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A Carbondioxide Emission-Absorption Potential (CEAP) Model for Carbon Balancing in the Environment

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Abstract:- Carbon dioxide is the highest emitted greenhouse gas in the world today, mostly due to fossil fuel based energy industries and deforestation. Hence, to address the issue of climate change, one of the most significant questions is how to reduce increasing levels of carbon dioxide in the atmosphere. One promising technology is carbon capture and sequestration (CCS), which consists of capturing carbon dioxide emissions from the sources of generation and sequestering them in deep geologic formations for long periods of time. Even though researches are carried out to crystalise this technology, there has been insufficient attention paid to develop an approach that seek to balance emissions from forest ecosystems and the management of such, with environmental stewardship and economic growth as objectives. In countries where forests account as a major player in balancing CO_2, this approach becomes extremely relevant. The carbon sequestration model is a step forward in developing a complete and interconnected set of accounting practices allowing for an accurate and credible analysis of past, present, and future carbon emissions relating to forestry in the region. This paper basically looks into the ways by which global warming and the climate changes can be averted to a greater extent by the use of carbon sequestration and suggests a two-part, carbon dioxide emission-absorption potential (CEAP) model in which all flows into and out of the system are mathematically accounted for. The model is a tool meant to be of help in the assessment and resolution of trade offs at different levels in the management to ensure sustainable and balanced climate system.

Keywords:- Carbondioxide Emission-Absorption Potential (CEAP) Model, Effective Balancing of Carbon , Environment

I. INTRODUCTION

Carbon dioxide is one of the greenhouse gases that cause the earth's atmosphere to warm up, allowing the short-wave length solar radiation to come in, but trapping much of the long wave out going radiation. This interaction is a major determinant of global temperatures and the average global temperature has increased considerably in the last century [1].Carbon sequestration, in its most simple terms can be defined as the process of directing the emission of carbon dioxide either by natural or man-made process into natural carbon sinks, oceans, terrestrial environment and geological formations. The most natural way of keeping the balance of carbon in the environment is by the carbon cycle. However, in the present scenario where the emission of carbon and its oxides have gone far beyond the limit, the carbon cycle proves to be unable to cope-up. Table 1 outlines the CO_2 emitted from various resources [2]. Emerging technologies for non-conventional hydrocarbons like oil from tar are also potentially large candidates for CCS.

Today's atmosphere contains about 370 parts per million CO_2, as compared to about 280 ppm before the industrial revolution, and levels are increasing at about 0.5 % per year [3]. Much effort is currently focused on ways of reducing carbon dioxide contributions to the atmosphere going from researching the science to understanding the fundamental biological and ecological processes in unmanaged and managed terrestrial ecosystems, to the development of protocols and new policies to address this global environmental dilemma. Hence in order to control the level of carbon and its oxides in the atmosphere there is a need for reducing the emission and increasing the storage of them by mechanical means.

Table1. Global stationary sources of CO_2 emission

Process	Number of sources	Global CO_2 emissions (Million tonnes per year)
Fossil Fuels		
Power	4924	10539

Cement production	1175	932
Refineries	638	798
Iron and steel industry	269	646
Petrochemical industry	470	379
Oil and gas processing	Not available	50
Other sources	90	33
Biomass		
Bio-ethanol and bio-energy	303	91
Total	**78689**	**13468**

It is in this context that the technology based on carbon sequestration serves as a relief in bringing down the percentage of the carbon and its oxides in the atmosphere. An overview of the state of the art carbon capture and storage technology is presented preceding section.

II. OVERVIEW OF CCS TECHNOLOGY

The CCS process consists of four stages, viz. capture process, compression, transportation and storage. The capture process involves separation of CO_2 produced from industrial, power generation or related processes. Capture processes are economically viable in places where the CO_2 emissions are comparatively large [4]. After capture CO_2 is compressed to form a compressed or super critical fluid and is transported to the storage site. Transportation could be through pipelines or tankers depending on feasibility. The storage site is usually more than 800 meters underground which could be deep saline aquifers, depleted oil and gas fields, active oil or gas fields for enhanced oil or gas production, coal seams or by direction into the water. CO_2 is then geologically trapped and leakage is prevented by means of a cap rock. The major carbon storage technologies may be generally classifies into oceanic carbon sequestration, terrestrial carbon sequestration and geological carbon sequestration. Ocean form about three-fourth of the earth, which means that there is a large reservoir for carbon storage in the oceans. They are the primary long term sink for human caused carbon dioxide emissions, currently accounting for global net uptake of about 2 gigatones of carbon. It is to be noted that the process of oceanic carbon sequestration is completely natural. But the carbon dissolved in the oceans make it more acidic, thereby dissolving some of the minerals and other sediments which are vital for the survival of micro-organisms and other marine organisms. If it is left uncontrolled it may lead to the disruption of food chain in the aquatic environment which will there by affect the net carbon cycle and also other biocycles.

