Carbon Sequestration: What Really Matters? - A Reply to Buckeridge & Aidar

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Abstract

This is a reply to Buckeridge & Aidar's (2002) **Point of View** on the possible usefulness of GMOs (genetically modified organisms) built to increase carbon sequestration, and Plant Gene Therapy (PGT), particularly in rain forests, as future tools to reduce excessive atmospheric CO_2. We argue that the alternatives to carbon sequestration they presented should not be treated as scientific or political priority, since their arguments have major ecological and socio-political flaws, such as ecological unpredictability, the existence of an already high potential for carbon sequestration by native non-manipulated plants, and the relevance of scientific and political sovereignty in regard to the global change issue.

Key Words: *Carbon Sequestration, Ecological Integration, Environmental Stress, Gene Therapy, Global Change, Rain forest*

Resumo

Esta é uma resposta ao **Ponto de Vista** de Buckeridge & Aidar (2002) sobre a possível utilidade de organismos modificados geneticamente para aumentar o sequestro de carbono atmosférico e de Terapia Gênica Vegetal, particularmente em florestas tropicais chuvosas, como futuras ferramentas para reduzir dióxido de carbono em excesso na atmosfera. Nós defendemos o argumento que as alternativas apresentadas naquele artigo não devem ser tratadas como prioridades científicas ou políticas, uma vez que pecam por não considerarem importantes aspectos ecológicos e sócio-políticos, tais quais imprevisibilidade ecológica, a existência de um grande potencial de sequestro de carbono por plantas nativas não-manipuladas, e a relevância da soberania científica e política no que se refere ao tema das mudanças globais.

Palavras-chave: *Estresse Ambiental, Floresta Tropical Chuvosa, Integração Ecológica, Mudanças Globais, Seqüestro de Carbono, Terapia Gênica*

Introduction

Science helps to solve practical societal problems. Ecological science, despite some scepticism (e.g., Peters 1991), has been increasingly solving problems related to applied issues such as biological conservation, restoration and management (Pickett et al. 1994). However, Ecology is still a young science as compared for instance to Physics and, as such, faces many problems related to theoretical formulation and methodological soundness (see Shrader-Frechette & McCoy 1993, Murray 2001). For instance, Foucault (1972) refers to biological disciplines as *"still imprecise disciplines that are perhaps doomed for ever to remain below the threshold of scientificity"*. Thus, theoretical and methodological problems have to be tackled since they impede or at least reduce the predictive power of Ecology, therefore reducing its ability to solve problems within a large spatio-temporal scale framework, such as global environmental change. Pickett et al. (1994) argue that theoretical advancement followed by practical application will only be achieved through "ecological integration", as they call it. One can think of ecological integration as operating at two major levels: (a) inward integration, where scientists succeed in integrating the different hierarchical levels of ecological science (molecules, cells, organs, organisms, populations, communities, landscape, biogeography); and (b) outward integration, where scientists succeed in integrating Ecology as a whole to non-biological sciences, more notably social and political sciences.

Buckeridge & Aidar (2002) call our attention to global environmental change, a major ecological, social and political problem that requires solving. They appropriately highlight all the controversies surrounding global change theory, and develop their paper based on which is probably the most likely of two alternatives, i.e., that current rising of atmospheric CO_2 and temperature is man-induced and may bring disastrous consequences to life on Earth as we know it. The authors do not follow the other hypothesis, that current changes are within the variability expected, and thus are a common climatological event in Earth's geological history. The existence of these two hypotheses in itself is evidence of the premature stage of current ecological theory in order to predict one or another outcome. Of course, that should be no reason to discourage scientist to pursue the first hypothesis and search for alternatives to prevent this problem. Buckeridge & Aidar eloquently did so and approached the problem within the integration perspective.

They reported some recent success in producing genetically modified organisms (GMOs) and of Plant Gene Therapy (PGT). They expressed the viewpoint that genetic modification of rain forest trees to increase their capacity to sequestrate carbon should be considered as a future alternative to control the current rise of atmospheric CO_2. Despite the intrinsic scientific interest of the information they presented, we argue that their viewpoint about the possible applications of this approach has two major flaws: (a) an ecological flaw, which consists of an over-simplistic, although integrative approach (ecophysiology, genetics, agro-forestry are some of the fields integrated by them), since it fails to acknowledge important spatio-temporal ecological processes at population, community and landscape levels; and (b) a socio-political flaw, which consists of not attempting to pursue an outward integration to social and political sciences that at the present stage are likely to be more relevant to this issue.

