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Forms of Estimating Carbon Stocks and Carbon Sequestration in our Terrestrial System using Carbon Capture Sequestration and Carbon Utilization Pathways

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Abstract

Measuring and analyzing how much carbon is sequestered in our atmosphere and quantifying its potential is a sure way of combating climate changes. However reporting how much carbon is being sequestered in our ecosystem on a regional scale is time consuming, complicated and challenging. Hence, remote sensing technology offers advancement for improved algorithm and finer spatial resolution for detecting biomass and reporting it in a large landscape-level irrespective of the weather and location of the terrain. Besides, we discuss the act of Capturing carbon and sequestering and critical challenges in developing it. Furthermore, the science and technology that is readily available for carbon capture and its utilizations to aid the available mode of sequestering carbons in our atmosphere, such as the forest systems. Furthermore, we pointed out how much china has sequester carbon in some of her provinces and how the pathways listed can aide in reducing carbon emissions.

Keywords: Remote sensing; Carbon estimation; Carbon sequestration; Carbon utilization; Cycling

Introduction

Carbon dioxide is a greenhouse gas that influences the world climate pattern concerning global warming and climate changes influences [1-3]. Green gases consist of carbon dioxide (CO2), nitrous oxide (N2O), methane (CH4), and ozone (O3) [4]. Carbon exists as carbon dioxide in our terrestrial atmosphere and devised of about 0.04% of gases surrounding the atmosphere. Green gases have raised the global temperature between 3°C and 5°C [5]. The concentration of carbon dioxide in our atmosphere has already exceeded 450 parts per million (ppm) for the very first time as at May 2013, which increased from 315 ppm as measured and reported in 1958 by the U.S National Oceanic and Atmospheric Administration [6]. Despite the efforts to curb emissions of CO2 and other Green House Gases (GHGs), emissions grew faster in the past few decades especially in the 2000's than in the 1990's, however, by 2010 it has reached approximately 50 Gt CO2 equivalent (CO2 eq) yr^{-1} [7].Carbon is sequester by the transfer of atmospheric carbon-dioxide into our ecosystem long-lived global pools such as oceanic, pedologic, biotic and geological strata to solely mitigate the increase or rise of CO2 in our atmosphere [8]. Carbons are absorbed by in our Forest trees, Saltmarshes or grass during photosynthesis, which converts or removes atmospheric carbon dioxide and stores the carbon in forest litters, plant tissues and soils and release oxygen from the conversion. Forest trees and are mostly referred to as tree or forest biomass. We estimate forest carbon stocks based on the estimation of forest biomass [1]. It is very crucial to quantify, monitor and estimate the amount of carbon that is lost or emitted during deforestation or any anthropogenic pressure and how much carbon that is stored or sequestered in the forest ecosystem. This act is relevant for the conservation of carbon stock and their role or effects on climate change mitigation.

Anthropogenic effects and activities such as deforestation, forest degradation, industrialization and combustion of fossil fuels have led to an increase in the carbon quantity and level in the atmosphere and have altered and disrupted the global carbon cycle. Nature has a way of maintaining and controlling the balance between its biological and inorganic processes. For instance, when plants or trees die or burnt, the carbon stores in them are released or emitted back into the atmosphere through the burning of forest biomass and decomposition plants and soil carbon. The rise of the carbon level in the atmosphere is specifically caused and accelerated by anthropogenic activities. These activities caused an increase in the concentrations of carbon stuck in the atmosphere, thereby affecting and increasing our average global temperature.

Currently, there is a strong interest and call to reduce and stabilize the increment of carbon dioxide and other greenhouse energy, because of the risk it poses to climate change and global warming [9,10]. Furthermore, there is a strategic way of lowering or mitigating carbon dioxide and green gas emission in our atmosphere [11]. They are: reducing global energy use, low/no-carbon fuel and sequestering of carbon dioxide through natural and applying engineering techniques and technology.

