

EFFECTIVE CARBON SEQUESTRATION AND MICROCLIMATE ALTERATION AS ESSENTIAL CLIMATE CHANGE MITIGATION STRATEGIES

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Abstract: This article delves much on the contribution of vegetation and water bodies in the mitigation of climate change problems. Researches on the climate change phenomenon seem to have been oversubscribed but conclusive resolution to associated risks still need to be sorted out. Research motives on this article have not been out of tranquil interests, but quest to yield globally acceptable mitigation strategies that harmonize life risks brought about by global warming. Global warming is believed to emanate from excessive atmospheric carbon accumulation leading to natural climatic patterns alteration. Disruption of the natural climatic patterns then alter food production processes, leading to non - other than food insecurity. Synthesized search literature dominated by empirical evidences have been coined in the study to yield suggested climate change mitigation strategies. Suggested mitigation strategies are without doubt assumed to proffer sound positive contribution to global food security. Effective carbon sequestration to minimize global warming and investment in the creation of multi-open water sources that create humid micro-climates as a means to cab recurring droughts have also been rigorously suggested. Establishment of open water sources was strongly recommended in communities down to small cluster levels by encouraging policy makers to enforce damming that harnesses excessively lost run-off water. Such water is deemed to alter atmospheric water vapour of the arid and semi-arid regions and thus creating humid conditions favourable for most food production activities.

Keywords: climate change, food insecurity, mitigation, global warming, carbon sequestration.

I. INTRODUCTION

Climate change has become a contentious phenomenon pausing threats to human peace and stability globally. ‘**Climate change** refers to significant, long-term changes in the global climate, especially a change due to an increase in the average atmospheric temperature.’ (Jadhav and Baliram, 2020). The United Nations Framework Convention on Climate Change (UNFCCC, 1992) defines climate change as, “a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time period”. Its great threat has been hardly dissociated from recurring natural disasters encompassing droughts, floods, fluctuating temperatures, irregularities in precipitation and yet all these get nerve centred on food insecurity. ‘**Food insecurity** is lack of consistent access to the foods necessary for an active lifestyle’. (Kersten, etal. 2018). As a result of these disastrous events, forced human migration become rampant as loss of shelter is also inevitable. This paper has not however, been meant to delve much into the climate change causes and problems, but much on sorting resolutions in as much simpler manner as to generically be applicable in varied economic settings. For smooth case flow purposes, the resolutions have been stringently attached to causes for exerting more weight and convincing meaning. The resolutions are mainly centred on the contribution of vegetation and water bodies in drawing up positive changes. Vegetation

and water bodies' roles form the thematic presentation. Genesis of the study has been rooted from existing cases where suggested perspectives are deemed to yield positive results. Geographical and agricultural principles aided in providing the theoretical basis on which to derive suggested practical views drawn. Contribution from different authors provided various climate change views which helped to retain the author's consistence in arguments.

II. LITERATURE REVIEW

Climate change causes seem to have been theoretically over - subscribed confined to Green House Gases effect, rooted from various gases dominated by carbon dioxide. Several sources have cited human activities as the generative source in the emission of gases in question. Margal et al, 2023 suggest five primary global carbon pools as interplay sources namely oceanic, geological consisting of fossil fuels (coal 85%, oil 5.5% and gas 3.3%) and actively decomposing organic matter derived from plant and animal residues at various stages of decomposition, micro-biologically and / or chemically synthesized substances resulting from the breakdown products and the bodies of live microorganisms and small animals along with their decomposing products. On use through combustion, the fossil fuels release a lot of carbon dioxide which concentrates atmospheric gases beyond optimal levels. Other than these sources, ordinary burning of carbon containing substances and various other air pollutant sources contribute to this concentration. 'Increase in the average temperature of the earth's lower part of atmosphere i.e., troposphere, is called **global warming** and is due to an increased amount of heat striking the earth from the sun is being trapped in the atmosphere and not radiated out into space. The earth's atmosphere is acted as "greenhouse" which captures the sun's heat. Various greenhouse gases like Carbon dioxide, Methane, Nitrous Oxide and Chlorofluorocarbon are responsible for trapping the heat in the atmosphere. Some natural and man-made events are responsible for Global warming.' (Jadhav and Baliram, 2020). It has therefore been through studies established that the gases bring instabilities to the natural systems flow, resulting in climate change phenomenon.