Ecological Flaws

Buckeridge & Aidar (2002) state that '*our goal has to be to find ways to sequestrate carbon with higher efficiency*', and that the use of genetically modified trees with enhanced capacity for carbon assimilation can help us achieve this goal. Even if we assume this goal as legitimate (see *Socio-political flaws* below), we see two major ecological flaws in their argument: (1) at present, with native plants as they are, there are no available models to explain or predict Brazilian ecosystem function in a changing environment, nor to predict the variation in magnitude of ecological processes along gradients of environmental stress; so genetic changes would come with a high level of unpredictability; (2) there are accounts of Brazilian species with a great intrinsic capacity for carbon assimilation, despite growing in resource-poor and stressful environments such as cerrados, restingas or rocky outcrops (Prado & Moraes 1997, de Mattos 1998, de Mattos et al. unpublished data); this can be seen as indication of an already great natural potential for carbon assimilation. Buckeridge & Aidar (2002) acknowledge the premature status, unpredictability and the dangers related to the application of their proposal and our aim in this section is to highlight, based on these two ecological flaws, some of the risks related to this type of practice.

Ecological Unpredictability

The current absence of a clear theoretical understanding of ecosystem function in tropical environments limits the application of techniques like the one proposed by Buckeridge & Aidar. We trust that this theoretical vacuum is due to an overall absence of efforts to link different spatial and temporal scales and different organisation levels of biological systems. Although they attempted to integrate levels, as mentioned in our Introduction above, comprehensively they failed to account for many relevant hierarchical interactions. For instance, genetically modified trees (organism level), constructed to increase carbon sequestration, could possibly develop as a side effect leaves with high nitrogen content (biochemical level). If this is so, failure of the bottom-up control of population growth of herbivores could be in order along with the increase in decomposition rates (population and community level). Major insect outbreaks and the increase in mineralization rates could result in unpredictable changes in energy transfer and flow between trophic levels and decrease the potential for carbon storage (ecosystem level) and imply in irreversible damages to the natural system (see Crawley 1996). This outcome would then result in smaller canopy cover, a consequent decline in productivity and, finally, a decrease in overall carbon sequestration and storage. This example shows how the absence of a theoretical framework limits our application of some management tools. In this case, the initial intention of increasing carbon sequestration would be twisted into just the opposite of the original goal. Moreover, a new problem would have to be dealt with: abnormally high insect populations.

Other examples of unexpected outcomes of genetic manipulation are likely to appear, if we only consider the ecological roles of species in the ecosystems. The usefulness of ecosystem services, such as carbon sink and storage, is well known (Vitousek et al. 1997, Tilman 1999), and also how some species alone can be directly responsible for the overall functioning of a given ecosystem (Lawton 1994, Brown 1995, Tilman 1999). In addition to diversity, species composition also matters (Tilman 1999). Thus, depending on the intrinsic buffering capacity of a given pool of species, changing conditions and resource availability may modify the physiognomy and function of ecosystems in a future world (Körner 2000). In Brazil, although some attempts have been made to pinpoint such keystone species (Scarano 2002), species roles in ecosystems are still largely unknown. Moreover, spatial and temporal variations are also likely to occur in regard to the functional role of a given species (Scarano et al. 2001). It is reasonable to assume at this stage that genetic manipulation to increase carbon sequestration may affect the very basis of ecosystem function, i.e., species composition and species interactions.

