat at the same time depleting its supply thus, exhausting them and making photosynthesis impossible. A study by Gregory in Chapman university indicates that photosynthesis begins to fail in tropical trees especial at 116 degrees Fahrenheit 46.7⁰C⁹. tree's nutrients should sustain itself in case of interruption in photosynthesis, the plant will starve to death. This could increase the amount of CO₂, a greenhouse gas in the atmosphere.

Objective

Analyzing the role of tree planting complexity as an enigma of climate change mitigation in the world of technology

Hypothesis On the Causes of Global Warming

In fighting climate change, trees are necessary if planted in the right places as they make ecosystems more resilient to climate change. Society is putting pressure on trees so that it can get the world out of the climate change emergency that has bedeviled human life. In bettering ecosystem, trees do so in several ways hence, in respects to these, there are right and wrong ways to planting, growing, and protecting the forests.

This study adopted three hypotheses contracting on the real cause of global warming; the first one claim that global warming is neither occurring nor climate change, the second one assumes that global warming and climate change occurs due to natural cyclic events not related to the activities of human being, the third assumption suggest that global warming and climate change occurs primarily as a result of the activities of human being. However, it defeats logic to defend the fact that nothing is happening in the visual faces and land-based mass or even data from satellite which keeps showing the average sea levels rising, increased temperatures on land, and masses of ice shrinking¹⁰.

Scientists observe that for over 200 years, climate change pace of acceleration is headed towards the realm of emergencies caused by greenhouse gas emission. This according to scientific discovery continues to raise the planet's temperatures by 1⁰C. This impact of heating is causing the Earth's poles to shed the ice, thus, raising the sea levels and heating up of oceans. The outcome is that the aquatic lives are under threats due to acidity of water and food security¹¹.

Climate skeptics on the other hand insist that global warming has been there as a natural occurrence hence cannot be attributed to human carbon emission activities. Their focus has been on the data indicating that in the past, global temperatures and CO₂ atmospheric levels have been higher. This according to their understanding is that the amount of radiation in the recent past can be attributed to the fact that the solar has been active and that its energy out varies between 0.1% and above for cycle which are short of between 11-50 years that are not entirely related to global warming. This indicates that solar activities globally affect climate through different forms although it could not be a factor of systemic change called global warming as to the skeptics (Shafer, 2023).

⁹<https://africa.businessinsider.com/science/extreme-heat-could-make-photosynthesis-impossible-for-tropical-trees-and-plants-that/t875d18>

¹⁰https://warmheartworldwide.org/what-causes-global-warming/?gclid=Cj0KCQjw2v-gBhC1ARIsAQOqKY0iYXfNuqy5GDg7kGQWthl6Fu28dqGkFdCjpdJZ9ZF_Mhh-KO2tWjlaAqqXEALw_wcB

¹¹ <https://latin.or.id/blog/>

The continued warming of the global and changes in climate resulting from man's activities (anthropogenic), currently attributed to the atmospheric warming by scientists, indicates there is increased levels of CO₂ in upper atmosphere with some tiny particles (black carbon-soot/smoke) in the lower atmosphere¹². The gases are released from fossil fuels burning and the incomplete burning of tiny trap of solar energy in atmosphere. This absorbs heat like a black blanket, which makes them attributed to greenhouse gases (GHG) according to the scientists. Their action is kind of reflective of a glass in the wrong way in the global greenhouse. The global warming trends of the current situation can be traced from the end of 18th C. and the beginning of 19th C. at time coal was first used. The increased usage of fossil fuel such as kerosene, diesel, gasoline, natural gases and petrochemicals like pharmaceuticals and fertilizers¹³ are just but accelerating the trend.

Although, recent studies done by University of California Riverside, titled "*Impact of potent greenhouse gas: a bit lower than previously thought*"¹⁴ study indicate that methane gas has some character of trapping heat in the atmosphere with some features of cooling clouds that offset 30 percent of heat. According to the study, methane gas creates an atmospheric blanket which traps energy and heat from the surface of earth in a process known as 'longwave energy'. This process prevents its radiation out in space, making a hotter planet.

It is important to note that unless electrified, this blanket does not create heat, at the same time, this gas absorbs the incoming energy from the sun in a process called '*short wave*' energy. Hence, the two forms of energies, long wave and short wave happen to escape more than they are absorbed in the atmosphere. The escaped energy from the atmosphere has to be compensated as it is useful heat created as water vapor which condenses into rain, hail, and snow or sheet. Here, precipitation process acts as a source of heat that balances the atmospheric energy (Kramer and Allen, 2023).