Many marine organisms and ecosystems depend on the formation of carbonate skeletons and sediments that are vulnerable to dissolution in acidic waters. Laboratory and field measurements indicate that CO_2-induced acidification may eventually cause the rate of dissolution of carbonate to exceed its rate of formation in these ecosystems. The impacts of ocean acidification and deliberate ocean fertilization on coastal and marine food webs and other resources are poorly understood [5]. Scientists are studying the effects of oceanic carbon sequestration on these important environments.

Terrestrial sequestration (sometimes termed “biological sequestration”) is typically accomplished through forest and soil conservation practices that enhance the storage of carbon (such as restoring and establishing new forests, wetlands, and grasslands) or reduce CO_2 emissions (such as reducing agricultural tillage and suppressing wildfires). In the United States, these practices are implemented to meet a variety of land-management objectives. Existing terrestrial carbon storage is susceptible to disturbances such as fire, disease, and changes in climate and land use.

Converting farmlands to forests or wetlands may increase carbon sequestration, enhance wildlife habitat and water quality, and increase flood storage and recreational potential, but the loss of farmlands will decrease crop production. Converting existing conservation lands to intensive cultivation, while perhaps producing valuable crops (for example, for bio-fuels), may diminish wildlife habitat, reduce water quality and supply, and increase CO_2 emissions. The effects of climate and land-use change on potential carbon sequestration and ecosystem benefits is a topic of serious research to provide information about these effects for use in resource planning.

However, the potential use of carbon sinks in forests and other terrestrial pools to offset emissions from other sources has been criticized on several grounds. Increasing carbon sinks differ from reducing emissions in three ways: the permanence issue, the saturation issue and the verifiability issue. Furthermore, if there is success in accumulating carbon sinks in terrestrial systems; there is a limited time for these sinks to grow until they reach saturation levels. A last point is that if these operations are successful, they must be accountable and verifiable.

The carbon pools are composed of live and dead above and below ground biomass, and wood products with long and short life and potential uses. According to the Kyoto protocol [6], there are three ways in which the carbon sequestered in these pools should be accounted for: afforestation, reforestation, and additionality. Afforestation implies growing trees where there were none before; reforestation addresses the idea of re-growing trees where some have been harvested, and additionality deals with the positive difference in sequestration achieved through management when compared to a base case scenario.

Generally, any approach should seek to balance emissions from forest ecosystems and the management of such, with environmental stewardship and economic growth as objectives. This is not a simple task, since it includes broad emissions inventories, emissions projections, data collection, oversight, and associated protocols. Carbon tax and carbon credit systems have been proposed to motivate increased carbon storage and/or reduce emissions [7]. Any system will require a credible accounting protocol to avoid counterproductive efforts.

Geological sequestration is the process of injecting carbon dioxide captured from the industrial or energy related sources into deep surface rock formation for long term storage. Detailed computer simulations indicate that the distribution of the injected carbon dioxide is initially dominated by gravity segregation, relative permeability effects and the permeability unisotropy of the rock formation. Complete dissolution of injected carbon dioxide is predicted to occur over hundreds to thousands of years depending significantly on the vertical permeability of the formation and the geometry of the top seal.

Considering the explosive nature of increase in CO_2 emission to the atmosphere resulting in global warming, a suggesting a single point corrective mechanism is illogical. The existing models for accounting and balancing- though moderately reliable- lack the holistic perspective. The model suggested by Manriques [8] is an attempt to improve the accuracy of maintaining the balancing of carbon – ecosystem. However, the model require modifications to incorporate corrective measures in a local time frame. The proposed Carbon dioxide Emission- Absorption Potential (CEAP) model is a step forward in developing a complete and interconnected set of accounting practices allowing for an accurate and credible analysis of relating CO_2 balancing in the region. The model is a tool meant to be of help in the assessment and resolution of tradeoffs at different levels in the management of forests as well.