The objectives of this study were to

- This paper reviews the potential methods of estimating carbon storage, and use of remote sensing technology to obtain carbon sequestration in large scale and places where data cannot be obtained.
- Review the pathways that can reduce carbon dioxide emissions in our industries, homes and environment.
- Review the pathways that can possibly reduce carbon dioxide emissions in our industries, homes and environment.
- We also reviewed forest carbon storage in China and how cities with low carbon sequestration can implement CCS and CO2 utilization Pathways.

Material and Methods

Carbon pools

The three main components of terrestrial carbon sequestration are Wetlands, soils and forests [8]. Terrestrial carbon sequestration is simply the transfer of atmospheric carbon dioxide into pedologic and biotic carbon pools. However, there are five known Carbon pools of our ecosystem which involves biomass, according to the IPCC [12], they are the above-ground biomass, below-ground biomass, the dead mass of litter, woody debris and soil organic matter. Whereas, the carbon stocks of interest are mainly above-ground and below-ground. In a typical terrestrial forest ecosystem, the leading carbon pool consists of the living biomass of trees, deadwood (standing and fallen stems and branches), woody debris, understory vegetation and soil organic matters.

Our tropical forest functions as an atmospheric sink or carbon reservoir. Forests play an essential and significant role in the global carbon cycle. The current world's forests carbon stock is estimated to be 861 Gt of carbon, where about 363 and 383 Gt of carbon is stored in the living biomass and up to 1 m of soil respectively [13]. A larger percentage of carbon is stored in aboveground biomass (56%) in comparison to 32% in the soil in tropical forest region [13]. Tropical forest stores up about 47% and 12% of the world's terrestrial carbon pool and holds about 87% percent of terrestrial above ground carbon and 73% percent of carbon stored in soil [14].

Above-ground biomass

The above-ground biomass of a tree is an important and visible part of our terrestrial forest ecosystems carbon pool[15,16], however, any slight changes like deforestation, degradation and fragmentation or any land system use has a direct impact in the carbon pool. A reliable estimation of AGB has to take into accounts the spatial distribution of trees, woods and forest metrics (allometric models) [17,18].

Below-ground biomass

The below-ground biomass is simply is and comprises of all the live roots. The roots help in the carbon cycle and recycle, such as transferring and storing carbons in the soil. Furthermore, the live and dead mass of litters and woody debris does not have much impact in the carbon pool as they contribute merely smaller fractions of carbon stocks in the forests. Acquiring Below ground biomass can be time-consuming, expensive, needs qualitative procedures as root systems have particular features and require highly specific procedures [19,20]. Most measurements of below-ground biomass are not correctly represented in a large spatial scale, and probably because of complex root systems. Thus, Three-Dimensional (3-D) root architecture data analysis methods are a new method that can be used to compute the spatial distribution of biomass, specific root length, coarse root volume, and external surface [20].

Soil carbon

Carbons are not limited only in tree biomass but also in marshes and forest soils. Carbons are stored in the soils as soil organic matter. The soil has the tendency and potential to store and or sequester carbon dioxide in some areas. Soils worldwide contain about three or four times more organic than vegetation. It is estimated to be 1500 Gt to 1 m depth, 2500 Gt to 2 m and 610 Gt for vegetation respectively, also, three times as much carbon as in the atmosphere 750 Gt [21-23]. The amount of carbon sequestered in our ecosystem soils can be measured and analysed by randomly taking samples in each plot by measuring soil profile depths on each layer. Soil carbons are derived by measuring both dry soils and wet soils. Carbon has to filter through soil microbes to create stabilized forms of carbon in the soil. Most of soil carbon carbons are stored in wetlands, peats and plant litter at the soil surface.