Methodology

This is a desktop or secondary study where information gathering, and insight analysis and synthesis is based on existing sources. Thus, the study relied heavily on published reports, books, articles and other available materials and studies carried out that make informed decisions.

Role of Trees in Climate Mitigation

While fighting against global warming, trees become powerful tools as they help trap carbon dioxide and lock it away. Yet, just planting of trees in billions may not be the whole solution in saving environment and ecosystem in general¹⁵. As impressive as they could be, trees provide oxygen to breathe, habitats for wildlife, and majorly absorbing CO₂ the heating trapping gas emanating from the burning fossil fuel. This out of scientific research has been regarded as the solution to the climate change. Globally, forests are approximated to be storing over 16 billion metric tons of CO₂ annually, with European countries

¹² https://scholar.google.com/scholar?q=anthropogenic+climate+change&hl=en&as_sdt=0&as_vis=1&oi=scholar
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<https://www.google.com/search?q=anthropogenic+climate+change&oq=anthropogenic&aqs=chrome.2.69i57j0i512l9.5540j1j7&sourceid=chrome&ie=UTF-8>

¹⁴ <https://scitechdaily.com/climate-science-shock-methanes-unexpected-cooling-impact-unveiled/>

¹⁵ <https://www.dw.com/en/is-reforestation-the-answer-to-storing-carbon-dioxide/a-62466216>.

contributing three times more yet, the forests continue to shrink at alarming rate (Muller & King 2022). Agricultural activities and its expansion are the leading factors when it comes to shrinking of forests increasing the CO₂ in the atmosphere¹⁶.

These has aggravated the situation forcing governments as well as companies around the world to invest in planting trees to boost forest cover. The elected government of Kenya 2022, through its leadership has pledged to plant over 15 billion trees by 2030, citizens of good will all over the world have captured this public imagination as a good idea and made them think over and over about it. Yet, according to Hardwick, a conservationist scientist from Royal Botanical Gardens (UK) reforestation can't be denied as part of the necessary solution to the problem. However, it should not be that all the focus be placed on trees alone¹⁷.

Carbon dioxide is absorbed for photosynthesis and locked up in the tree trunks, branches, leaves, roots and in the soil. The burning of fossil fuel and land use contributes to an average of 40 billion metric tons of CO₂ every year. Studies indicate that afforestation restoration of new forests ones could contribute towards absorption of between 40 to 100 billion tons of carbon dioxide if only the trees reach the maturity stage. This off course could take decades to be achieved, still UK's Royal Society estimates that reforestation could only contribute to the removal of about 3-18 billion tons of carbon dioxide from the atmosphere yearly. The improved levels of forest management on the other hand could help save 1-2 billion tons¹⁸. Different studies indicate that restoration and protection of tropical forests could be more crucial as their level sequestration for carbon is more compared to their counterparts that are temperate (Tyson and Kennedy, 2020). Susan Cook a US based scientist alludes that it's hard to get a concrete figure due to the potential of carbon capture variation based on geographical location in the planted trees and if they can be monitored to maturity¹⁹.

Hardwick suggests that not all the focus should be placed on tree planting, but rather restoration of the habitats such as grassland and peatlands which have potentials of storing some significant amount of carbon without trees. The progress of the projects is dependent entirely on planting the right tree in the right place to avoid damage and at the same time supporting the ecosystem. Planting trees on carbon rich soils such as peat leads to emission of more carbon from the very soil than gaining from the growing of the same trees. This enhances high carbon contribution in the atmosphere. According to Laura Duncanson, many reforestation projects put their focus on the number of trees planted thus paying less attention to how well they survive, how diverse the resulting forests are going to be, and how much carbon they can store. Little is known about what is working well²⁰.

Therefore, tree planting alone is not the sole solution, there is a need to revolutionize the energy sector, reduce green gas emission. Even though there's a need of keeping forest as forest, there have to be improvement in management and pursuing the promising options either within agricultural sector, the

¹⁶<https://www.dw.com/en/brazil-amazon-deforestation-hits-new-high/a-61717387>.

