Modeling The Mechanism Of Carbon Capture And Sequestration (Ccs) In A System

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Abstract: Rate of carbon sequestration or annual uptake was modeled. Data from Mississippi Delta, ponderosa pine and black walnut, all in USA were used to validate the models. The co-relations of these models for these three sources of data were very high, suggesting that carbon sequestration is modelable and predictable provided that there is a perfect experimental method to capture and sequester the carbon compound with time. This work is a stepping stone to solving carbon capture and sequestration problem of our planet earth. Through a global engineering and technology it is feasible.

Keywords: Carbon Capture, Sequestration, model, annual uptake, cumulative, calculus.

1 INTRODUCTION

Carbon capture is the withdrawal of carbon compounds (CO_2) from the atmosphere. This carbon or carbondioxide are made to be naturally or artificially occurring in the atmosphere through bush burning, respiration and more especially, nuclear activities and other fossil fuel combustion so that we have more than normal the amount of carbon or carbon-dioxide in the atmosphere, [1]. This heat retention process is critical to maintaining habitable temperatures. If there were significantly less $C0_2$ in the atmosphere, global temperature would change to levels to which ecosystems and human societies have adapted. As $C0_2$ level rise, mean global temperatures would drop below level to which ecosystems and human societies have adapted, [2]. It is important that we note the problem globally and start solving it on time before the ozone layer or the ice bag will melt completely as a result of excessive gas emission in the system. There has been research on mechanism to increase the rate at which the oceans can be used to extract and store carbon from the atmosphere, [3]. Additionally, it may be possible to increase the rate at which ecosystem removes $C0_2$ from the atmosphere and store the carbon in plant materials, decomposing detritus and organic soil, [4].

1.1 Drift Origin

Most analyses to data of options for mitigating the risk to global climate change have focused on reducing emissions of carbon dioxide and other green house gases (GHG_s). Much less attention has been given to the potential for storing or sequestering significant amounts of carbon in forests and other ecosystems as an alternative means of offsetting the effect of future emission of GHG concentrations in the atmosphere. The tendency to overlook sequestration opportunities can lead to incorrect and overly pessimistic conclusions about the cost and feasibility of addressing global climate change in the decades ahead, [5]. It is necessary to decide whether carbon sequestration should be part of the domestic portfolio of compliance activities, [4].

2 DEVELOPMENT OF MODELS

Agro forestry is the practice of combining forestry production and agricultural production to derive synergistic benefits. For example, biomass grown in short rotation plantation can displace fossil fuel in the provision of energy service and so decrease carbon emissions, [5]. Urban forestry makes use of space in urban area to increase carbon sequestration and reduce energy used for heating and air conditioning, [3]. To sequester mean to set apart, seclude, withdraw from others, to isolate a thing from the system or environment, [6]. Therefore, carbon sequestration means to isolate or withdraw carbon from the atmosphere. This carbon or carbon dioxide is made to be there naturally and artificially through burning of bush, respiration, more especially nuclear activities so that we have more than normal amount of carbon or carbon dioxide in the atmosphere, [1]. Sequestering carbon will involve man's global technology if properly co-ordinated. Unsaturated carbon compounds (like carbon monoxide) in a very hot environment; like freshly released from nuclear activities, react with so many other things in the environment including ozone which is fencing the sun heat and thereby creating ozone layer depletion and so changing God's atmosphere and space, [7]. The ruptured ozone layer fencing the sun leads to enormous heat from sun, passing through the layer and heating up the earth. Evidence of these is seen in the melting, for the first time, of the colossal ice-bags which has been standing like mountains on the polar regions of arctic and Antarctic. How this carbon compound can be capture and sequestered has been the literature of so many academicians today. However, few have attempted to model this global engineering and technology with minor successes, [6]. Rate of carbon sequestration on forest lands depends on the management practices adopted, the species of trees involved and the geographic area covered. But globally the time rate of sequestration of carbon or uptake of carbon is a joint variation:

1. The time rate of change (annual uptake) of carbon is proportional to the exponential decreases of time i.e.

$$\frac{dc}{dx} \alpha\ e^{-kx} \ or\ \frac{dc}{dx} = be^{-kx} \qquad \text{........................} \qquad (i)$$

2. This time rate of change of carbon is also proportional to time itself raised to a constant power, n, i.e.

$$\frac{dc}{dx}\ \alpha\ x^n \ or\ \frac{dc}{dx} = ax^n \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (ii)$$

so that jointly combined we obtain

$$\frac{dc}{dx} = abx^n\ e^{-kx}$$

or

$$\frac{dc}{dx} = Bx^n\ e^{-kx} \ \ldots\ldots\ldots\ldots\ldots\ldots \qquad (1)$$

Model (1) is a dumbbell annual uptake of carbon or Carbon Sequestration Rate (CSR). The result of integration of this model yields cumulative carbon sequestered (CCS) over a region with time.

Thus,

$$CSR = \frac{d(CCS)}{dx} = BX^n e^{-kx}$$

Therefore

$$CCS = \int (CSR)dx = B\int X^n e^{-kx} dx$$

For n = 1,

$$CCS = B\left(M - \left(\frac{X}{K} + \frac{1}{K^2}\right)e^{-kx}\right) \qquad (2)$$

Generally,

$$In = \int X^n e^{ax} dx = \frac{X^n e^{ax}}{a} - \frac{n}{a}\left(\frac{X^{n-1}e^{ax}}{a} - \frac{n-1}{a}\left(\frac{X^{n-2}e^{ax}}{a} - \left(\ldots\left(\frac{e^{ax}}{a}\right)\right)\right)\right) + M$$

Thus,

$$B\int X^n e^{-kx} dx$$

$$= B\left(\frac{X^n e^{-kx}}{-k} - \frac{n}{-k}\left(\frac{X^{n-1}e^{-kx}}{-k}\right)\left(\frac{X^{n-2}e^{-kx}}{-k}\left(\ldots\left(\frac{e^{-kx}}{-k}\right)\right)\right)\right)$$

$$+ M$$

If n=1

$$I_1 = B\left(\frac{Xe^{-kx}}{k} - \frac{e^{-kx}}{k^2} + M_1\right) = B\left(M - \left(\frac{x}{k} + \frac{1}{k^2}\right)e^{-kx}\right) \qquad (2)$$

If n=2

$$I_2 = B\left(\frac{X^2e^{-kx}}{-k} - \frac{2}{-k}\left(\frac{Xe^{-kx}}{-k} - \frac{1}{-k}\left(\frac{e^{-kx}}{-k}\right)\right) + M\right) = B\left(M - \right.$$
$$X2k+2Xk2+2k3e-kx \qquad (3)$$

If n=3

$$I_3 = B\left(\frac{X^3e^{-kx}}{-k} - \frac{3}{-k}\left(\frac{X^2e^{-kx}}{-k} - \frac{2}{-k}\left(\frac{Xe^{-kx}}{-k} - \frac{r}{-k}\left(\frac{e^{-kx}}{-k}\right)\right)\right) + M\right) =$$
$$B\left(M - \left(\frac{X^3}{k} + \frac{3X^2}{k^2} + \frac{6X}{k^3} + \frac{6}{k^4}\right)e^{-kx}\right) \qquad (4)$$

2.1 Data Collections

Sequestered cumulative and annual data were sourced and obtained via the internet as shown in tables 1 and 2.

Table 1: Cumulative C-Sequestered with time, [7], [8].

Time (yrs)t	0	10	15	20	25	30	35	40	45	60	70	80	90
cumulative C-seqd (tons/acre)	0	20	40	60	80	90	100	110	120	142	147	150	154

Table 2: Annual C – Uptake with time, [9]

Time (Yrs)	0	15	25	35	45	75	85	95	105	115	135	145	155
C – seqn rate ponderosa CSR$_{pp}$ $\left(\frac{ton}{acre.yr}\right)$	0	1.75	1.75	2.0	2.36	2.75	2.65	2.50	2.00	1.65	1.00	0.85	0.65
C–seqn rate, walnut CSR$_{bw}$ $\left(\frac{ton}{acre.\ Yr}\right)$	0	1.50	1.63	1.58	1.55	1.	1.0	0.8	0.77	0.70	0.50	0.50	0.4

2.3 CURVE FITTING

The data collected as shown in table 1 & 2 are used to validate the models 1 and 2 using tool box of MATLAB package 7.0.