Studies have revealed the need to adopt sound mitigation strategies in reducing climate change related challenges. **Mitigation** is defined as a human intervention to reduce the sources or enhance the sinks of greenhouse gases as well as other substances. It may contribute directly or indirectly to limiting climate change, including for example through the reduction of particulate matter emissions that can directly alter the radiation balance (black carbon) or through measures that control emissions of carbon monoxide, nitrogen oxides, volatile organic compounds and other pollutants that can alter the concentration of the troposphere ozone, which has an indirect effect on the climate (IPCC, 2014b; UNFCCC, n.d.a) in (UNESCO, 2020). Carbon sequestration approaches are part of the intervention strategies in question. '**Carbon sequestration** occurs when the carbon from decomposing residues is converted in the soil to humus or soil organic carbon (SOC). Farmers, ranchers, and foresters can employ carbon BMs, including cover crops, buffer strips, conservation tillage, no-tillage, selective harvesting, and planting of grasses, to ensure sustainable yields and protect land and water resources while, at the same time, offsetting GHG emissions.' (Glasener and Wagester (n.d).

In a more complex approach, Margal et al, (2023) stress on the need to sequester carbon in two broad ways namely through biotic (Natural) and abiotic (Artificial) means. In natural means, terrestrial carbon sequestration, also known as biological sequestration, involves implementing conservation practices in forests and soils to enhance carbon storage. These practices include activities like forest restoration, establishing new forests, wetland preservation, and grassland management. They also encompass efforts to reduce CO₂ emissions, such as minimizing agricultural tillage and controlling wildfires. However, the practices could only offset approximately 30 percent of the country's fossil-fuel CO₂ emissions, only a small portion of this uptake is specifically attributed to intentional carbon sequestration activities. The approach can also be vulnerable to various disturbances, including fire, disease, and shifts in climate and land use. Therefore, decisions regarding terrestrial carbon sequestration need to carefully consider priorities and trade-offs among different resources. For instance, converting farmlands into forests or wetlands could increase carbon sequestration, improve wildlife habitat, and water quality, and enhance flood storage and recreational opportunities. However, this would come at the expense of reduced crop production. On the other hand, transforming existing conservation lands into intensive cultivation, while potentially yielding valuable crops like bio fuels, may lead to the loss of wildlife habitat, diminished water quality and supply, and increased CO₂ emissions. Natural carbon sequestration can also occur through photosynthesis, where plants absorb CO₂ from the atmosphere, convert it into organic compounds, and store it in their biomass. Forests, grasslands, and wetlands are key examples of ecosystems that facilitate significant carbon sequestration through photosynthesis. Carbon storage in soils can be through death of plants or shed leaves, their organic matter decomposes, releasing CO₂ back into the atmosphere. However, a portion of this organic matter can become incorporated into the soil through various processes, such as microbial decomposition and physical stabilization. Afforestation and reforestation also utilize the concept of sequestering carbon

through photosynthesis as trees absorb CO₂ and store carbon in their biomass. These activities not only sequester carbon but also provide additional benefits such as biodiversity conservation, water regulation, and soil protection. Bio energy with carbon capture and storage combines the use of biomass for energy generation with carbon capture technologies. Biomass feed stocks, such as agricultural residues or dedicated energy crops, are converted into bio energy, and the resulting CO₂ emissions are captured and stored underground. Bio energy with carbon capture and storage has the potential to achieve negative emissions by removing CO₂ from the atmosphere.