¹⁷<https://conbio.onlinelibrary.wiley.com/doi/10.1111/j.1523-1739.2010.01632.x>

¹⁸<https://royalsociety.org/topics-policy/projects/biodiversity/deforestation-and-biodiversity/>

¹⁹ <https://www.nature.org/en-us/what-we-do/our-priorities/tackle-climate-change/climate-change-stories/reforesting-united-states-susan-cook-patton/>

²⁰ <https://www.researchgate.net/scientific-contributions/Laura-Duncanson-2192533766>

Greenland and wetland with new trees, their air, water and shade serve as part of solutions to the emerging issues of climate change.

Planting of trees such as alien acacia, pine, eucalyptus must be regulated. According to National Environment Management Authority Kenya (NEMA) an established body 2002 to supervise and coordinate environmental activities. NEMA's amendment Act 2015, restoration and subsequent regulation, the body banned the planting of the eucalyptus trees along the riparian areas or shorelines to a distance of at least thirty meters from the riverbanks to preserve water sources, six meters away from the road reserves and common boundaries, and also six meters away from buildings due its spreading roots and breaking branches. This type of trees in native shrub land displaces local flora leading to shortage of water²¹.

Although some conservationists recommend planting variety of native species rather than just one as they tend to reduce vulnerability to fire, drought insect's attacks, pests and diseases and storm damage due to monocultures. Mix species according to them could be more stable and resilient. However, as suggested earlier, some species could affect the growth and development of other trees including animals in the ecosystem. At the same time, involving local communities through allowing their deriving some economic benefits. As they keep the forest intact through such activities as eco-tourism can help increase their sustenance (Stanturf and Mansourian, 2020). In her quest to recover flora and fauna in different areas of Quito, Ecuadorian Lilian 29 years' student of environmental studies in Melbourne focuses on native plants which also guarantees the acceptance of citizens, authorities and industries in general.

In her project 'friendly roofs' the native plants reduce air pollution and promote urban ecology that develops towards green infrastructure and restoration of ecology. Her research focuses on identifying and cataloguing the very native tree plant species that could better adapt the urban environment and be resilient to climate change²². Native plants have a great potential to be used in green roofs as they are adapted to the local conditions of the cities²³.

²¹https://www.google.com/search?sxsrf=AJOqlzUWflo0bCXuMwKZycZkK50n25bepA:1678529282134&q=environmental+management+and+co-ordination+act,+2015+pdf&sa=X&ved=2ahUKEwiJ_ezsONP9AhUiuaQKHRFbB6YQ1QJ6BAG3EAE&biw=1366&bih=657&dpr=1

²² <https://sagateve.com/en/liliana-jaramillo-young-champion-of-the-earth/>

²³ <https://youtu.be/vQl6UA2izEk>

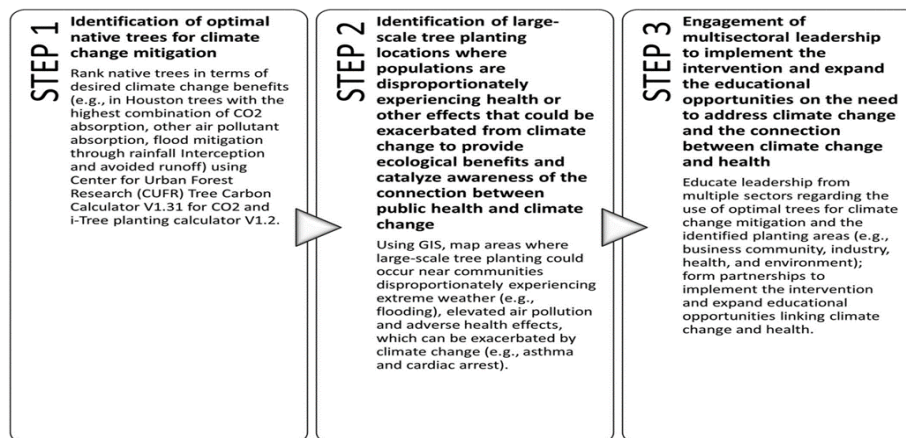


Figure 1: Three-Part Framework to Implement Large Scale Tree Planting to Address Climate Change and Health and Promote Multisectoral Leadership. (source web)

Identifying Optimal Native Trees

The first action would be to identify existing native tree species at regional level, the shrub ordinance which is developed by experts of the state forester, landscape, and trees planted locally. Additionally, identify ecosystem services as they are ranked on their environmental and climatic benefits. The identification of large-scale native mixture of tree planting locations for provision of important benefits as the populations could disproportionately be experiencing health or other effects exacerbated through increasing rates of air and water pollution, flooding, due to climate change. Also, engaging multisectoral leadership while implementing mitigation and adaptation efforts for interventions and expansion of educational opportunities at the nexus of public health, environment²⁴ and climate change.

