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Samruthi M
Assistant Professor,
Kalasalingam University,
Virudhunagar, Tamil Nadu,
India

Kannan V
Assistant Professor,
Kalasalingam University,
Virudhunagar, Tamil Nadu,
India

A Bharathi
Assistant Professor,
Kalasalingam University,
Virudhunagar, Tamil Nadu,
India

Corresponding Author:
Samruthi M
Assistant Professor,
Kalasalingam University,
Virudhunagar, Tamil Nadu,
India

Carbon farming: A pragmatic approach to tackle greenhouse gas emission

Samruthi M, Kannan V and A Bharathi

Abstract
Carbon farming implies the transfer of atmospheric GHG (Greenhouse gas) into other long-lived global pools including oceanic, pedologic, biotic, and geological strata to reduce the net rate of increase in atmospheric CO2. The literature summarized providing a perspective on how agriculture can reduce its GHG burden through conservation measures. A terrestrial ecosystem like bamboos can sequestrate carbon at a much faster rate. Impacts of agricultural practices and strategies to prevent GHG emissions like conservation tillage, Biochar and bioenergy are reviewed which helps to mitigate adverse effects of GHG in the atmosphere. Seed weed aquaculture contributes to reduce GHG through photosynthesis where they absorb carbon and generate oxygen which in turn reduces the effect of ocean acidification.

Keywords: GHG emission, conservation measures, biochar, bamboo, seaweed farming, biofuel

Introduction

Carbon farming is the umbrella term used for a growing suite of agricultural and land management practices that remove carbon dioxide from the atmosphere and stores it in soils and plants. It has been proposed that increasing the amount of carbon in soil could be an effective means of mitigating climate change (Scharlemann, Tanner, Hiederer, & Kapos, 2014; Smith *et al*., 2008) [27], while also benefiting soil fertility, given the central role of soil carbon in regulating soil physical, chemical and biological properties. Low carbon society is the order of the day and for this, there is an urgent need in urban and rural societies especially in developing countries to devise strategies and prepare road maps for achieving this goal. Soil organic carbon supports the soil's structure, improving the physical environment for roots to penetrate through the soil. Farming practices that reduce soil organic matter such as burning, tillage, overgrazing and continuous cropping run the risk of contributing to a decline in soil conditions which may not become evident for many years. The term soil C sequestration implies the transfer of atmospheric CO2into soil C pool through: (i) humification of crop residue and other biosolids added to the soil, and (ii) formation of secondary carbonates or leaching of bicarbonates into the groundwater such that CO2thus captured is not immediately re-emitted. The residence time of C thus sequestered ranges from a few weeks to millennia depending on the nature of carbonaceous substances, the stability of secondary carbonates formed and depth of leaching. In addition to advancing global food security, the terrestrial C sink plays a major role in the global C cycle. It is strongly believed that the so-called missing C is absorbed in some terrestrial sinks (Fung 2000, Pacala *et al*. 2001; Scholes and Noble 2001) [9, 25, 28]. The implementation of the Kyoto Protocol in 2004 has enhanced the interest in the terrestrial C sink, of which soil C sequestration is an important component.

Different strategies used for mitigating ghg (greenhouse gas) emission

Bamboo

India is the fourth-largest emitter of greenhouse gases after China, the US, and the European Union. India's emissions increased by an alarming 4.7% in 2016 compared to the previous year. In the 39th meeting of the Executive Board of Clean Development Mechanism (CDM), it was decided that both bamboos and palm trees can be considered as a suitable alternative for climate change mitigation (Lobovikovat *et al*., 2009) [23]. Bamboos are the fastest-growing woody plant in the world with a unique rhizome- dependent system, highly dependent on local soil and climatic conditions. Due to its biological characteristics and growth habits, it is not only an ideal economic investment but also has enormous potential for alleviating many environmental problems. It is a widely distributed renewable resource which is productive, versatile, low-cost environment- enhancing resource. One of the challenges in bamboo sequestration is unmanaged bamboos. In unmanaged bamboo clumps, carbon sequestration due to the production of new culms will be almost the same as that of carbon release due to decay and death of old culms (INBAR, 2009) [14]. To avoid this, harvesting bamboo to make bamboo products makes logical sense. This will ensure carbon is locked and secured and thereby inhibiting its release back to the environment. The speed with which a plant grows has a part in determining how much carbon dioxide it can absorb in a given time. Bamboo potentially acts as a valuable sink for carbon storage and on average, one hectare of bamboo absorbs about 17 tonnes of carbon per year.