The carbon sequestration analysis takes into account all that flows into and out of the system and is represented mathematically. It is at the input and output level where simplifications were made so that forest carbon balance questions could be defined.

III. THE EXISTING MODEL

There are two main parts in the carbon model: the forest module and the product module [8]. The displacement and substitution analysis are derived from the products module. The carbon forest module includes the following components: branches (dead and live), foliage, stem and bark, standing dead trees (snags), coarse roots and litter (harvest slash, dead branches and foliage). Forests are considered a standing pool of carbon at any point in time. The forest module of the carbon model is based on accounting for all allocations through biomass estimates at discrete points in time, which establishes where and how much is sequestered in what components. This allocation changes in time through losses by decomposition, and harvest operations that use fossil fuels.

Carbon additions or reductions to atmospheric pools resulted from forest growth, silvicultural treatments and decomposition. These additions (sequestration) and reductions (emissions) were calculated as the difference between total estimated forest carbon storage the growth period before treatment and total estimated forest carbon storage for the growth period post treatment (Figure 2).

Snags were determined by the tree mortality predicted by the FVS growth model. The general equation for calculating snag biomass (SB) uses species specific equations for live trees corrected for density

SB = (biomass of live tree stem * density of snag / density of live tree

The snag carbon content was estimated by multiplying the snag biomass times the species carbon factor, which is very close to the live tree carbon factor. The change in carbon content with regards to the biomass of the component remains relatively constant between live and dead trees. Existing stumps were not considered in the carbon pool, because data on those components was not available for calculation.

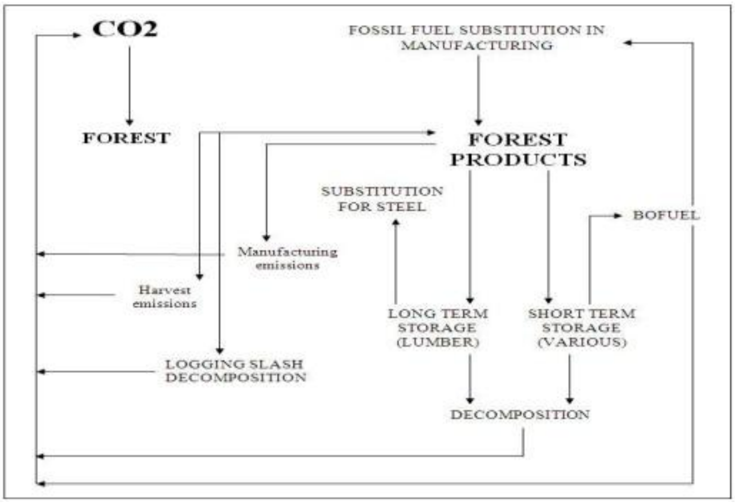

Figure 1. The forest module and its components within the carbon model.

Products are modeled with a constant rate of products loss to the atmosphere, as most studies that have addressed products have done. The model does not allow for changes in time in terms of technological improvements in manufacturing efficiencies and product use, and does not include disposal since it includes continuous decomposition. The model considers the raw biomass harvested, its conversion to products through manufacturing, and the accumulation and decomposition of the product pool through time.

The products module takes all the biomass harvested at different points in time, allocating part of it to long term and part to short term carbon pools. The long term products constitute the base for the substitution assessment. The short term products are the base for the displacement of fossil fuels by biofuels. Harvesting and manufacturing emissions are also part of the carbon model accounting.