Soils are one of the largest terrestrial carbon cycle reservoirs. Soil organic matter is second to the above-ground biomass in the contribution of carbon stocks of a forest, and soils are a significant source of carbon emissions following deforestation or any anthropogenic pressure or degradation It is crucial to estimate the amount of biomass in our forest ecosystem, and also the amount of carbon that has been sequestered by the forest from the atmosphere. It is crucial because we can be able to track changes in the carbon stock of forest and global carbon cycle scales. Carbons are stored in soils when dead plant material like leaves, root litter, and decaying and decayed woods and losses from decomposition and mineralization of organic matter (heterotrophic respiration). Nevertheless, most of the carbon goes by back to the atmosphere via autotrophic root respiration and heterotrophic respiration or popularly known as 'soil respiration or soil CO2 efflux'. [24-27].

There are lots of limitation in obtaining a reliable soil carbon stock inventory, especially an inventory with a repeated soil carbon sampling as its time consuming and costly [28]. Thus, the need for combination of models and additional measurements is needed for this task. Thus, the need for a combination of models and additional measurements is needed for this task. Soil carbon models can be used in estimating carbon stocks and their changes. However, some parameters and validations are needed for each land use, soil type, climatic condition and vegetation cover. Serious attention should be paid to the changes in soil carbon stock and its changes with time via soil carbon modeling and direct measurements, as well as the regional variation/changes of soil carbon stock [29]. Improving the opportunity of soil carbon sequestration can be limited and influenced by some factors such as climatic conditions [30], soil type and climate rather than by tree species at regional or national scales [31].

Furthermore, the new methodology is using geographic information system (GIS) to calculate Soil organic carbon densities for each forest type within a region and forming a soil database from satellite-derived land cover information and the need to use direct measurements of Soil carbon, regression approach in which regional SOC densities are related to several auxiliary variables such as temperature, precipitation, age class, and land-use history in order to determine absolute errors in these approaches [32].

Methods for measuring and estimating biomass and carbon stock

These measurements can be done or carried out through Field measurement, remote sensing and GIS techniques. Field measurement consists of two methods; the direct and the indirect methods. Direct method is simply known as harvest or destructive method. This method is mostly used in the estimation and obtaining of carbon stock and biomass in our forest ecosystems [33]. Destructive methods are the act of harvesting and cutting down of trees or saltmarshes in a specific or mapped out area and determining their biomass by measuring the weight of all the harvested tree trunk, leaves, and branches and its weight after being oven-dried [34]. This method is limited or done on a small area with different same tree or forest samples sizes. Though this method is tiresome, expensive, strenuous and resource-consuming, yet, it determines accurately the biomass stored in a particular given area. Furthermore, it is suggested that this method is not applied in a degraded forest or places with endangered species. Secondly, the indirect or non-destructive method is a way of obtaining carbon stock and biomass of a given area, without felling of trees. This method is applicable for ecosystems with rare or protected tree species, where harvesting of such species is not very practical or feasible. This indirect method is mostly based on the use of mathematical equations that relates or equates to biomass of tree variables such as DBH (Diameter Breath Height), total height, wood density, crown diameter, among others. In direct Above- ground biomass can be calculated by using an equation called "allometric equations". The indirect method saves cost, less time and resources.

The structure, composition and factors of a forest determine its carbon holding capacity and can vary most times. For instance, most forest like a rain forest with its diversity and size of individual trees or forest in them is assumed to have greater carbon storage capacity than that of the dry forest [5]. Field activities, research objectives, laboratory analyses, tree density and diameters determines the number and type of plots to be used are considered in the coverage are considered in determining in carbon estimation or investigations in any particular area

Allometric equations for carbon stocks and biomass calculations

Allometric equation is considered to be a non-destructive method or an indirect method used in the estimation of biomass. Lots of allometric equations have been generated and developed for the calculations for forest inventories for the sole purpose of assessing carbon stocks in different types of forest and tree species. Allometric equations developed for biomass estimation need to be validated. However, validation of these equations requires the felling or cutting and weighting of tree components [35, 36]. Thus, these equations are developed by developing a relationship with the physical parameters of a tree, such as breast height, tree trunk height, crown diameter, tree species and total height of a tree and age. Many researchers have developed generalized biomass prediction equations for different types of forest and tree species [37, 38]. Equations developed for single species and mixture, or varieties of species give the estimation of biomass for a specific site, also for large-scale global and regional comparisons.