Seaweed farming

Seaweed aquaculture, the fastest-growing component of global food production, offers a slate of opportunities to mitigate, and adapt to climate change. Seaweed is currently grown on a small scale for use in food, medicines, and beauty products. Seaweed is allowed to grow to maturity, harvest it, and then sink it in the deep ocean where the captured carbon dioxide would be entombed for hundreds to thousands of years. Seaweed production, both from wild stocks and from aquaculture, represents an important conduit for CO2 removal from the atmosphere, with strongly autotrophic seaweed communities globally taking up 1.5 Pg C year^{-1} via their net-production (Krause-Jensen,Duarte, 2016) [19]. In addition, increased CO_2 may increase the yield of seaweed aquaculture (Callaway *et al*., 2012) [2]. Through photosynthesis, seaweeds absorb carbon, nitrogen and other excessive nutrients to generate new biomass (the material used for energy production) and produce oxygen. Ocean warming may reduce fucoid canopies through physiological stress as well as additional associated pressures from warm-water herbivores (Harley *et al*., 2012) [11], increased storm energy and reduced nutrient supply (Callaway *et al*., 2012) [2], possibly reducing seaweed aquaculture yields. We like to call it 'charismatic carbon' because it has additional benefits, such as potentially providing habitat for fish and other marine life, reducing ocean acidification and oxygen depletion, and taking up excess nutrients in local areas. Carbon sequestered in both living and non-living biomass in the ocean and coastal habitats have been termed 'Blue Carbon' by the United Nations Environment Programme (UNEP) (Nellemann *et al*., 2009) [24] and such blue carbon environments provide many ecosystem services. Natural seaweed communities provide a range of ecosystem services (Smale *et al*., 2013) [30], and similar roles can be ascribed to artificial seaweed aquaculture beds (SABs). Even though SABs are artificial ecosystems, they fulfill many of the functions exhibited by natural kelp forests and seaweed beds. Seaweed aquaculture beds cover extensive shallow coastal areas, particularly in the Asia-Pacific region, and although still accounting for only a small portion of global agriculture, seaweed aquaculture is growing more rapidly than other components of production (Sondak *et al*., 2016; Duarte *et al*., 2017) [31, 4].