3 RESULTS

The result of the computation in the previous section are as shown in figs 1a & b, 2a & b, 3a & b and table 3 to 5 respectively.

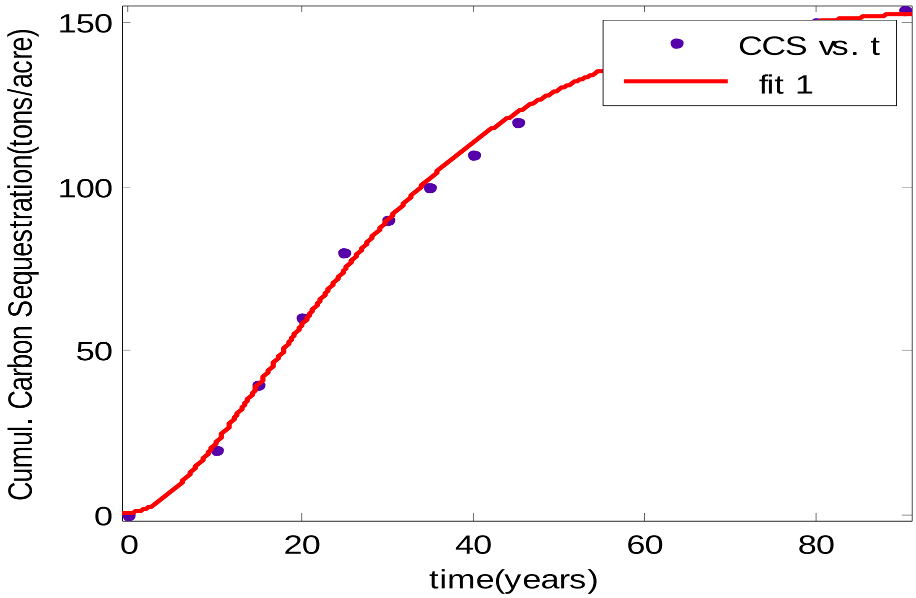

Fig.1a; Cumulative Carbon Sequestration versus time, model 1