Generally, the carbon concentration of the different parts of a tree is presumed to be 50% of the biomass [39]. The biomass estimation of forest can be obtained by using any of the methods or integrating the methods mentioned. Besides, when choosing suitable methods for biomass estimation, one should keep hearing the applicability or the suitability of the methods to the study area, forest type and treeing species. The allometric equations and regression models, for biomass estimation, should not be used outside their scope of validity [40, 41]. These allometric equations are useful, especially in estimating biomass of temperate and tropical forests and those with complex diversity structure. Height and diameter are the uttermost standard dependent variables for assessing tree biomass, height of individual trees are complicated to measure; thus, most allometric models for tropical forests are based only on tree diameters. In exceptional cases where tree height is the primary independent variable for explaining variations in biomass like in Palms trees, measurements of DBH, which is are mostly use for trees, explains that more than 95% of the variation in tree biomass even in highly species-rich tropical forests [42].Currently, there are no allometries equations based on destructively sampled trees for most trees in some continents or places like Central Africa [43].

Drawbacks in using Allometric Equation in estimating Biomass.

The estimation of tree biomass in some countries is done by sampling 10-30 samples of trees per species, which is few for tree biomass estimation [19]. The precision in biomass estimation are dependent on the accuracy of the original measurements used in the development of biomass assessment tools, like allometric models, biomass expansion factors (BEFs), generic equations [44,45] and species group-specific volume-to-biomass models. The lack of representativeness is the major drawback with current biomass equations.

Sampling sufficient trees to acquire information on species and size distribution in a forest especially in a highly diversify tropical forest is time-consuming and costly to achieve and can give a regression equations with high r2 greater than 0.95 tropical forests. Except in special cases where unique plant forms occur e.g. are species of palms and early colonizers, thus, developing local regression equations is highly recommended. Furthermore the representation of tropical forest biomass stock and its distribution in regional scales are poorly resolved [46, 47]. In addition, consensus on how much carbon is being emitted by changes in tropical land use are yet to be reached or ascertained [48]. Improving the methods for determining tropical forest biomass and its spatial distribution are urgently needed for calibrating.

Up scaling measurement and observation

The challenges often faced in accounting for carbon sequestration are upscale measurement. In Upscale measurement and observation, Carbon sequestration is reported from the unit area level to landscapes, regions and beyond [49,50]. Thus the main issues facing spatial upscaling are drain sample size, nonlinearities, sample extent and growing stage must be considered in Upscale measurement and report of Carbon sequestration[49,51].

Remote sensing

Remote sensing is an exciting and dynamic technology which implements techniques for acquiring data, recording data, observing and storing electromagnetic data of our natural resources, terrestrial, atmospheric, and marine system or area from a distance [52]. An object can be analyzed without any contact with the object or area in which is/are being examined. These are possible by sensing and capturing electromagnetic waves of energy being dissipated by a target object or area such as oceans, and earth land surfaces. Remote sensing technology provides a synoptic view of a geographical area of interest, thereby capturing the spatial variability in the attributes of interest [53-56]. Significant advantages of remote sensing technology are that it can acquire information about an area of interest, thereby making it possible to revisit areas or place of interest on a regular cycle; also, it aids in facilitating the acquisition of data to reveal changing conditions over time, most especially in places or terrain that is difficult to access or inaccessible. The increase in the high rate of carbon and greenhouse emissions globally has brought attention on the development of high-quality systems to enable the assessment of how much carbon is sequestered, and their changes in the terrestrial system with time. Carbon stocks in our terrestrial system and forest can be estimated by using remote sensing and applying carbon density values from data gotten from the ground or "ground truth data or national forest inventories across land cover/vegetation maps obtained by remotely-sensed data. Thus, a Remote sensing method provides scientific and technical information on ground base measurement to report Carbon sequestration spatially and regionally [57,58]. Information from various satellite sensors like the optical sensors can be related to ground based measurement or ground truth data in estimation carbon stocks.