Conservation tillage

Conservation tillage is an agricultural management approach that aims to minimize the frequency or intensity of tillage operations to promote certain economic and environmental benefits without damaging soil organic carbon. These include a decrease in carbon dioxide and greenhouse gas emissions, less reliance on farm machinery and equipment, and an overall reduction in fuel and labor costs. The soil C pool constitutes a major global reservoir comprising both SOC and soil inorganic carbon components. The SOC pool consists of " a mixture of plant and animal residues at various stages of decomposition, of substances synthesized microbiologically and/or chemically from the breakdown products, and of the bodies of live microorganisms and small chemically from the breakdown products, and the bodies of live microorganisms and small animals and their decomposing products" (Schnitzer, 1991) [34]. The SIC includes elemental C and carbonate minerals of primary and secondary origin. Primary carbonates are derived from the parent material and secondary carbonates are formed through the reaction of atmospheric CO2 with Ca+2 and Mg+2 (Lal and Kimble, 2000) [21]. The SOC affects soil physical quality through the change in soil structure, aggregation, total and microporosity, susceptibility and ease of root system development. It has been recognized that soil structure is the key to high yield and erosion control (Yoder, 1946) [34]. Soil chemical quality depends on its ability to maintain a favorable balance among macro and microelements. Soil biological quality involves population and species diversity of macro and micro fauna, microbial biomass C, microbial processes leading to the transformation of biomass, and denaturing and detoxification of applied chemicals and other pollutants. Excessive tillage deteriorates soil organic carbon. Before the invention of motorized tillage equipment, reduced or shallow tillage was the traditional mode of seedbed preparation and still in several regions of the tropics and subtropics. The modern concepts of conservation tillage have evolved since World War II because of the realization that accelerated erosion has severely adverse impacts on soil and environment qualities (Faulkner, 1942) [7]. Thus conservation tillage has been promoted for erosion control since the 1950s (Buchele, 1956; Meyer and Mannering, 1961) [1]. In the 1990s, the usefulness of conservation tillage was recognized for C sequestration to reduce the risks of an accelerated greenhouse effect (Lal *et al*., 1998; Lal, 2000) [21, 22]. It is in this context that a strong need exists to extend the ecological limits of application of conservation tillage adaptive and soil- specific research, especially in soils and crops of the tropics and subtropics. While erosion control leads to the maintenance of the SOC pool, the need for C sequestration in soil strengthens the development of innovative technologies for the widespread adoption of conservation tillage systems. Several impediments are adopting conservation tillage systems in developing countries. Crop residue, an important input for erosion control and enhancing the SOC pool, is needed for multifarious purposes, important among which is the use of residue as fodder, fuel and construction material.

Biochar

Biochar is a heterogeneous substance rich in aromatic carbon and minerals. It is produced by pyrolysis of sustainably obtained biomass under controlled conditions with clean technology and is used for any purpose that does not involve its rapid mineralization to CO2 and may eventually become a soil amendment. Applying biochar to contaminated rice paddies can substantially reduce cadmium pollution. Biochar and other organic materials have been applied to soil as the most valuable amendments for increasing carbon sequestration, soil health improvement, and reduction of greenhouse gas emission from soil. Being recalcitrant, biochar is highly efficient in storing carbon in soils. Due to its capability to actively reduce the atmospheric concentrations of greenhouse gases, biochar technology may be considered as geoengineering solution. It may also be considered as a long wave geo-engineering option for climate change mitigation as it plays a role in the removal of CO2 from the atmosphere. A biochar system is a carbon sink, where crops are grown and is subsequently pyrolyzed to produce biochar, which is then applied to the soil. This means that CO2 from the atmosphere is sequestered as carbohydrates in the growing plants and that conversion of the plant biomass to biochar stabilizes the carbon. The stabilization of carbon in biochar delays its decomposition and ensures that carbon remains locked away from the atmosphere for hundreds to thousands of years. In addition, biofuels can also be made by utilizing the gases released during biochar production. In carbon cycle, plants remove CO2 from atmosphere via photosynthesis and convert it into biomass. But all of that carbon (99%) is returned to the atmosphere as CO2 when plants die and decay, or immediately if biomass is burned as a renewable substitute for fossil fuels. In the biochar cycle, half (50%) of that carbon is removed and sequestered as biochar and the rest half (50%) is converted to renewable energy co-products before being returned to the atmosphere. Increasing the C sink in the soil will help reduce the amounts of CO2, CH4 and N2O emission in the environment. Increased soil aeration from biochar addition reduces denitrification and increases sink capacity for CH4. Biochar can reduce N2O emission due to inhibition of either stage of nitrification and/or inhibition of denitrification, or promotion of the reduction of N2O.