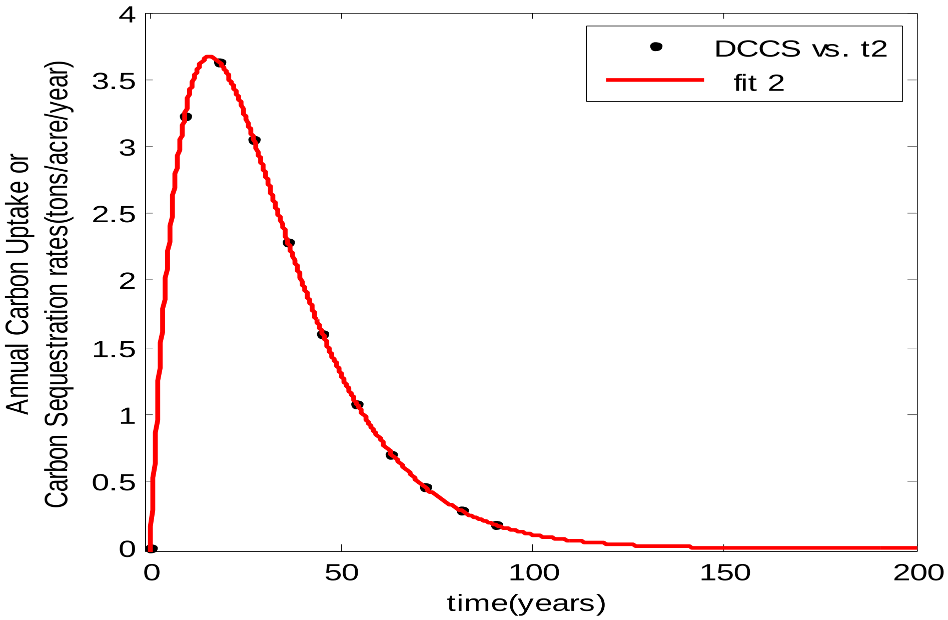

Fig.1b;Annual Carbon Uptake versus time(Carbon Sequestration rates),model 1

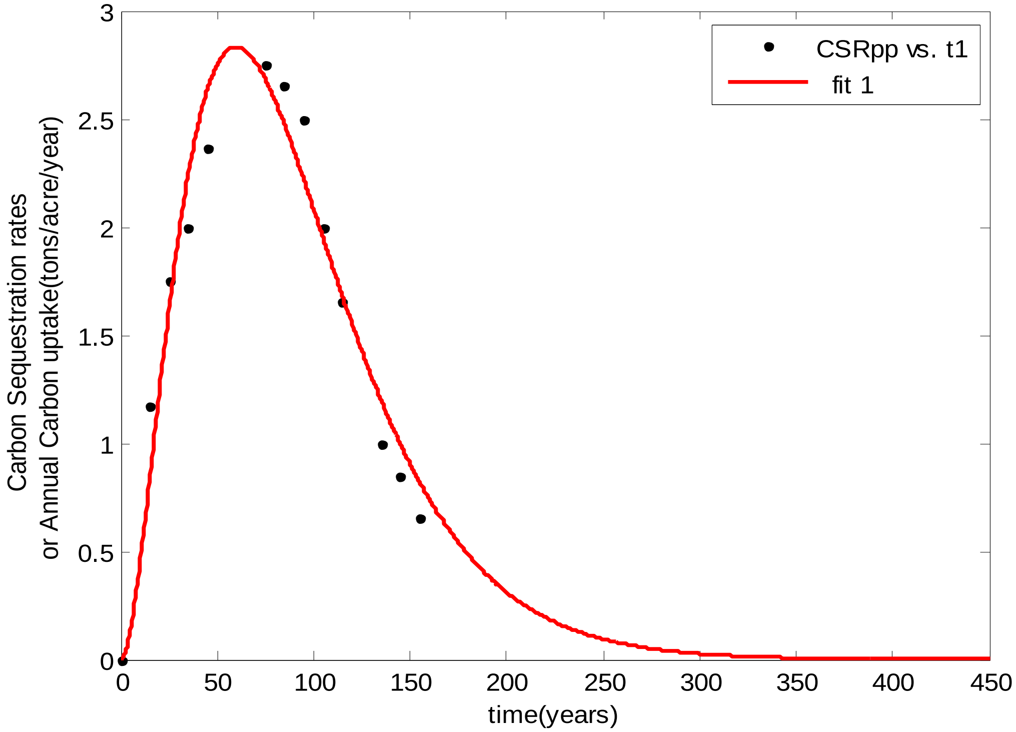

Fig.2a; Annual Carbon Uptake versus time or (Carbon Sequestration rates),model 2