Fine and high-resolution commercial earth observation satellite imagery such as Quick Bird, aerial photographs or IKONOS, Medium spatial resolution imagery such as Landsat have been used widely to collect and map out carbon stocks in our terrestrial systems. This high-resolution imagery is all available at a resolution of 1 m, 4 m, 15 m and 30 m etc., and is publicly available. In a place where optical sensors have a limitation, radio detection and ranging (radar) and light detection and ranging (LiDAR) data are being used.

These are due to its capability in penetrating through the forest canopy in all seasons and weather. Direct measurements of AGB are time-consuming, exhausting and bounded to small forest areas; thus, space-borne instruments can be used to measure and estimate tropical forest carbon stock and biomass from data gotten from the ground. There are several approaches in which remote sensing data can be used in estimating AGB at larger spatial scales. These approaches include using multi-stage sampling, non-parametric k-nearest neighbour technique (k-NN), multiple regression analysis, neural networks, or indirect relationships between forest attributes, and determined by remote sensing and biomass.

Most allometric models for calculating carbon stock in tropical forests are based only on tree diameter, moreover, Height and diameter are the most common dependent variables for assessing tree biomass, and thus the limitation in getting height of individual trees for allometric models has been difficult to measure. We can use remote sensing satellite small footprint LiDAR data to retrieve tree height by providing ground reference for remote sensing, which aides in estimating regional biomass.

LiDAR (Light Detection and Ranging) extensive footprint data such as Geoscience Laser Altimeter System – (GLAS) and small footprint LiDAR data like Airborne Laser Scanner (ALS) can be and has been used to retrieve indirect tree height and estimating tree heights. However, the limitations in the elevation differences present within extensive footprint LiDAR data can be substantial in comparison as its challenging to estimate tree height accurately cos of large associated errors when performing ground forest inventories [59,60]. Terrestrial laser scanning are directly used to estimate tree height at the plot level. Moreover, tree height, branches and stand density not only increases the quality of information obtained from the terrestrial laser scanner, but it also increases point spacing. Also, it decreases inherent occlusion effects results and the related uncertainty, such as whether the highest returns are echoes from the treetops or inside the tree canopy due to data quality problem [19].

Remote sensing has enabled us to monitor natural resources on a continental, even on a global scale. It is also the only realistic cost-effective reliable, time saving and can facilitate a deep understanding of our environments; wetlands land covers and its management, also effective ways of acquiring data over a large area. Remote sensing is a technique and technology used for observing, recording, and storing electromagnetic data, waves of energies that are being dissipated by a target object, or from a given area [61,62]. Remote sensing has enabled us to monitor natural resources on a continental, even on a global scale. It is also the only realistic, cost-effective, reliable, and time-saving and can facilitate a deep understanding of our environments; wetlands land covers and its management, also effective ways of acquiring data over a large area. Remote sensing is a technique and technology used for observing, recording, and storing electromagnetic data, waves of energies that are being dissipated by a target object, or from a given area.

Results and Discussion

Consequence of reducing carbon emission

There is an urgent call to reduce global greenhouse gas emission drastically, in order to mitigate catastrophic climate change [63]. For the decline in carbon emission to be achieved, the demand and reliance of fossil fuels need to decrease, though as population's increases, the demand for these energy increases. Thus, embracing, supporting and complying with renewable energy use, is a sure way to mitigate greenhouse gas emission and prevents severe impacts of climate changes [64]. Thus, it is ideal for capturing, sequestering and limiting the emission of carbon dioxide to the atmosphere, which causes global climate change. However, most countries in North America, Asia and Europe have adopted the option of Carbon Capture and Sequestration (CCS) techniques. Thus the challenges facing the technologies for it includes developing a policy driver to incentivize deployment, defining a flexible and regulatory framework, funding large scale projects to demonstrate and resolve technical uncertainties. In order to reduce the global energy use, we need to develop low or no-carbon fuel and sequestering emissions and also develop a technology to reduce the rapid of increase of atmospheric carbon dioxide (CO2) concentration from our process industry, land-use conversion and soil cultivation as this sectors account for 8.6 $PgCyr^{-1}$ annual emission of carbon dioxide from energy [8].

