Climatic Change (2008) 87:329–334
DOI 10.1007/s10584-007-9385-6

EDITORIAL

"Biosphere carbon stock management: Addressing the threat of abrupt climate change in the next few decades." By Peter Read. An editorial comment.

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Received: 14 October 2007 / Accepted: 24 October 2007 / Published online: 26 February 2008

This essay by Peter Read (2008) is a timely exploration of the potential to facilitate significantly increased carbon sequestration through additional land based photosynthetic processes (bio-sequestration) in the context of recent carbon cycle trends reported by Canadell (Canadell 2007);

- the rate of CO_2 accumulation in the atmosphere is now significantly higher than the highest estimates used in the Intergovernmental Panel on Climate Change (IPCC) models,
- the carbon intensity of economic activity has begun increasing again since about 2000, reversing a falling trend of some 100 years duration,
- the efficiency of natural carbon sinks is decreasing.

These trends suggest that the world needs to consider all possible rapid and large scale actions to avert the consequences of potentially abrupt climate change, particularly where this may produce early results and remove CO_2 rather than just reducing emissions.

Read also points to the potential for improvements in bio-sequestration through land based agriculture and forestry to improve the livelihoods of the people engaged in these activities, particularly where this takes place in developing countries. He is not the first to suggest this possible happy coincidence of goals. There were significant efforts to promote such investment in the lead up to the signing of the Kyoto protocol in 1992 and these efforts have continued since, particularly for tropical forests (Chomizt 2007).

What is new in this essay is the suggestion that it may be possible to reduce atmospheric carbon to, or even below, the levels existing at the beginning of the industrial revolution even with increasing industrial emissions, (F in Read's figure 1) if the world is 'managed' to achieve and maintain atmospheric carbon at levels to preserve its 'health' rather than by 'managing emissions' as is now proposed.

This is a valuable thought experiment as it may have the effect of refocusing attention on the potential for bio-sequestration to contribute to climate change abatement after it had

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been almost sidelined at the time of Kyoto due to methodological and social reasons (Gullison et al. 2007). These included;

- that photo synthetic processes might be only a 'one shot' contribution until forest canopies close again,
- that land based sinks were considered more diffuse and difficult to monitor than industrial emissions and to be more subject to 'leakage', for example, where reforestation is offset by more forest clearance elsewhere for logging and food production, often exacerbated by governance issues inhibiting the control of logging in many tropical regions.

Underlying these concerns at the time of Kyoto was the fear that the possibly cheap gains to be made in the tropics would divert the industrial world from the far more important goal of controlling industrial emissions in the long term.

Apart from the accelerating signs of climate change due to human activity noted above, there are several reasons why the concerns that inhibited a broad inclusion of agricultural and forest carbon sinks into the Kyoto protocol in 1992 should be reconsidered. The science of monitoring and accounting for carbon pool changes in above ground vegetation has advanced, as has the resolution of satellites. More case studies have shown the potential for cost effective bio sequestration by rehabilitating degraded tropical regions and the potential for more secure carbon storage in soils is better understood (Leake 2007).

However a difficulty acknowledged by Read is the 'daunting organisational prospect' of reorienting the management of the planet on the scale necessary for net negative emissions to occur at the rate he has suggested. The same sense of urgency of action due to signs of accelerating climate change (e.g. the significant increase in seismic events in Greenland suggesting significant ice slippage and the North Sea ice melt over 2005–2006) caused this author to also review the potential to address climate change by increasing photosynthesis, particularly in the tropics (Leake and Flannery 2007).

The focus of our review was to look for case studies of where the carbon market might be used to fund a process to reverse the 'negative' succession processes that have led to accelerated emissions from deforestation and agriculture in the tropics. Case studies that have tested the possibility that the slash and burn agriculture, indiscriminate forest clearance and mechanical agricultural practices that have led to increased emissions can be modified by mobilising the real interest of people who live in degraded tropical areas to improve their livelihoods by improving their production base.

This contrasts with a wholesale reorientation of the agricultural economy to manage carbon stocks as suggested by Read. Our review of case studies of different land and near shore systems in the tropics and subtropics resulted in an estimate that some 192 Giga tonnes might be sequestered over a 50–80 year period (depending on the sequence of start up) as summarised in Table 1 below.

The assumptions behind this estimate are detailed in a paper submitted for publication in this journal (Leake 2007). This estimate can be placed in the context of a range of global estimates by different authors, including Read, as summarised in Table 2 below (ibid). Converting this estimate to compare with net emissions from the time of the Industrial Revolution provides substantiation for the equity argument that the west should invest to make a 'one shot' contribution to the ongoing problem of combating climate change. The result is a wide range of estimates from 25% to 6 times the net emissions since 1800 (207 g t).

