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Climate and Land: Tradeoffs and Opportunities

J.M. Reilly and J.M. Melillo

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MIT Joint Program on the Science and Policy of Global Change

Massachusetts Institute of Technology
77 Massachusetts Ave., E19-411
Cambridge MA 02139-4307 (USA)

T (617) 253-7492 **F** (617) 253-9845
globalchange@mit.edu
http://globalchange.mit.edu

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Climate and Land: Tradeoffs and Opportunities

Reilly JM[1]* and Melillo JM[2]

Keywords

Land management; Land carbon; Global economy; Climate change; Land use; Land cover

Introduction

Land management for carbon sequestration offers an opportunity to avoid about 0.5°C of warming if landowners have full economic incentives to participate in a global greenhouse gas mitigation policy [1]. In an energy-only policy aimed at about 550 ppm CO_2-eq stabilization the additional 0.5°C of avoided warming brings the world close to staying below the 2°C above preindustrial target. While greater incentives for mitigation from energy and land would be needed to actually meet the 2°C target even holding temperature to 2.2°C or so would be a great improvement over the path we are on now. Even with success at the 21st meeting of the Conference of the Parties (COP21) in Paris in 2015, we would still be heading toward a global mean surface temperature increase is in the range of 1.9 to 2.6°C (central estimate 2.2°C) by mid-century relative to the pre-industrial level (1860–1880 mean), and 3.1 to 5.2°C (central estimate 3.7°C) by 2100 [2]. This preliminary assessment awaits a full interpretation of the implications of agreements at COP21 with greater clarity on just what countries pledges mean and how they will be implemented. But this first look estimates that the COP21 pledges would shave about 0.2°C more from warming compared with previous international commitments. From that perspective, a half-degree of avoided warming from land carbon sequestration and avoided deforestation, if we could achieve it, is significant. The relatively small contribution from the COP21 agreement says less about the significance of the commitments—many countries stepped up and offered important goals that will mean changes in their energy systems—but rather more about the challenge of weaning the global economy from its dependence on greenhouse gas emitting activities. It also highlights that no source (or potential sink) can be ignored.

Discussion

The land carbon story is not as simple as one might think as there are complex interactions. The capacity of the land to store carbon depends on changing environmental factors (climate, atmospheric carbon dioxide and ozone concentrations, nitrogen availability, and solar irradiance reaching the ground or possibly obscured by aerosol pollution). While nitrogen fertilizers can enhance biomass productivity and turn fertilized cropland into carbon sinks under the right management conditions that nitrogen can also turn into nitrous oxide, a powerful greenhouse gas [3]. Nitrogen deposition from industrial emissions of nitrogen compounds into the atmosphere by itself enhances the productivity of natural and managed ecosystems and hence increases land carbon storage [4]. Increased atmospheric carbon dioxide enhances vegetation growth if other essential plant resources such as water and nitrogen are not limiting, but at the same time, carbon dioxide affects climate. Climate change has many different effects on land carbon storage depending on the nature of the change. Warming, with sufficient precipitation, can enhance vegetation productivity particularly in colder climates, but it can speed up decomposition and the release of carbon from soils.

A second set of complexities is the multiple ways in which land use and land cover change affect the climate. Already noted are the tradeoffs between nitrogen fertilization, vegetation carbon, and nitrous oxide emissions. Land cover also affects the surface albedo and the hydrological cycle. Hallgren et al. [5] found cooling effects from reduced albedo due to clearing of forests on the same order as the warming effect of CO_2 released due to the deforestation. The effects were more complex in tropical rainforests, where their disappearance also strongly affected the water cycle. Of course, the regional patterns of temperature and precipitation change were very different as the particular spatial pattern of land cover change gives a different fingerprint of climate change than does the forcing from a well-mixed and long-lived greenhouse gas. Thus, the apparent offsetting effects globally can still mean substantial changes at the regional level.

A third set of complex interactions is the interaction of environmental and climate change and human-driven changes in land use and cover. Reilly et al. [1] found that in a highly polluted world where greenhouse gases were uncontrolled, tropospheric ozone levels were also very high. With warming cropping moved pole ward, but with substantial ozone damage much more cropland was needed to for food production, and these two effects exacerbated deforestation and carbon emissions from land use change. Albeit, high CO_2 concentrations contributed to forest growth and carbon storage where forests remained intact. In a mitigation policy aimed at 550 ppm CO_2-eq a big contributor on the mitigation side was bioenergy, and surprisingly land use change was lower than in the highly polluted case. There was less need to migrate cropland pole ward into currently undisturbed forests, and much less need for expanding cropland because as a co-benefit of GHG mitigation, emissions of ozone precursors were greatly reduced and so there was much less crop damage. Food prices rose modestly from current levels. Again a surprising result was that even with much less ozone damage to crops and less need to migrate cropping, food prices in the energy-only GHG policy were about the same as in the highly polluted scenario. While avoided climate and ozone damage would lower food price effects, land devoted to bioenergy, the higher costs of energy inputs to food production, and the need to control methane and nitrous oxide all added to the cost of food production.

Finally, Melillo et al. [6] highlight the importance of protected areas in terms of carbon sequestration as well as the preservation of ecosystems that provide critical habitat. They find that protected areas currently sequester 0.5 Pg C annually, one-fifth of carbon sequestered

***Corresponding author:** John M Reilly, Co-Director, MIT Joint Program and Senior Lecturer Sloan School of Management, Massachusetts Institute of Technology, Cambridge, MA 02139-4307, USA, Tel: 617-253-8040; E- mail: jreilly@mit.edu, jmelillo@mbl.edu

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by all land ecosystems. They predict this rate could drop to 0.3 Pg C by 2100 with predicted environmental change, or if effective protection fails then economic forces as projected in Reilly et al. [1] could lead to conversion of about one-third of currently protected areas, dropping carbon sequestration on protected areas to zero.

Conclusion

Land systems play a complex role in regulating our climate. They affect climate and atmospheric composition and are affected by changes in the climate system. Land systems are a crucial resource for food production and provide a wide range of ecosystem services. Some of these are complementary (carbon storage and ecosystem protection), some are competitive (cropping and ecosystem protection), and some may be complementary or competitive depending on the economic incentives that affect how they are practiced (biomass energy, carbon storage, and food production). The spatial dimension to the interaction of climate/atmosphere, vegetation, land, and economy is critical. Warming that may be damaging in one place may be a benefit somewhere else. Cropping may move from areas where environmental conditions worsen to those where it improves. The teleconnections in the earth system and in economic systems (through trade and migration) are also essential elements of the land system. Underlying any evaluation of the system are critical spatial data sets that have improved in recent years but where greater specificity and resolution are needed.

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Author Affiliation

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[1]*MIT Joint Program on the Science and Policy of Global Change, 77 Massachusetts Ave, E19-429L, Cambridge, MA 02139, USA*

[2]*The Ecosystems Center Marine Biological Laboratory, Woods Hole, MA, 02540 USA*

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