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What is needed to create a low carbon society? A qualitative reasoning approach to modeling the role of biofuels and the carbon market.

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Abstract

The concentration of atmospheric CO_2 began to increase at the end of the 18th century, with the Industrial Revolution. During that period large quantities of mineral coal and petroleum were burned as energy source. Since then, the CO_2 concentration has increased from 280 ppm (parts per million) in the year 1750, to 393 ppm today, and this increase has been associated to global warming. Nevertheless, greenhouse gases (GHG) emissions (such as CO_2) derived from fossil fuel and the destruction of natural areas, as tropical forests, replaced by human-tailored areas, continues to be high, aggravating a multitude of environmental problems, including climate variations.

The work described here presents qualitative models that focus on two approaches taken to handle the situation: replacement of fossil fuels by alternative sources of clean energy, and the use of economic instruments to stimulate actions to reduce GHG emissions.

Consider, as a working example, the dilemma of a community of farmers that holds a piece of land covered with natural vegetation, and need to make money out of the land. What should the farmers do, in order to find a balance involving engagement in productive activities without emitting CO_2 in excess and preserving the natural vegetation that stabilizes the climate and contributes to remove the GHG from the atmosphere? This paper shows how qualitative models may inform the decision making process of the farmers.

There is an increasing interest in alternative sources of energy, mainly in those that replace pollution-intensive sources and promote the decrease of CO_2 and other GHG emissions. An option is to use biofuel (also biological fuel) such as wood, vegetal coal, bio-ethanol and biodiesel produced by the etherification of vegetal oils. Methanol and ethanol are seen today as probably the most viable alternatives. As a consequence, large extensions of agricultural areas are being transformed into 'energetic plantations' (e.g. sugar cane), increasing the capacity of producing biofuel.

The *Biofuel* model aims at answering the following questions:

(a) How is biofuel produced?

(b) What are the advantages of producing and using biofuel when compared to non-renewable sources of energy?

In answering the questions, the model shows that, by absorbing atmospheric CO_2 via photosynthesis, plants assimilate the carbon and transform it in vegetal biomass, which is further transformed into fuel. Used in transport and by the industry, combustion releases CO_2 into the atmosphere again. All in all, it is possible to have a balance between the two processes, resulting in energy being generated and used without additional release of carbon dioxide to the atmosphere. The farmers mentioned above could spare part of their land to invest in agriculture to produce biofuel betting on the carbon balance between photosynthesis and combustion.

A landmark in the efforts towards the low carbon society was the Kyoto Conference, held in 1997 in Japan, when important concepts such as carbon sequestration was established and economic mechanisms have been created to compensate those who contribute with the reduction of GHG. The carbon market may have interesting offers for the farmer. Accordingly, the *Carbon Market* model should be able to answer the following questions:

(c) How does work the mechanism that defines the balance between carbon assimilated and released both by natural vegetation and by agricultural plants?
(d) How can carbon credits promote a sustainable use of land for both conservation of natural vegetation and agriculture and be reverted into economic gain for the local people?

The model shows the complexity involved in the Carbon market: the trade-off between conservation of natural vegetation and agricultural projects may produce positive outcomes, in which both the biomass of natural vegetation and biomass of agricultural production reach dynamic equilibrium, leading to similar equilibrium between revenue from carbon credits and profits for the community of farmers. However, these favourable conditions may change and result in an unbalanced situation, where the more carbon is being introduced in the atmosphere and revenues from carbon credits go down.

Playing with the model, the farmers could see the possibility of reaching a situation in which carbon assimilation and release are in equilibrium in a system where natural vegetation and agricultural land coexist. Based on the results of the two models, the community of farmers may conclude that it would be possible to combine farming, biofuel production and natural vegetation conservation to generate revenues without increasing the CO_2 concentration in the atmosphere. However, it would be also clear that more knowledge is required to solve ambiguities in the model and explain what should be done to obtain the desired results.

The combination of the two models provides an overview of basic aspects of a low carbon society, and as such becomes a powerful tool for learning activities mediated by the DynaLearn workbench. More than producing prescriptive solutions, the models offer causal explanations of the fundamental mechanisms operating in complex systems and, in doing so, contribute for the user to run an informed decision making process.

Integrating models and simulations about alternative sources of energy and economic mechanisms for the control of GHG emissions in educational contexts are ongoing work. It includes combining the two models described here into a single model, producing didactic materials and evaluating the whole set with experts and students.

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