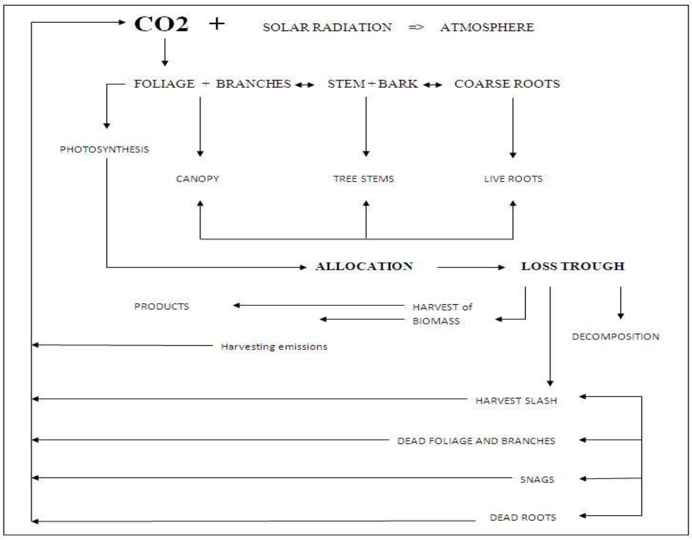

Figure 2. The products module and its components within the carbon model.

The carbon pools of lumber and co products were estimated to decompose according to species-specific annual decomposition rates [9]. Estimation of carbon loss to the atmosphere through decomposition were calculated with specific constants describing the decomposition of long and short term storage products. This calculation works for long term and short term storage products, and the decomposition of these two products pool is calculated separately within the products module of the carbon model. The model suggested increasing afforestation and intensifying forest management as possible objectives.

Carbon sequestration and global CO_2 balance have been studied by various researchers [9, 10, 11].These studies demonstrated the level of complexity needed to adequately account for carbon sequestration related to forest management.

IV. THE PROPOSED CARBONDIOXIDE EMISSION- ABSORPTION POTENTIAL (CEAP) MODEL

Based on the discussion elsewhere, it may be observed that one of the potential causes for increased rate of emission of CO_2 to atmosphere are burning of fossil fuels (oil, gas and coal) by human including industrial activities, heating, power generation and automobiles used for transportation. This estimated to be about 6%-7% of the total CO_2 emission to atmosphere. Natural processes like volcano eruption in addition to the biological decomposition processes and decay contributes steadily to the CO_2 emissions. Deforestation reduces the CO_2 absorption rates, which indirectly contributes to the increasing rates of CO_2 formation in the atmosphere. The CEAP model considers all these factors in the generation (emission) side that is represented schematically in Figure 3.

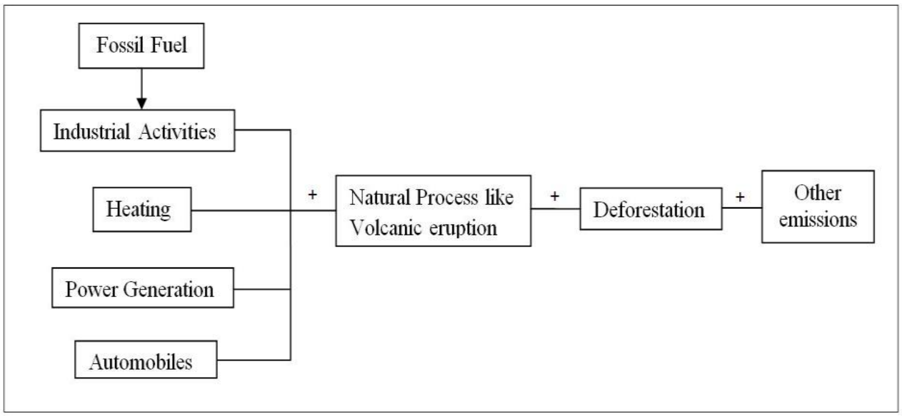

Figure 3. Factors in the emission side of the CEAP model.

A term called the Carbon dioxide Emission Potential (CEP) is defined which is the rate at which CO_2 is expected to emit to the atmosphere due to an activity. Thus the Net Carbon dioxide Emission Potential (NCEP) may be mathematically represented as,

$$NCEP = \sum_{i_1=1}^{n_1}\sum_{j_1=1}^{k_1}(CEP)j_1 + \sum_{j_2=1}^{k_2}(CEP)\,j_2 + \sum_{j_3=1}^{k_3}(CEP)\,j_3 + \sum_{j_4=1}^{k_4}(CEP)\,j_4 \quad (1)$$

On the other hand the three carbon storage technologies like oceanic carbon sequestration, terrestrial carbon sequestration and geological carbon sequestration that will help in reducing the CO_2 content in the atmosphere. Afforestation, reforestation and additionality are also viable means in reducing the net CO_2 content. The factors in the absorption side of the model is represented schematically in Figure 4.