Climate mitigations options such as CCS are believed to be an ideal option in fighting climate change and green gas emission and stabilizing atmospheric concentrations at feasible degree. CCS is presumed and view as three steps process: Capturing, Transporting and Sequestering of carbon dioxide. The idea of capturing, transporting and sequestering of carbon dioxide and using it to create valuable products might help in the reduction of carbon dioxide in our terrestrial atmosphere and lower the net costs of reducing emissions globally.

Capturing, transporting and sequestration of carbon dioxide using available technology

Capturing carbon is simply using technology to capture carbon dioxide from the flue gas and fuel before burning in pre-combustion decarbonization, hence it also comprises the idea of separating carbon dioxide from industrial and energy related process and emission into a pure stream and getting it readily for transport from our power plants, fertilizer plan, steel mills, refineries and cement plants as these plants emits carbon dioxide to the atmosphere globally in large volumes. In addition, carbon dioxide can be captured in large quantities from industrial practices such as natural gas purification which doesn't involve fuel combustion. Though most of these options are costly, whilst most of them are cheaper. Reducing cost is an essential objective of these technological innovations.

Transportation

Carbon dioxide needs to be delivered to a source from the point where it has been captured. The most reliable way of transporting captured carbon dioxide is through pipelines, ships and tankers. However, Environment risk assessment, regulatory tariff bodies and Energy regulatory commission should play a vital role in ensuring the safety of these projects, as new pipelines structures and underground storage capacity will be needed for such a project and in oil recovery projects.

Sequestration of carbon dioxide

Carbon dioxide can be sequestered or stored into deep reservoirs by direct surjection of carbon dioxide into depleted oil and gas wells or reservoirs, un-mineable coal seams and saline reservoirs Etc. Hence, the provision and installation of different mechanisms to mitigate carbon dioxide to moving to earth's surface. These can be achieved by using a primary trapping force of impermeable cap rock layers overlying the sequestration site with additional mechanisms such as capillary trapping, and dissipation of carbon dioxide in aquifer fluids and eventual mineralization [65].

It is estimated by IPCC [66] that geological sequestration capacity of carbon dioxide throughout the world ranges from two trillion tons to 11 trillion [67], which have enough volume to serve global century's worth of carbon emissions. Challenges in sequestering carbon dioxide are mostly in identifying the best sites for sequestering it in terms of safety, cost and permanence. Most countries like U.S, Canada, China, Korea, Japan and Australia have an enormous potential site for sequestering carbon whilst most of them have little sequestration capacity [67].

It is essential to note the safety and public confidence issues in building the basics of any CCS projects or works. There are categories of physical, environmental, health and safety risk that are associated with CCS projects if not correctly managed or supervised [68-75] these risks are:

(a) Human health risk from operational problems or leakage of carbon dioxide to the earth's surface where it reacts as asphyxiate.

(b) Contamination of groundwater from direct Carbon dioxide leakage into a drinking water source.

(c) It can induce seismicity when the pressure build-ups from injecting a large volume of carbon dioxide underground [76-84].

(d) Property damage risk, underground assets contamination, environmental degradation, and impacting trees, soils and vegetation negatively if there is a direct leakage to the surface.

Although this associated risk of CCS deployment can be mitigate and curb at the beginning stage of carbon dioxide deployment and minimum likelihood of occurrence. Having a working and dedicated Systems that can provide prices for taxes for carbon emission and carbon sequestration can have major effects on the emission and sequestration levels [85-90].

