Climate Relevant Land Use and Land Cover Change Policies

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Abstract: Both observational and modeling studies clearly demonstrate that land use and land cover change (LULCC) play an important biogeophysical and biogeochemical role in the climate system from the landscape to regional and even continental scales. Without comprehensively considering these impacts, an adequate response to the threats posed by human intervention into the climate system will not be adequate.

Public policy plays an important role in shaping local to national-scale land use practices. An array of national policies has been developed to influence the nature and spatial extent of LULCC. Observational evidence suggest that these policies, in addition to international trade treaties and protocols, have direct effects on LULCC and thus the climate system.

However, these policies, agreements and protocols fail to adequately recognize these impacts. To make these more effective and thus to minimize climatic impacts, we propose several recommendations: 1) translation of international treaties and protocols into national policies and actions to ensure positive climate outcomes; 2) updating international protocols to reflect advancement in Climate-LULCC science; 3) continued investment in the measurements, data bases, reporting, and verification activities associated with LULCC, and LULCC relevant climate monitoring; and 4) reshaping Reducing Emissions from Deforestation and Forest Degradation+ (REDD+) to fully account for the multi-scale biogeophysical and biogeochemical impacts of LULCC on the climate system.
Observational and modeling studies clearly demonstrate that land use and land cover change (LULCC) (e.g., Fig. 1) plays an important biogeophysical and biogeochemical role in the climate system from the landscape to regional and even continental scales (Foley et al. 2005; Pielke et al. 2011; Brovkin et al. 2013; Luyssaert et al. 2014; Mahmood et al. 2014). The biogeochemical effect on the carbon budget is well recognized in the both scientific and policy making community. The Biogeophysical effect on the water cycle and surface energy fluxes, and thus on the human role in affecting the climate system is also well documented by the scientific community. Although the CO₂ linked biogeochemical effects have some spatial heterogeneity, it is much less compared to LULCC driven biogeophysical impacts and, overall, biogeochemical impacts on climate are more homogeneously distributed.

Hence, we suggest that the biogeophysical effects need to be better communicated among policy makers. In this vein progress has been made through Land-Use and Climate, Identification of Robust Impacts (LUCID) modeling activities (de Noblet-Ducoudré et al. 2012) and the Coupled Model Intercomparison Project 5 (CMIP5) (Brovkin et al. 2013) and planned to be included in the Coupled Model Intercomparison Project 6 (CMIP6) (Meehl et al. 2014). Without adequately considering the biogeophysical impacts of LULCC on climate, an adequate response to the threats posed by human intervention into the climate system will not be sufficiently addressed (Lubowski et al. 2008).

Public policy plays an important role in shaping local to national-scale land use conversions and management practices (Miles and Kapos, 2008; Pannell, 2008). Global
demand for food, fiber and energy also affect national policies that drive regional
LULCC (Mattison and Norris, 2005) (Fig. 2-3). Specific examples include the global
demand in beef resulted in deforestation in Australia, Brazil, and Colombia (McAlpine et
al. 2009). Moreover, public policies affecting LULCC may have specific environmental
or economic goals, but significant climate system consequences can occur.

Observational evidence confirms that policy-driven LULCC impacts convection,
cloud cover, near surface atmospheric moisture content, precipitation, temperatures and
long-term temperature trends in many parts of world including the Amazonia, the
al. 2004; Mahmood et al. 2006; Bonfils and Lobell, 2007; Sen Roy et al. 2007, 2010;
Kumagai et al. 2013). In some areas, precipitation has declined more than 10% (Marshall
et al. 2013) and, depending on LULCC type and latitude, temperature changes were
several degrees of warmer (Negri et al. 2004) or cooler (Bonfils and Lobell, 2010).

Observational data suggests that, in some cases, impacts of these LULCC can be felt far
beyond the regions of changes (DeAngelis et al. 2010). Modeling research suggest that
LULCC would modify temperature extremes (Avilla et al. 2012). In some cases LULCC
did not even deliver economic benefits (Gullison et al. 2007). Moreover it is reported that
since 1990s 1.5 billion metric tons of carbon has been released annually to the
atmosphere due to deforestation which is about 20% of total anthropogenic carbon
emissions (Gullison et al. 2007).

An array of national LULCC policies, international trade, treaties, and protocols
have direct effects on land use and land cover, with important biogeophysical and
biogeochemical impacts on the climate system. However, these policies, agreements and protocols are diverse and failed to adequately recognize these impacts. Here, we highlight the challenges associated with these diverse approaches and propose actions that can help to mitigate their adverse climatic impacts.