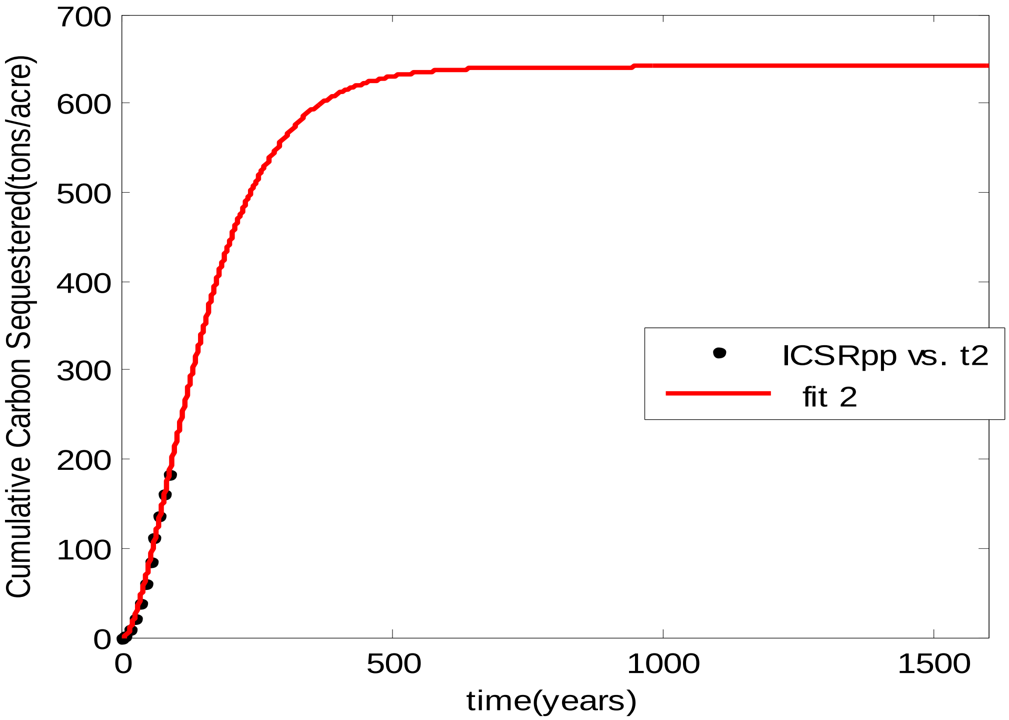

Fig.2b; Cumulative Carbon Sequestered versus time, model 1

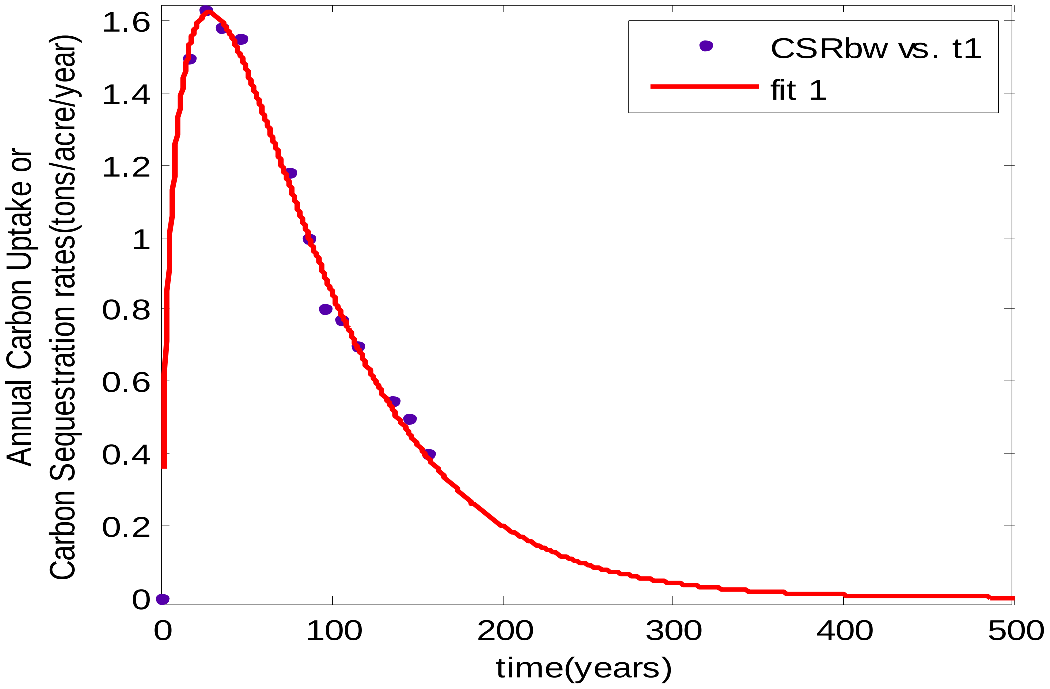

Fig.3a; Annual Carbon Uptake versus time or (Carbon Sequestration rates), model 2