However, as noted in most of the papers we reviewed and by the IPCC, (Montreal 2000), the most difficult assumption is the percentage of suitable areas over which uptake of

Table 1 Estimates of total carbon sequestration by year 50[(1)]

Land system	Area in million ha[a]	Carbon seq. per million ha at full development[b] (a range) & est. million t	Uptake in % at year 30 of each project[c]	Total carbon[d] at year 30 in Mt
Degraded forests	1,344	(58–110) 85	65	74,256
Mixed crop lands in the same degraded forest areas	1,344	(50–400) 20	5	1,344
Fire climax grasslands	200	(50–400) 85	75	12,750
Mixed crop lands in the same fire climax grasslands	200	(50–400) 50	5	500
Subtropical grasslands	2,000	(50–70) 55	70	77,000
Mixed crop lands in subtropical grasslands	1,000	(10–60) 30	60	18,000
Mangroves and coastal coral	1	(178–1,900) 200	25	50
Salty and other low quality irrigable land	77	200	50	7,700
Total				191,600

[(1)] 50 years includes start up period of 20 years for each situation.

[a] FAO figures adjusted for estimates of availability.

[b] 'Full development' is taken as the point where the degraded forest canopy closes and when the associated agro forestry is sufficient to support the population. Actually soil carbon storage in these cultivated areas would continue under the land uses suggested, including under agriculture.

[c] A professional estimate of possible uptake by the author.

[d] These figures are gross turnaround, including the carbon emissions that cease over the land treated.

changed land management practices might be expected, as this will depend on the incentives provided and a wide range of cultural, logistical, market and political factors.

These estimates may have influenced a major recent forestry initiative proposed for Asia-Pacific Economic Cooperation (APEC) countries in July 2007. Unfortunately, by focussing on the forestry part of our estimates, the authors of this initiative may too have over-estimated the possibilities for success due to the same socio-economic factors not fully taken into account by Read. The most important of these factors is likely to be

Table 2 Global estimates for the potential for bio-sequestration

Authors	Estimate range (% of fossil emissions)	Time period (years)	System dealt with	Adjusted for net emission since 1,800 (g t)
IPCC (Moffat 1997)	12–15	55	All terrestrial systems (soils understated)	125–130
FAO (2005)	15	50	Forestry & agro-forestry	130
Winjum (1992)	12.5–25	50	Forestry & agro-forestry	125
CSites (2002)	50 – 100	80	Forestry	111–277
Read (2008)	25 – 600	60	Arable lands	50–1260

consideration of the livelihoods of the people who live in these areas upon whose efforts and subsequent actions success will largely depend.

Many of the case studies reviewed note that of the factors important for success, secure rights to use the land and forest resources in which people are expected to invest and also to allow food production, are fundamental. These factors can be addressed;

- Food and Agriculture Organization (FAO) reports that some 80% of 'forest' lands world wide are still under Government titles and therefore there is considerable scope for Government to contribute these assets as significant non cash inputs where people meet agreed objectives.
- The ability to grow food for sustenance and local sale can be greatly enhanced by attention to soil fertility in such a way as to reverse carbon loss.

The ability to sequester carbon into soils, particularly in the tropics has long been a controversial consideration in carbon accounting even though it is acknowledged, including by the IPCC (Montreal 2000), that more carbon is stored in soils than in vegetation including roots. This is partly because of difficulties measuring and monitoring soil carbon and partly because soil carbon is commonly considered to be ephemeral and easily lost through oxidation processes associated with cultivation and disturbance, particularly in the easily leached soils of the tropics.

Fortunately recent work has shown that very secure soil carbon stores can be, and have been, built up under a wide variety of land systems. Some of this consists of organic decomposition products that are only soluble with changes in pH (Fulvic acids), some that are not soluble at any pH (Humic acids) and charcoals that result from incomplete burning of vegetable matter during cultivation. These 'recalcitrant products' of organic decay have been shown to have retention times in the soil of hundreds of years (Berg and Laskowski 2006). Indeed the carbon in some soils (termed Terra Preta) has been found in the Amazon Basin to have remained stable for thousands of years (Lehmann et al. 2005). Additional work by the same author has shown that such soils might be easily replicated by modification of traditional cultivation practices in the tropics in many areas and that they provide additional benefits to the farmer in terms of water holding capacity and nutrient uptake efficiency (cation exchange capacity). It may be significant that these processes lock away more carbon than oxygen and, as the cycle time of atmospheric carbon averages only 8.3 years compared with oxygen at 4,000 years (Rickelfs 1979, quoted in Berg and Laskowski 2006, p 4) increasing soil carbon stores may provide more climate abatement 'leverage' than sequestering $C0_2$ or dissolving more of it in the sea.