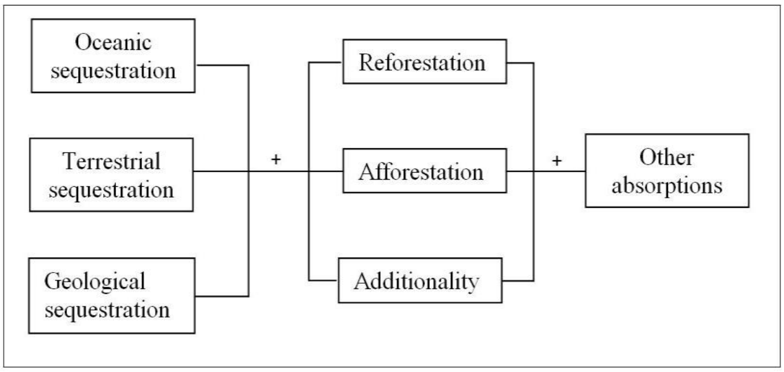

Figure 4. Factors in the absorption side of the CEAP model.

A term called the Carbon dioxide Absorption Potential (CAP) is now defined which is the rate at which CO_2 is expected to be absorbed from the atmosphere due to individual activities. Thus the Net Carbon dioxide Absoption Potential (NCAP) may be mathematically represented as,

$$NCAP = \sum_{i_5=1}^{n_5}\sum_{j_5=1}^{k_5}(CEP)j_5 + \sum_{i_6=1}^{n_6}\sum_{j_6=1}^{k_6}(CEP)j_6 + \sum_{j_7=1}^{k_7}(CEP)\,j_7 \quad (2)$$

For maintaining the balance of CO_2 in the atmosphere, it is essential that NCEP=NCAP. Thus,

$$\sum_{i_1=1}^{n_1}\sum_{j_1=1}^{k_1}(CEP)j_1 + \sum_{j_2=1}^{k_2}(CEP)\,j_2 + \sum_{j_3=1}^{k_3}(CEP)\,j_3 + \sum_{j_4=1}^{k_4}(CEP)\,j_4 = \sum_{i_5=1}^{n_5}\sum_{j_5=1}^{k_5}(CEP)j_5 + \sum_{i_6=1}^{n_6}\sum_{j_6=1}^{k_6}(CEP)j_6 + \sum_{j_7=1}^{k_7}(CEP)\,j_7 \quad (3)$$

In the above equations, i_1, i_5, i_6 take care for the fossil fuel burning, carbon sequestration and forestation components respectively while j_1 to j_7 represents the summation of individual components that contribute to NCEP and NCAP.

This is a simple but very powerful model which reveals the measures that has to be taken to maintain a balance of CO_2 in the atmosphere, avoiding any further global warming. For example, an automobile manufacturer will be increasing the NCEP which is the left hand side of the equation (3). Hence by calculating the net emission caused by the manufacturer per year, based on the industry's CEP, it may be made mandatory that the industry contribute to an equal amount to the NCAP (the right hand side of equation (3). This may be achieved by contributing to any of the term or terms in the RHS, i.e. to afforestation, geological carbon sequestration etc. or a combination.

Authors suggest that an international body be constituted - with subsidiaries in the national level- to monitor the activities that may result in the increase of NCEP of the globe. Present international laws may be amended to make it mandatory for new/existing establishments in any region to contribute to an equal amount of NCAP as their NCEP. This will effectively seal further deterioration of the climate and ecosystem due to global warming caused by carbon dioxide. This model may be extended to other potential causes of global warming and used to suggest corrective measures. Ensuring preservation of what we have to the future generations.

V. CONCLUSION

In this paper, we have attempted to develop a Carbondioxide Emission-Absorption Potential (CEAP) model to address the liability associated with potential contributors to global warming due to carbon dioxide accumulation in the atmosphere. The issue of CO_2 formation and the current status is discussed in detail along with the carbon sequestration technologies. Existing models for carbon balancing have been critically evaluated and a simple, realistic but powerful model has been developed. The necessity of an international body to monitor and restrict the emission CO_2 to the atmosphere has been emphasised. The CEAP model has been developed as a tool to assist decisions on the impact and remedial measures to control global warming due to CO_2. The proposed CEAP model may be used to restrict global warming due extensive increase of CO_2 in the atmosphere and ensure preservation of what we have for the future generations.

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