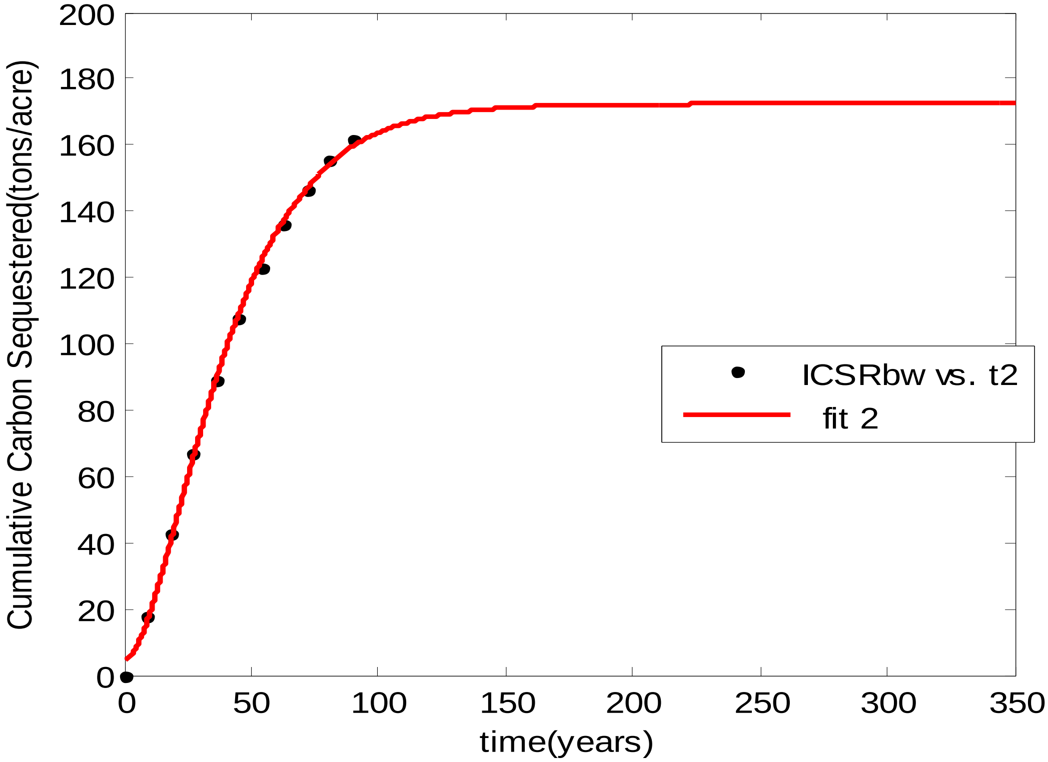

Fig.3b; Cumulative Carbon Sequestered (tons/acre) model 1

Table 3: Coefficients and Goodness of fit for model 2: CCS Mississippi delta USA

Coefficient and Goodness of fit (Model 2: fig. 1a)	Time (yrs.)	DCCS (tons/acre/yr
M = 244 B = 0.6395 K = 0.06417 n = 1.0 SSE = 68.02 R^2 = 0.9978 R^2 – Adjusted = 0.9974 RMSE = 2.608 tpk:f(16)=3.66577(from fig. 1b)	0 9 18 27 36 45 54 63 72 81 90	4.05×10^{-9} 3.23 3.63 3.05 2.29 1.60 1.80 0.707 0.454 0.2865 0.1787
$B\left(M-\left(\frac{X}{K}+\frac{1}{K^2}\right)e^{-kx}\right); fig. 1a$	$BXe^{-kx}\ ; fig. 1b$	