Another key requirement for success in bio sequestration in this way is that both buyers and sellers of carbon can be similarly informed about carbon movements to facilitate desired responses and a transparent market. This is likely to be best achieved by involving farm families in the 'ground truthing' activities necessary to validate remote satellite monitoring and this will require locally available simple 'web capable' computing facilities and a good organisational process that allows communication with regional and national governments as well as facilitating other governance activities. There has been considerable development of 'participatory' organisational processes in recent years to achieve the necessary interdisciplinary approach for such communication but the tendency for large organisations to organise activities around disciplines such as 'forestry for trees' or 'agriculture for cropping etc' mitigates against such communication and may be an important reason why the mix of incentives, soils, cultural and market circumstances faced by the people who are expected to implement activities are not always well addressed in large programs such as the recent APEC forestry initiative (although details of this initiative have not yet been announced).

A related factor is the evaluation of such interdisciplinary programs with a multiplicity of ‘on and off site’ costs and benefits. Policy makers are naturally concerned to find cost effective approaches to climate change abatement. The costs of carbon sequestration through avoided deforestation and reforestation have been estimated by various authors on a basis of financial cost and the opportunity cost of the resource base. Estimates of cost have ranged from $0.01 per tonne to $15.00 per tonne as reported by the IPCC (Montreal 2000). Estimates of the opportunity cost range from $2.00 per tonne of carbon to $40 per tonne for degraded forests in the Philippines (Sheeran 2006). Although the opportunity cost is a more realistic value than the financial cost as it takes into account production forgone, it too may miss the full value of an investment to facilitate carbon sequestration to the various participants and so miss attractive opportunities.

As noted in previous sections this is because investments to facilitate forestry protection, reforestation and associated agro forestry have a number of direct and indirect on site and off site benefits, many of which are difficult to ascribe adequate economic values for analysis, and difficult to assign to relevant stakeholders to provide the necessary incentive for action (Lipper and Cavatassi 2003). This is particularly so for environmental benefits such as carbon sequestration and bio-diversity conservation. This has in the past meant that often only on-site direct benefits are given numeral values in economic evaluations. FAO reviewed 5 studies of projects previously funded to illustrate the differences (Cavatassi 2004). These are shown in Table 3.

The authors noted that although the projects had environmental benefits as the main goal, it was the on-site private benefits that provided the justification for the investment. They commented that the inadequate calculation of on and off site public benefits did not allow for reaching a conclusion about the worthiness of their inclusion. They also commented that in some of the cases many indirect on-site benefits in terms of food or livestock production were not, or only indirectly, estimated, which meant the economic rate of return (ERR) was inadequate for even private benefits.

The same may be said for off site costs, notably in the area of bio diversity loss, where different strategies have the potential to either enhance bio diversity conservation, where natural flora and fauna corridors and refuges are enhanced, or negatively where a plantation approach is taken and neither option can be assessed adequately.

Table 3 The impact of offsite costs and benefits on the returns from carbon sequestration

	Maharatsra	Gujarat, Orissa and Rajastan	Philippines	Nepal	Andrapradesh
ERR with only on-site private benefits	7%	13.5%	Reforestation 43% Agro forestry 48%	14%	22%
ERR including on-site public benefits	Not available	14%	Reforestation 43% Agro forestry 48%	17%	Not available
ERR with Global environmental benefits at 0 per tonne	10%	Not available	Reforestation 53% Agro forestry 52%	18%	29%

It proved impossible to ascribe economic values to bio-diversity conservation benefits with available data. ERR: Economic Rate of Return, used by many agencies such as the World Bank as a means of ranking the economic performance of projects using world parity pricing.

The conclusion is that the economic literature on activities to facilitate bio-sequestration may be underestimating the potential benefits (or costs) and that a much wider frame of reference is required to adequately assess bio-sequestration investments and this is without considering the suggestions of the Stern report as to the possible wide economic consequences of inaction.

The same can also be said for the whole approach to bio-sequestration, whether by managing carbon stocks as suggested by Read or by rehabilitating degraded tropical areas. It is a multi disciplinary activity and requires inputs from a wide variety of stakeholders, national, international and local, for success and will have many other benefits. This needs to be communicated so that major initiatives can be formulated appropriately, and supported by western electorates and business, which is necessary for sustained funding.

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