Alternatively, we have been developing a model to explain and hopefully predict the effects of atmospheric CO_2 enrichment and global climate change in ecological hierarchies and their interactions (Figure 1). The main premise of this model is that productivity and carbon storage of an assemblage of species are processes which integrate ecosystem responses to the constraints imposed by climate and soil, species composition, diversity and biological interactions, historical use and current anthropogenic nutrient load, mainly nitrogen. However, our own research and that of other Brazilian scientists has been focusing on only a few of the various aspects presented in this model. Of course, we are far from a robust theoretical construct and more research effort will be needed to accomplish this task, particularly in quantifying the relative effects of variability in spatial and temporal scales along gradients of environmental stresses on ecosystem properties related to productivity, decomposition, species diversity and biological interactions. As pointed out by Buckeridge & Aidar (2002), it may then be too late for sound conservation and management initiatives to be undertaken, but that should not discourage functional ecology studies nor be an excuse to premature manipulation at the molecular level.

The natural ecophysiological potential

The second ecological flaw of Buckeridge & Aidar's (2002) is related to the fact that they have overlooked recent studies showing some relevant information regarding plant survival under adverse environmental conditions for different Brazilian vegetation types (Scarano & Franco 1998, Scarano et al. 2001, de Mattos et al. 2002, Scarano 2002). Plants from poor and stressful

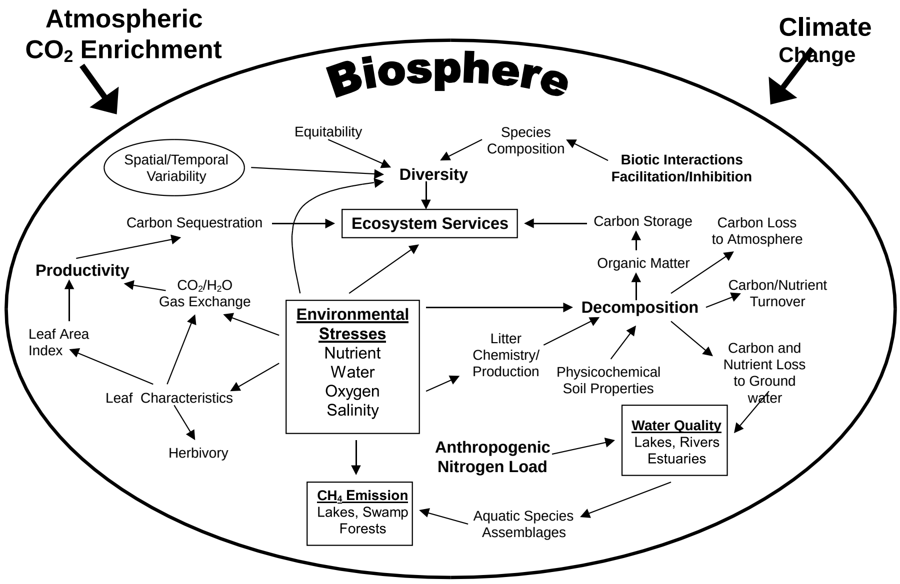

Figure 1: *General Path Model or Hypothesised Causal Relationships between Scales, Processes and Ecological Hierarchies that Should be Affected by CO_2 Enrichment of the Atmosphere and Global Climate Change.*

environments are able to survive by showing a constellation of attributes that may confer a great resistance to environmental stresses but negatively affect photosynthetic carbon assimilation (Chapin et al. 1993). Thus, more important than achieving high photosynthetic rates are the intrinsic abilities to cope with environmental stresses. Curiously, however, recent studies show unexpectedly high carbon assimilation rates of Brazilian plants in resource-poor environments during non-stressful periods (Prado & Moraes 1997, de Mattos 1998). Moreover, some native species are able to recover rapidly from environmental stresses and also have the capacity to maintain a higher carbon balance over periods of favourable conditions (de Mattos et al. 2002).

It seems as the example above indicates that Buckeridge & Aidar neglected another important topic of current photosynthetic research, namely how plants dispose solar energy in excess to drive photosynthesis under stressful conditions (de Mattos 1998, Scarano et al. 2001, de Mattos et al. 2002 and references therein). *In situ*, species respond to a multiplicity of stress conditions, which regulate population performance in dynamic environments. In a global change scenario, rise in atmospheric CO_2 would be only one of many other possible stress factors. Fortunately, it seems that light stress alone may be used to study the convergent effects of multiple environmental factors on the short and on the long-term patterns of leaf carbon balance (de Mattos 1998).