Table 4: Coefficients and Goodness of fit for model 1: CSR ponderosa pine USA

Coefficient and Goodness of fit (Model 1: fig. 2a)	Time (yrs.)	ICSR (tons/acre/yr)
B = 0.007186 n = 0.03241 K = 1.935 SSE = 0.4767 R^2 = 0.9452R^2 = 0.9452 R^2 – Adjusted =0.9343 RMSE = 0.2183 **<u>Fig 2b</u>** U:F (1576) = 641.151 M = 69.5 K = 0.01197 B = 0.09231	0 9 18 27 36 45 54 63 72 81 90	0 1.25 7.705 20.55 38.94 61.29 85.92 111.36 136.43 160.30 182.43
$BX^n e^{-kx}\ ; fig. 2a$	$B\left(M-\left(\frac{X}{K}+\frac{1}{K^2}\right)e^{-kx}\right); fig. 2b$	

Table 5: Coefficients and Goodness of fit for model 1: CSR Black Walnut USA

Coefficient and Goodness of fit (Model 1: fig. 3a)	Time (yrs.)	ICSR (tons/acre/yr)
B = 0.5307 n = 0.4842 K = 0.01768 SSE = 0.0164 R^2 = 0.995 R^2 - Adj = 0.994 RMSE = 0.0405 **Fig. 3b** U:F (327) = 172.375 B = 0.3684 M = 467.9 K = 0.04683	0 9 18 27 36 45 54 63 72 81 90	0 17.78 42.51 66.85 88.62 107.34 123.03 135.96 146.51 155.03 161.86
$BX^{n}e^{-kx} : fig.3a$	$B\left(M - \left[\frac{x}{k} + \frac{1}{k^{2}}\right]\right)e^{-kx};\ fig.3b$	

DISCUSSION

From the figs. 1a to3b and tables 3 - 5 gotten from this work it is evident that carbon sequestration is model able. It behaves like the natural resource - time variations by giving a sigmoidal cumulative profile and a dumbbell annual rate profile. Its peak and exhaustion, even ultimate value, can be determined. The dumbbell annual uptake model established was integrated to fit the sigmoidal cumulative carbon sequestered data obtained from the internet (Tables 1, 3 and Fig. 1a). The differentiated data (DCCS) was obtained by the help of analysis of MATLAB tool box to plot Fig.1b (annual carbon uptake). In fig 2a, the data (Table 2) were obtained as annual sequestration uptake which is already a dumbbell data and it is fitted to the developed dumbbell model 1 as shown in table 4. When the model is integrated (ICSR in Table 4) and re-plotted with model 2 (Fig. 2b) cumulative carbon sequestration resulted. In fig 3a, like fig 2a, another dumbbell data (Table 2) were plotted, straight, with dumbbell model 1. It fitted as shown in table 5. When the model is integrated, Fig 3b, a cumulative carbon sequestration was the result. Therefore, it is a simple calculus: moving from dumbbell to sigmoidal and back, it depends on what type of data is available. From the data obtained from these three sources i.e. in table 1, (Mississippi data), table 2 (Ponderosa pine and Black Walnut) all in USA, it seems that carbon sequestration technology is model able right now. To capture and sequester is one thing, to store is another. Storing of captured and sequestered carbon compound is posing a lot of problem; some suggested reinjection into an empty oil well, others suggested advanced and complicated reactions with other chemicals making it inactive or liquefying it so that it can be stored at the floor of the deepest oceans. Its reaction to bio- life in the ocean has not been determined, if this is to be done. Also its lickage and coming back to the atmosphere, if injected into empty oil wells, has be discussed widely without concrete scientific assurance that this solution will be permanent. Therefore, this model is a tip of the ice-bag as for handling of sequestered carbon compound are concerned.

CONCLUSION

Rate of carbon sequestration or annual uptake was modeled. Data from Mississippi Delta, ponderosa pine and black walnut, all in USA were used to validate the models. The co-relations of these models for these three sources of data were very high, suggesting that carbon sequestration is model able and predictable provided that there is a perfect experimental method to capture and sequester the carbon compound with time. This work is a stepping stone to solving carbon capture and sequestration problem of our planet earth and consequently a panacea to global warming and other environmental challenges, if properly harnessed.

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