Where should Trees be Planted?

Lately, the society is piling pressure on trees to get us out of emergency brought about by climate change in the whole world. Trees make life better in many respects, however, there could be right ways in equal measure to plenty of wrong ways of growing the forests (Waring, et al. 2020). Tree types and location affects their environmental impacts, low albedo for instance of boreal forest in comparison to the snowy land replace means planting trees in the North or far South could speed up local warming. Unfortunately, this leads to a lot of snow and ice melting²⁵. Forests have naturally been habitats of animals including man yet, the greedy of man has destroyed this natural resource displacing over 100,000 people. A case of Mbata forest which was the habitat of pygmies in three countries of Democratic Republic Congo, Central Africa Republic, and Republic of Congo.

According to Global Forest watch and Encyclopedias, (2018), an estimate of 193,000 hectares (475,000Acres) of land more than a fifth of total forest cover has been destroyed due to commercial logging and illicit wood cutting²⁶. The point here is, there's a big difference between planting of trees and growing of trees yet, people including the government are insisting on tree planting and not tree growing. Its until

²⁴ <https://nph.onlinelibrary.wiley.com/doi/10.1002/ppp3.10245>

²⁵ <https://www.sciencenews.org/article/trees-crops-agroforestry-climate-biodiversity>

²⁶ <https://nation.africa/africa/news/forest-plundering-leaves-aka-pygmies-exposed-in-central-africa--4187370>

there's good will from; the government, citizens, NGO's, well-wishers, and any organization of similar thoughts we won't go far with tree planting.

Planting deciduous trees for instance in temperate regions due to their leaves which are more reflective than conifer trees show complicated effects on global temperatures. During winter, the leaves are lost to allow light to be reflected by the ground (FAO, 2020). This has the effect of reducing surface temperatures and releasing water into the atmosphere during summer.

Reducing overall temperatures could be achieved by planting trees in the tropics as the region receives more sun energy²⁷. Thus, trees grow and absorb CO₂ faster and release more water vapor from forming clouds producing a cooling effect. This will outweigh any decrease in albedo (*Albedo* is the measure of the fraction of light that a surface reflects) since the clouds formed reflects the incoming solar radiation back into the space²⁸. Apart from trees there are other forms of carbon dioxide capture that could be of significance in reducing greenhouse gases. Such forms include.

'ALGAE' the Magic Plant in Reducing CO₂ from the Atmosphere

Algae are aquatic plants, primarily photosynthetic aquatic organisms but lack stems, true roots and leaves. They are significant to our ecosystem as they produce around 50-80 percent of the earth's oxygen and reduce carbon emissions by storing it. They also act as sources of food for aquatic organisms which are the sources of nutrition in many cultures. They can also be source of crude oil, medicines, and solidifying agents like agar²⁹. Despite trees consuming carbon into their trunks and roots through photosynthesis and releasing oxygen in the atmosphere, Algae could consume more CO₂ than trees. In addition, they could cover a bigger surface area, grow significantly faster and could be more easily controlled by bioreactors.

In conjunction with efficient bioreactors algae are 400x more efficient than trees in removing CO₂ from the atmosphere. This means a big reduction of carbon from atmosphere can be achieved by feeding the sequestered carbon from industries to algae in photobioreactors. Algae photobioreactors are efficient biological carbon capture technology based on algae biomass production from active CO₂ sequestration, a minimum of 1.8 kg. of CO₂ for each kg of algae biomass produced. Algae biomass process offers various opportunities like cosmetics, health products, bioplastics, green cement, nutrition for animals and fish and CO₂ credit market³⁰.

Trees serve as the most important factor in conserving the atmosphere through their interaction with the climate in many different ways. However, they may not be all solutions to climate crisis. This is because different types of trees need to be planted in different areas and some of the factors to be considered include the amount of energy and light from the sun the trees absorb. Lower albedo indicates less heat and energy reflected plus more absorbed on the surface of the earths in acceleration to warming (Fleischman, et al, 2020). Therefore, while dealing with climate change, there is no single solution to it. While trees are

²⁷<https://www.sciencenews.org/article/planting-trees-climate-change-carbon-capture-deforestation>

²⁸<https://www.gao.org/documents/card/en/c/ca8642en>.