Geological carbon sequestration involves capturing CO₂ from industrial processes, such as power plants and cement factories, and storing it in geological formations. Carbon capture technologies, including post-combustion, pre-combustion, and oxyfuel combustion capture, are utilized to capture CO₂ emissions before they are released into the atmosphere. Once captured, the CO₂ is compressed and transported to suitable geological formations, such as depleted oil and gas reservoirs, saline aquifers, and deep underground rock formations. The CO₂ is injected into these formations, where it is securely stored over long periods, preventing its release into the atmosphere.

The oceans act as a natural sink for atmospheric CO₂. Through physical and chemical processes, such as ocean mixing and carbonate reactions, CO₂ dissolves in seawater and forms bicarbonate ions, which are stored in the ocean. This process, known as oceanic carbon sequestration, contributes to the reduction of CO₂ levels in the atmosphere. The Earth's oceans serve as the primary long-term reservoir for anthropogenic CO₂ emissions. This natural absorption occurs through chemical interactions between seawater and atmospheric CO₂, without any deliberate sequestration efforts. However, this process also leads to ocean acidification as CO₂ is absorbed, which poses a threat to various marine organisms and ecosystems that rely on carbonate formation for their skeletons and sediments. Research conducted in laboratories and field settings suggests that increased CO₂-induced acidification may eventually surpass the rate of carbonate formation in these ecosystems, resulting in the dissolution of existing carbonate structures. The implications of ocean acidification and intentional ocean fertilization on coastal and marine food webs and other valuable resources are not yet fully understood. Scientists are actively investigating the effects of carbon sequestration in the oceans on these crucial environments.

Non-biological carbon capture sequestration involves utilizing physical and chemical reaction. Geological carbon storage, also known as subsurface carbon storage or geological injection, involves capturing, liquefying, transporting, and injecting CO₂ from industrial sources into deep geological formations can also be implemented. These formations can include coal seams, old oil wells, stable rock strata, or saline aquifers (Tsang et al. 2002; Klara et al. 2003; Baines and Worden 2004; Gale 2004) in (Margal et al, 2023) Saline aquifers are porous sediments filled with brackish water located below freshwater reservoirs, separated by impermeable layers. CO₂ is pumped into these aquifers where it is sequestered through hydrodynamic processes and chemical reactions that form carbonates.

Biotic carbon sequestration involves actively managing higher plants and microorganisms to remove CO₂ from the atmosphere. It focuses on interventions that go beyond emission reduction or offsetting. Enhancing resource efficiency, such as water and energy, is also considered a means to manage the carbon stored in terrestrial ecosystems. Biological processes play a significant role in carbon sequestration in the ocean through photosynthesis. Phytoplankton photosynthesis is a key mechanism in capturing carbon, and part of this organic material produced by phytoplankton settles to the ocean floor, effectively sequestering carbon (Raven and Falkowski 1999) in (Margal, et al, 2023).

Terrestrial carbon sequestration refers to the process of transferring atmospheric CO₂ into the organic and soil carbon pools within terrestrial ecosystems and emitted annually into the atmosphere, approximately 40% of the anthropogenic CO₂, is retained in the atmosphere due to unspecified terrestrial sinks that sequester atmospheric CO₂. These terrestrial sinks play a crucial role in the global carbon cycle. Terrestrial ecosystems act as significant carbon sinks by utilizing photosynthesis to capture and store CO₂ in living and decaying organic matter (Lal et al. 2003) in (Margal, et al 2023), as it provides multiple advantages even in the absence of the threat of global climate change. The three main components of terrestrial carbon sequestration are i) Soils, ii) Forests, and iii) Wetland.

Soil carbon sequestration involves increasing the concentration and pools of soil organic carbon (SOC) and soil inorganic carbon (SIC) like secondary carbonates through various practices and land-use conversions in agricultural, pastoral, and forestry ecosystems. It also includes the restoration of degraded and heavily disturbed soils. Unlike geological sequestration, which involves injecting CO₂ at depths of 1-2 km, SOC sequestration focuses on depositing carbon in the surface layer of the soil, typically within a depth of 0.5-1 m, through natural humification processes.