Conclusion

CO2 utilization and the carbon cycle

The main purpose of carbon capture and utilization (CCU) processes are strictly on carbon dioxide removal (CCR) from our terrestrial atmosphere. These processes are a little identical with Carbon capture and Sequestration (CCS). Although CCS can contribute to the mitigation of CO2, by reducing net emissions Energy and steel plants for example and atmospheric removals of carbons, for example, by direct air carbon capture and storage (DACCS). CO2 utilization is of interest to the scientific community, due to its benefits in climate change mitigation considerations and also because using CO2 as a feedstock can result in an affordable and cleaner production process than when compared using conventional hydrocarbons. Carbon utilization is a step forward towards the successful implementation of CCS.

Furthermore, the amount of carbon dioxide being utilized by a pathway is not the same as the amount of carbon dioxide removed or stored. It does not necessarily reduce emissions or deliver a net climate benefit, mostly when indirect and other effects are already accounted for after a thorough analysis in determining its overall impact as it varies as a function of space and time. Furthermore, The amount of carbon dioxide being utilize by a pathway is apparently not the same as the amount of carbon dioxide removed or stored, also, literally, does not necessarily reduce emissions or deliver a net climate benefit, especially when indirect and other effects are already accounted for after a thorough analysis in determining its overall impact as it varies as a function of space and time. The pathways mentioned above are non-exhaustive selection of CO2 utilization pathways and they provide a transparent assessment of the potential scale and cost for each one. They are as follows:

(1)CO2-based chemical products, including polymers: The chemical catalytic conversion of carbon dioxide from flue gases or it's like into chemical products, such as methanol, urea and plastics.

(2)CO2-based fuels: Catalytic hydrogenation conversion of CO2 from flue gas or other sources into carbon dioxide fuels and Fischer–Tropsch- derived fuels. CO2-derived fuels such as methanol and methane.

(3)Microalgae fuels and other microalgae products: The Uptake or collection of CO2 from the air or other sources by microalgae biomass. The utilization finished products are Bio-products (aquaculture feeds) Biofuels, and biomass. Fuels gotten from CO2 can be deployed within any transport infrastructure; also they are argued and said to be an eyebrow-raising option in the decarbonization process and can be used in the aviation sector as this sector is hard to decarbonize. These fuels can serve as potential CO2 energy carriers' fuels for transportation.

(4)Concrete building materials: decomposition of CO2 from flue gas into industrial waste materials, and CO2 curing of concrete into concrete products. CO2 utilization pathways in building materials like concrete and steels are estimated to remove, utilize and store between 0.1 and 1.4 Gt CO2 yr^{-1} over the long term—with the CO2 sequestered well beyond the lifespan of the infrastructure itself—at interquartile. Regular cement uses calcinations of limestone, which is an emission-intensive process, but if the calcinations process is paired with carbon capture and sequestration, it can reduce carbon dioxide emission in building-related pathways.

(5)CO2 Enhanced Oil Recovery (CO2-EOR): Geological sequestration and injection of CO2 from flue gas or other sources into oil reservoirs. Enhanced oil recovery (EOR) using CO2 accounts for about 5% of the total US crude oil production. It is estimated that within 1.1 and 3.3 barrels (bbl) of these oils can be produced per ton of CO2 injected under conventional operation and within the constraints of natural reservoir heterogeneity.

(6)Bio-energy with Carbon Capture and Storage (BECCS): Growing biomass/bioenergy plants or crops. BECCS is the biological capture of carbon by photosynthetic processes in the atmosphere, with this producing biomass that can be used for fuel or the generation of electricity. However, there is substantial uncertainty regarding the total quantity of available biomass. BECCS provides bioenergy and atmospheric CO2 removal distinct services.