²⁹<https://www.studysmarter.co.uk/explanations/biology/biological-organisms/algae/>

³⁰https://algasolrenewables.com/carbon-sequestration/?gclid=Cj0KCCQjw27mhBhC9ARIsAIFsETFZqFjCVzE6FTw6JtsvV0EvPwfk_XYAQG3p0mAhmF0KVjzQ_5j0uUwaAjZoEALw_wcB

powerful in CO₂ sequestration, they are not the 100% solution to the crisis. Thus, reducing our reliance on fossil fuels could serve as part of the solution to climate change³¹.

Not Only Trees Does this but Technology Can Also Be Applied

Apart from reforestation, technology plays an important role in reducing CO₂ in the atmosphere. Such technology like Direct Air Capture (DAC) where CO₂ is removed from the atmosphere by use of fans that are high powered, and the air drawn to be processed in certain facilities to enable separation of CO₂ in a series of chemical reactions after which CO₂ is stored underground and can also be used in making some other products like material for building and fuel of low carbon. Carbon Engineering Direct Air Capture technology draws air in by use of large fans, air is mixed with chemical solution which binds to CO₂ molecules³². CO₂ rich solution is passed by reaction in different series which separates it, make it pure and compressed. The current 18 DAC facilities could be operating at minimal levels of capturing about 0.01 million tons of CO₂, the future projection scales towards 500,000 to 1 million tons of CO₂ capture per year³³.

Another form of technology is by Geological sequestration³⁴ where captured CO₂ is stored underground into the reservoirs to prevent its release in the atmosphere hence, protecting the ecosystem against heating. Geological sequestration process involves capturing CO₂ either at industrial facilities like power plants or manufacturing operation by use of DAC technology. The captured CO₂ is made pure and is compressed in superficial phase. In this state, it is a property that is combined with liquid and gas. Later the CO₂ is injected under the surface through a well in reservoir underground. When CO₂ reaches the reservoir of over 5000 feet down it is safely sequestered in four mechanisms of trapping³⁵; here it will be sealed by a nonporous, impermeable hydrodynamic trapping caprock. This giant lid isolates CO₂ which could be injected from the underground below, this layer that is rocky and thick keeps CO₂ trapped securely.

CO₂ is locked in the pores such as residual trappings, here CO₂ is rendered immobile by containing it in tiny pores of the rock. The injected CO₂ is dissolved to form fluid i.e. solubility trappings or even dissolved in natural occurring salty brines in a reservoir. Due to increased density of the dissolution, the brines sink lower in its formation hence, the upward migration CO₂ reduces. Lastly, through geological sequestration the fourth stage is mineral trapping where CO₂ interacts with the present minerals in the rock formation through geochemical reactions resulting in the formation of a new stable and solid mineral from carbonate which forms part of the rock³⁶.

The third form of technology is through carbon engineering which deploys air to fuels³⁷. The process is capable of turning atmospheric CO₂ from Direct Air Capture (DAC) facilities into low-carbon fuels which is compatible with today's infrastructure and vehicles. The captured CO₂ is fed into a CO₂ fuel synthesis; the process is powered by clean energy leading to low-carbon fuels. The air fuel can serve as mission critical

³¹ <https://www.1pointfive.com/dac-technology>

³² <https://www.iea.org/reports/direct-air-capture>.

³³ https://www.1pointfive.com/dac-technology?gclid=Cj0KQCQiAtbqdBhDvARIsAGYnXBOJXZsCffDtzUEX6koQBCxiHrOZIPkC95IRfw7TQE4Ousuh6U4LgA_AaAnPAEALw_wcB

³⁴ <https://www.1pointfive.com/sequestration>

³⁵ <https://www.iea.org/commentaries/the-world-has-vast-capacity-to-store-co2-netzero-means-we-ll-need-it>.

³⁶ <https://www.iea.org/commentaries/the-world-has-vast-capacity-to-store-co2-netzero->

³⁷ <https://www.1pointfive.com/air-to-fuels>

tool for difficult-to decarbonize sectors like aviation, maritime, rail and long-haul trucking. In general, air fuel has some benefits such as high emission reduction, low carbon intensity, global scalability, drop-in compatible, clean burning, resource friendly, flexible blending, and hydrogen supportive.