Socio-political flaws

Buckeridge & Aidar (2002) admit that reducing CO_2 emission is no trivial task, since it would mean a change in the current economic paradigm. They correctly assess that the highest CO_2 emissions in the world come from the United States of America (USA), who are unwilling to decrease economic and industrial activity contrary to the plea of a large group of Nations who signed the Agenda 21 in the Rio 1992 meeting. Indeed, USA along with the other developed nations, add up to only 20% of the world's population, consume no less than 80% of all the energy produced in the world and generates 80% of the pollution, including greenhouse gases (additional discussion on the new *Tragedy of the Commons* and related topics can be found at:
http:// members.aol.com/trajcom/private/trajcom.htm.
It is quite clear then, that if the global change hypothesis is correct, this is mostly due to the lifestyle of the population of only a few out of some 190 countries in the world. Would it be politically sane to offer Brazilian trees in some sort of genetic sacrifice to absorb excessive CO_2 produced by other nations? Other than that, this act itself would further contribute to the perpetuation of an economic model that, Buckeridge & Aidar (2002) agree, should change. For instance, companies with the technology to produce reagents and equipment necessary to perform such a large genetic enterprise all stand north of the Equator, on the west.

We saw there a major socio-political flaw in their assessment. The acknowledgement of political facts presented by the authors turned the scientific alternative proposed in the rest of the paper even more incoherent and, indeed, politically out of context. Basically, the authors assume that it shall be easier in the near future to genetically transform Brazilian trees to absorb higher rates of CO_2 than it should be to politically convince the world's highest CO_2 emitter, the USA, to slow down their economic and industrial activities! The authors compare the current economic system to "*a transatlantic cruise ship, which may break and hurt lots of people if changing directions takes place too quickly*". Can this not be said of ecological systems as well, where changes in direction often break down the system and hurt lots of people and other beings? Indeed, Ecology and Economics resemble each other also in the fact that they have low predictive power (Shrader-Frechette & McCoy 1993).

Scientists and policy-makers make choices and establish priorities on a daily basis, and global issues such as environmental change should be analysed from a very broad perspective. In addition to presenting ecological flaws, Buckeridge & Aidar's (2002) paper also assumed as an unchangeable fact the major socio-political problem that surrounds the global change issue. The scientific results they reported are of utmost interest and clearly their goal was to provide tools to tackle a problem in case we have to face it. However, we believe, or else, hope, that in the present formulation it is an unlikely priority to be pursued scientifically and/or politically.

Final remarks

Lawlor (2002) summarizes our ecological considerations above in the following statement: *"Changing C- or N-assimilation requires modifications to many processes to effect improvements in the whole system; genetic engineering/molecular biology alterations to single steps in the central metabolism are unlikely to achieve this, because targets are unclear, and also because of the complex interactions between processes and environment"*. It is comforting, however, that if global change turns out to be a fact, either man-induced or not, there are many plant species that will be able to adjust, survive and persist under a new environmental scenario (Scarano et al. 2001, Scarano 2002). For instance, along with changes in CO_2 concentration, changes in the hydrological cycle may expose species in the near future to warmer and drier conditions in some places and wetter and prone to inundation in others. Some species are naturally capable to adjust to such changes, and it seems that many Atlantic rain forest species have done so in a recent geological past when they colonized lowland swamps and restingas (Scarano 2002). Therefore, understanding species plasticity and stress-persistence may help predict the capacity of given plant community to buffer or survive under more extreme conditions. Lawlor (2002) also argues "*unless this* (i.e., the relevance of ecological interactions) *is rapidly appreciated, the current loss of plant biochemical and physiological expertise in many countries in favour of molecular biology, will distort the knowledge base"*. Indeed, this should be a major concern to us in Brazil, since it may be already occurring to key biological fields such as plant taxonomy.

Buckeridge & Aidar (2002) finalise the paper with a question to the reader: *"if our patient* (Earth) *is really ill, nearly terminal: shall we use gene therapy to save it?"* We answer yes, as long as with gene therapy it would be possible to turn insensitive politicians sensitive: both the politicians imposing global environmental change upon us, and those that, out of complacency and lack of political sovereignty, are too lazy or too incompetent to react to the whims of our tyrants. In the meantime, let our trees be.

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