(7)Enhanced weathering: Mineralization of atmospheric CO2 through the process of applying pulverized silicate rock to cropland, grassland and forests. The output products are Agricultural crop biomass. Terrestrial enhanced weathering on croplands could increase crop output or yields. However, oil carbon can likely increase yield enhancement from nutrient uptake, facilitated by pH effects.

(8)Forestry techniques, including afforestation/reforestation, forest management and wood products: Afforestation and reforestation in large scales are one of the proposed strategies for increasing Carbon sequestration, Trees sequesters carbon through photosynthesis. Photosynthesis the act whereby plants remove CO2 from the atmosphere and stores carbon in standing forests. When used for sustainable forestry, a large portion of the assimilated carbon enters production processes and, after some minor energetic losses, they are turned in wood products. Furthermore, these standing forests and wood products are of economic values and can be seen or regard as CO2 utilization. Sustainable harvesting maintains carbon stocks in forests whilst providing a source of renewable biomass.

(9)Biochar, soil carbon sequestration and land management: Planting of biomass crops for pyrolysis and application of char to soils. Land management and agriculture sectors contribute about approximately 81 per cent of the total carbon emissions reductions in some countries like Australia. CO2 absorbed in land management, and biochar pathways are said to be utilized if it essentially increases agricultural output. The application of biochar can lead to an increase in tropical biomass yields, as crop productivity increases, the better economic returns for farmers and operators. It is estimated that by 2050, about 0.9 to 1.9 Gt CO2 yr^{-1} may be used up by soil carbon sequestration techniques on croplands and grazing lands.

CO2 utilization pathways can be characterized as ‘cycling’ ‘closed’ and ‘open’ utilization pathways. Conventional industrial utilization pathways like CO2-based fuels and chemicals are tagged ‘cycling because they move carbon through industrial systems for quite a long time, weeks or months. Cycling Pathways can displace fossil fuels reduce emission through industrial capture of carbon dioxide, but can do not remove Carbon dioxide from the atmosphere. Closed Utilization pathways are the storage of carbon dioxide in our lithosphere through CO2-EOR or BECCS and hydrosphere in the deep ocean through terrestrial enhanced weathering and biosphere. ‘Open’ pathways are based on biological systems. Each of these conventional pathways-chemicals, fuels, microalgae, building materials and CO2-EOR can utilize about 0.5 Gt CO2 yr^{-1} or more in decades to come and that between 0.2 and 3.2 Gt CO2 yr^{-1} could be removed and stored in our lithosphere or the biosphere for ages.

Carbon Sequestration in China

From the National Forest Resource Inventory data for China, the direct field measurement data for forest biomass and soil carbon storage data shows that between early 2000’s to date, forests sequestered more than 0.36 Pg C yr^{-1} (1 Pg=1015 g) on average, with above 0.30 Pg C yr^{-1} in vegetation and 0.06 Pg C yr^{-1} in 0–1 meter soil. The southwest region recorded 32% of the total carbon sequestration in the country which is the highest, then seconded by the northeast and south central regions. The forest ecosystem carbon sequestration in china could offset about 21% of her annual Carbon emission, especially forests in the south west province. China has planned, implemented and initiated nationwide a forestation strategies and programs, also in order to increase her Carbon sequestration in its regional Carbon budgets. The Annual average Carbon emissions from the burning and combustion of fossil fuels were recorded to be 1.7 Pg C yr^{-1}. It is reported that carbon sequestration in all china’s provinces was unequal. Provinces like Tibet, Guangxi, and Yunnan provinces achieved zero net Carbon emission and Carbon sequestration over Carbon emission. But, provinces like Shanghai, Jiangsu, and Tianjin had below 1% carbon sequestration from its forest systems. This clearly shows that energy saving, and emission reduction plan in these provinces are inevitable. Moreover, by applying in these provinces, CCS and Carbon utilization pathway in provinces and industrial sites with 1% carbon sequestration will be a sure way to realize their aims and objectives in cutting down Carbon emissions.

Declaration of Interest

No potential conflict of interest was reported by the authors

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