Jinkyu Lim et al (2023) indicates that scientists have developed technology where CO₂ is converted by bacteria into polyester. Chemical and biomolecular engineers from advanced institute of science in Korea describe the process as a way of preventing emissions, bacteria (*Cupriavidus necator*) are used to pull CO₂ from air and then used to make polyester. These bacteria were tested and found that it can pull CO₂ which could be used in making some biodegradable plastics³⁸. According to scientists, this process used in converting CO₂ into polyester although it may require electricity it is efficient compared to other methods and not costly hence, it can be scaled up.

Despite its lowest form of greenhouse gas contributor, increasingly Africa is becoming extremely vulnerable to climate crisis and its effects, countries like Nigeria have lost over 600 lives in the worst flooding in a decade. Kenya is experiencing the worst drought in 40 years, while still about one-sixth of the world's population is endangered with floods, heatwaves, and drought. A report by World Bank estimates 282 million Africans are on the brink of malnutrition due to such factors as environmental degradation, drought, and displacement³⁹.

Every time drought or flooding hits, there's reduced food security by 5-20 per cent. Unless some significant change is implemented through climate-resilient farming, the projection of continental food import bill by 2025 is estimated to reach \$110 billion. Which calls for an urgent need to invest in adaptive food systems to reduce the effects of global warming. Since 70 percent of African livelihood have depended on agriculture, governments and organizations should be in partnership to find innovative solutions to precision farming by use of advanced technologies in revolutionizing food production with an aim of eliminating poverty and hunger⁴⁰.

Conclusion

The natural forest restoration in the region could be challenging since the quality of soil could no longer be able to support native or local species. Still, tree planting could require more space in terms of land thus reducing available land for farming. Less farming will in the end affect the potential ability to produce enough food which will make food prices go up. Alternatively, one partial solution to this could be adopting agroforestry where growing trees and food plants are done on the same piece of land.

Trees also protect land from degradation through soil erosion hence, improving the ability of soil to store water and nutrients, while reducing the impacts of heatwaves through provision shade which acts as a cooler to the surrounding reducing the rate of evaporation from their leaves. Trees will also reduce flooding; therefore, restoration of natural forests is very efficient, safe and fast way as a tool of carbon sequestration.

³⁸<https://phys.org/news/2023-03-bacteria-co2-air-polyester.html>

³⁹<https://www.worldbank.org/en/topic/water/overview>

⁴⁰<https://www.businessdailyafrica.com/bd/corporate/technology/how-technology-is-powering-sustainable-growth-in-africa--4059520>

Thus, saving and rehabilitating of forests that are existing will provide more benefits that are socioeconomic and ecological to local/indigenous communities that have rights to the land.

Decarbonization can be achieved by restoration of natural forests which should involve stopping deforestation and changing human consumer behaviours which tend to encourage deforestation. Blue carbon is the captured and stored carbon by coastal ecosystems, this ecosystem stores a lot of CO_{2s} for a long term per unit area. Coastal ecosystem does more than just absorbing CO₂ most conservation efforts look towards protecting the ecosystems and reducing emissions of the stored carbon dioxide escaping to the atmosphere hence, research is increasingly looking into rebuilding damaged coastal wetlands in order to store more CO₂.

Recommendations

Working toward restoring nature by removing CO₂ could provide more benefits to nature. Existing technology could also be made affordable to enhance the reduction of CO₂ from the atmosphere even though, the project should be carried out with more care to avoid damaging existing ecosystem and the livelihoods of people. However, planting of trees is not a silver bullet as solution to climate change issues rather it should be taken as an essential piece of much larger puzzle. Investing in projects such as promoting algae which consumes more CO₂, grows faster and covers more surface area hence, carbon removal from the atmosphere can be achieved faster through feeding sequestered carbon from industries.

Global warming and climate change is a serious issue in the current world, leaving people helpless, with little options to choose from, such includes recycling, re-using water, when possible, turn off unused lights, planting native trees such as black walnut, Oak, blue spruce, tulip tree, London plane trees are good for their longevity. In the event there's no space for tree planting shrubs can be effective at carbon storing, such shrubs like hedoma, rosemary, dalmonita, esperanza, shrubby bullseye could be suited for environment than even trees⁴¹.

Another aspect for serious consideration in the arena of environmental conservation is learning to plant trees and growing those trees. Most of the tree planting projects ends at planting and forget about growing them leading to multiple times of doing the same. As a society, there should be a way to reduce emission of greenhouse gases by replacing fossil fuels with renewable energy sources like solar power and wind power energy.

⁴¹ <https://www.happysprout.com/gardening/trees-global-warming/>

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