Integrated nutrient management (INM) plays a crucial role in soil organic carbon (SOC) sequestration. The humification process, which contributes to SOC formation, can be impeded by the limited availability of essential nutrients such as nitrogen (N), phosphorus (P), Sulphur (S), and other components necessary for soil humus formation. Increasing the application of biomass C and N can enhance the rate of SOC sequestration (Campbell et al. 1991; Janzen et al. 1998; Halvorson et al. 1999, 2002). Liebig et al. (2002) in Margal, et al, 2023) found that high N application rates resulted in higher SOC sequestration rates compared to unfertilized controls. The application of organic manures and other organic amendments is an important strategy for soil organic carbon (SOC) sequestration. Higher sequestration rates can be achieved through practices such as no-till farming, retaining crop residues as mulch, incorporating cover crops in rotation cycles, and implementing complex farming systems like agroforestry. Integrated nutrient management (INM), including manuring, and afforestation for restoring degraded soils also contribute to higher sequestration rates.

Forest ecosystems act as a storage for carbon through lignin and other resistant polymeric compounds. Carbon is sequestered not only in harvestable timber but also in woody debris, wood products, and woody plants expanding into grasslands (Wofsy 2001). Nevertheless, increasing CO₂ concentrations can limit net primary productivity (NPP) due to deficiencies in nitrogen, phosphorus, water, and other factors. Managing the interactions between carbon, nitrogen, phosphorus, and water cycles can enhance terrestrial carbon sequestration. Afforestation is a viable option for carbon sequestration in terrestrial ecosystems and estimates suggest that reducing clear-cutting of primary tropical forests to zero over 50 years by 2050 could avoid carbon emissions, by approximately 250 million hectares in the tropics or 400 million hectares in the temperate zone. However, large-scale afforestation can impact water resources, with documented reductions in stream flow, soil salinization, and acidification where careful consideration must be given to potential adverse impacts on water availability when planning large-scale afforestation for carbon sequestration. Biodiversity decline in tropical forests due to water depletion levels through monoculture plantations is also a concern, which must be critically assessed (Bunker et al. 2005) in Margal, et al, 2023).

Wetlands have the capacity to store and sequester significant amounts of carbon, making them valuable in mitigating greenhouse gas emissions and combating climate change. Extensive draining for agricultural and forestry purposes has caused decomposition and subsidence of drained wetland soils, primarily due to oxidation, occurring at a rate of 1-2 cm yr⁻¹ (Rojstaczer and Deverel 1995) in Margal et al, 2023). Restoring wetlands can reverse this process and transform them back into sinks of atmospheric CO₂.

III. CLIMATE CHANGE MITIGATION STRATEGIES

Mitigation strategies of climate change should start by coming up with the best way to deal with Green House Gases effect reduction. Converging ideas by most climate change studies come up with consensus in regarding carbon sequestration as the best way to solve climate change challenges. In this case, such carbon originates from carbon dioxide. So, the best model to solve the challenge should be dominated by trees. Once carbon gets eliminated, it would then be possible to fuse in other climate resolutions strategies. Means to generate microclimate could be deemed necessary in areas where climate change impacts yield catastrophic results that threaten human existence. As such, any measures to do with induction of micro-climates would be also wisely accepted as climate change mitigation strategies.

Carbon sequestration through use of trees.

Trees have been established to be best sequesters of carbon, which is up taken as CO₂ gas through photosynthesis, storing carbon in their biomass and the soil. These activities not only sequester carbon but also provide additional benefits such as biodiversity conservation, water regulation, and soil protection (Margal, et al, 2023). As such, to use them involves strategic placement so that they efficiently absorb carbon dioxide. In the case of exhaust carbon from vehicles, trees could be established or allowed to naturally grow covering a width of 5m to 10 m along roadsides depending on land availability so that they trap carbon dioxide as they photosynthesize. These trees can also be planted around industrial sites where similar gases are produced. Absorbed carbon is assumed to be stored by the trees and volumes stored depend on tree size, i.e., the thicker the tree the more carbon is likely to be stored. While trees are good carbon sequesters, they tend to deplete underground water on sites where they are if poorly managed by being allowed to overgrow. 'Forestry tree plantations must be correctly sited to minimize underground water depletion impacts' (Gwemende, 2023). In the same vein, studies by Horia, et al. (2025) indicate that 'as woody cover increases, excess water decreases especially in arid regions—owing to enhanced transpiration. This reduction in net water surplus has significant implications for groundwater recharge and ecosystem functioning, as increasing woody vegetation competes with herbaceous species for limited moisture. Consequently, these

shifts in vegetation structure demand adaptive management strategies to preserve water availability under future climate scenarios'