Bioenergy

The energy sector is the largest contributor to GHG emission therefore, it is essential to curb consumption of fossil fuels if progress is to be made in curtailing GHG emission. Carbon-neutral (causing no net change in atmospheric C concentration) and/or C-negative (causing atmospheric C concentration to decline) fuels are needed. Numerous energy alternatives to fossil fuels exist (e.g., biomass, solar, geothermal, wind, ocean thermal, and tidal), which currently represent only a small fraction of the global energy used (Hoffert *et al*., 2002) [13]. There is ample solar energy; however, current costs of recovery and conversion are high relative to current fossil fuels (Crabtree and Lewis, 2007) [3]. Biomass, similar to other renewable energy sources, has a low power density (about 0.6 Wm_2) and that alone would not be expected to contribute significantly to climate stabilization (Hoffert *et al*., 2002) [13]. However, biomass can be used to produce C-neutral fuels to power the transportation industry (Hoffert *et al*., 2002) [13]. Biomass fuels are C-neutral because it releases recently fixed CO2, which does not shift the C-cycle. However, the potential for biomass pyrolysis to produce liquid biofuels and a biochar co-product returned to the soil can be C negative (Fowles, 2007) [8]. Energy balance estimates for grain ethanol production range from negative (Pimentel and Patzek, 2005) [26] to positive (Kim and Dale, 2005; Shapouri *et al*., 2003) [18, 29]. Farrell *et al*. (2006) [6] concluded grain ethanol could have a small positive energy balance, such that 26% of the energy could be considered truly renewable and reduce GWP by about 13%, with a considerably greater reduction in GWP with cellulosic ethanol. Soydiesel in the United States is estimated to yield a net energy return of about 93% (Hill *et al*., 2006) [12]. The higher energy return for soy diesel is partly due to the greater energy content of the fuel, but largely due to lower inputs for feedstock production (e.g., fertilizer inputs, energy, and equipment). Technology is rapidly advancing to utilize crop biomass, perennial grasses, woody perennials and forest products for the production of ethanol via a cellulosic platform and/or utilizing pyrolysis to generate syngas and other products/ co-products (Johnson *et al*., 2007b) [16]. As the new technology develops, it is important to avoid negative environmental consequences such as accelerated soil erosion or loss of SOC. Many estimates on the amount of crop biomass that can be harvested are based primarily on erosion risks (e.g., Graham *et al*., 2007; Nelson *et al*., 2004; Perlack *et al*., 2005) [10] with limited estimates that consider the amount of biomass needed to prevent loss of SOC (Johnson *et al*., 2006) [17]. As has been noted by several researchers (Lal, 2004b; Larson, 1979; Wilhelm *et al*., 2004) [20], crop non-grain biomass is valuable for the land; thus a conservative approach is necessary to develop sustainable biomass harvest rates. Johnson *et al*. (2007b) [16] concluded that (1) biomass energy feedstock should come first from material diverted from landfills (e.g., bagasse, culled fruits and vegetables, food processing wastes, sawdust and used vegetable oils); (2) agricultural biomass (e.g., straw and stover) should only be harvested once the needs for protecting the soil from wind and water erosion and loss of SOC have been met; (3) feedstocks (annual and/or perennial) need to be regionally developed to meet local needs; and (4) management strategies are needed to assure that the soil resource does not lose its ability to provide food, feed, fiber, and fuel.

Conclusion

The amount of carbon dioxide in the atmosphere has increased since the beginning of the industrial age, anthropogenic activities such as the burning of fossil fuels have released carbon from its long-term geologic storage as coal, petroleum, and natural gas and have delivered it to the atmosphere as carbon dioxide gas. Of the total carbon released into the atmosphere, 30% is sequestrated by oceans and remaining is incorporated into the terrestrial ecosystem. As carbon dioxide concentrations rise in the atmosphere, more infrared radiation is retained, and the average temperature of Earth's lower atmosphere rises. The soil C once sequestered remains in the solum as long as the recommended practices are continued and the soil is not disturbed. While soil C sequestration is not a panacea for all environmental issues, it is certainly a step in the right direction to restore degraded soils, increase agronomic yields, improve water quality, reduce erosion along with suspended and dissolved loads, reduce anoxia in coastal ecosystems, and mitigate climate change. Reservoirs that retain carbon and keep it from entering Earth's atmosphere are known as carbon sinks. The strategies which are reviewed in this literature are serving as carbon sinks. In addition to the improved agriculture practices, preservation of the terrestrial ecosystem is important for the continued sequestration of carbon.

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