Temperature regulation role of trees

Exposure of plants to solar radiation during daytime makes them absorb, reflect, and transmit it. (Naik, et al, 2017) This creates temperatures that are conducive for survival of different organisms with humans included. As trees trap light energy, utilization of carbon from the vehicles travelling along the roads become possible, minimizing carbon accumulation in the atmosphere. Temperatures within the tree canopy are bound to decline following the cooling effect of evaporation because as a wave of high temperature passes through a tree canopy, it triggers an increase in transpiration, during which water on leaf surface evaporates inducing some cooling effect, and this creates an environment suitable for rain formation depending on the vegetation density and time of the year. Strategic placement of high canopied plants like trees around sources of carbon within reach of extreme solar radiation become a double burel climate change mitigated resolution as this effectively sequester carbon and bringing to normal would-be extreme heat effects.

Tree roles on humidity/rainfall formation.

Strategic placement of macro plants in once hot, deserted and carbon concentrated areas could bring about a new relatively microclimate by intensifying atmospheric vapour that is likely to alter drought impacts of that locality as the genesis of a new rainfall pattern become possible. While other authorities might argue that intensified rainfall in areas of high carbon concentrated areas might promote acidified rains, but that could still be solved by other farming activities like liming that recondition soils especially if it happens to occur in arable lands.

Microclimate

Preceding discussion concentrated much on the role of plants as important sequesters of carbon to reduce its concentrations minimizing greenhouse effect. Existence of macro plants at a place emit a lot water vapour whose intensity has rainfall resultant potential. Similar results that surpass the later can also be yielded by ensuring existence of multiple open water sources in climate change prone areas especially in the drought impacted extremes. Construction of micro to macro dam structures is likely to alter climate for the better through increased atmospheric water vapour intensities. So as a matter of policy, if large volumes of lost summer runoff water is harnessed by damming, combining with transpired water vapour, could possibly create micro-climates that can mitigate climate changes that are inclined to drought as rainfall pattern would definitely change for the better. The later is strongly recommended especially in the rural communities where governments should highly subsidize the initiatives to ensure green grounds capable of absorbing excessively emitted carbons are created globally

IV. CONCLUSION

To the affected people climate change is a detrimental phenomenon, but becomes an opposite scenario if the change is for the better. Climate change therefore becomes associated with advantages and disadvantages.

Advantages of climate change.

- Shifting of a high rainfall pattern into once drought prone area changes some agriculture activities for the better.
- An excessive downfall of rainfall that fills large water sources alters and improves livelihoods of people as well as creation of new micro – climates that may no longer reverse.
- Some economic activities can change for the better.
- Change in climate has a bearing towards feeding habits transformation as with cultural dynamism and this minimizes global trade complexities.

Disadvantages of climate change

- A change in climate is commonly associated with high risks such as floods and extreme colds.
- Some measures that are taken to mitigate climate change related issues may be expensive especially for the developing nations.

- Signs that help to predict natural events leading to associated climate change are quiet irregular and sometimes not easily foreseeable making it impossible to prepare for its forthcoming.
- Some conservative societies take time to accept change and as such, could be caught unaware due to relocation resistance, in particular coastal areas people for this threatens them to leave sea resources benefits like fish but ignoring the floods risk.
- Some proposed mitigation measures may take more time to yield results, for instance, measures taken to create a sound new microclimate could demand several years to provide generally acceptable outcome.
- Tree growth conditions in highly carbon dioxide concentrated areas may hardly grow where they are intended to, making it difficult to sequester carbon.

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