**Protocols and challenges**

International protocols, such as the United Nations Framework Convention on Climate Change (UNFCC) and United Nations Convention to Combat Desertification (UNCCD) are well-known for directly addressing the human role in the modification of the climate system. However, they only have an impact when the following actions occur: (a) donors embrace the goals and developing countries and donors work collaboratively to establish appropriate national capabilities and policies that are aligned with the treaty, and (b) developed countries define objectives in their national policies that align with the convention goals. Another challenge with these treaties and protocols is that they are typically sector specific. For example, the UNFCC addresses emissions reductions through focused efforts on forestry and agriculture. The UNCCD addresses sustainable development in arid, semi-arid and dry sub-humid areas and includes climate-specific objectives (Mattison and Norris, 2005; Cowie et al. 2007).

Although not specifically focused on climate, the Convention on Biodiversity (CBD) has clear climate-connected land use implications due to strategic goals that include a target to dramatically reduce the rate of loss of native ecosystems (Peter, 2004). Plans by the 2012 United Nations Rio+20 Conference on Sustainable Development and
the CBD to restore at least 15% of degraded landscapes globally to enhance ecosystem resilience and carbon stocks does not consider biogeophysical climate processes and feedbacks. While these treaties collectively can improve Land Use, Land Use Change and Forestry (LULUCF) practices, they will only have the desired positive effects if national policies and programs are aligned with LULUCF objectives. Unfortunately, there is no consistency at national levels to achieve this alignment. In the U.S., for example, farm, energy, and conservation policies have clear land use implications, but the policies themselves do not necessarily embrace climate. According to a recent survey only 35 of 50 states of the U.S. adopted a state-level climate mitigation plan. The approaches and priorities are diverse with different LULCC and climate outcomes (Rittenhouse and Rissman, 2004). Even small differences in the definition of forest by the Food and Agricultural Organization (FAO) of the United Nations and a sovereign country can result in large discrepancies in estimates forest extent and deforestation (Romijn et al. 2013) and subsequent policy response with climate consequence.

Despite the recognition of both the biogeophysical and biogeochemical climate impacts of LULCC by the scientific community, a major weakness of international protocols is that they do not directly address biogeophysical impacts. Most protocols only focus on the reduction of carbon emissions (biogeochemical impacts) resulting from LULCC and potential adaptation and mitigation strategies. On the other hand, planned afforestation to increase carbon sequestration may inadvertently modify local and regional climate by altering surface albedo, heat, moisture, momentum, and turbulent fluxes. In other words, some of the protocols are geographic region, time- and spatial-
scale dependent. Hence, the current approach does not bring the climate impacts of
LULCC to the attention of policy makers and the general public in its entirety and makes
these protocols inefficient and ineffective in dealing with the biogeophysical and
biogeochemical impacts of climate.

**Recommendations**

In short, these diverse national and international policies and the subsequent
shaping and or reshaping of land use and land cover complicates efforts to mitigate the
LULCC impacts on climate. Hence, several key steps need to be adopted which may help
reduce unintended impacts of LULCC on climate. They are as follows:

1) **Translation of international treaties and protocols into national policies and actions**
which deliver positive climate outcomes.

International policies are primarily focused on forests and their role in the carbon
cycle. National policies, whether government-based or market-driven, tend to focus on
the primary resource-based economic sectors (e.g., agriculture, forestry, grazing, energy).
Brazil’s soy moratorium is a voluntary market-based program to curtail soy expansion on
lands deforested since 2006 (Gibbs et al. 2015). The moratorium resulted in reduced
deforestation in the Brazilian Amazon. This is a clear case where agricultural land use
policy aligned with Reducing Emissions from Deforestation and forest Degradation+(REDD+)
and UNFCCC objectives with mutually beneficial results.

The relationships between national and international policies are obviously
important. As with the approval of many other international treaties or protocols (e.g., trade agreements), incentives that lead to both the reduction of negative impacts of LULCC on climate and that include clear economic benefits should be identified as priority actions at the national level.

An additional concern is the impact of changes in governing bodies on national policies. Governing changes can shift policies for better or worse LULCC and climate outcomes. For example, there is evidence that changes in majority parties in Brazil have had weakening effects on deforestation control (Rodrigues-Filho et al. 2015).

International bodies should approach various nations through established communication channels and encourage dialogue and initiatives to address this challenge (recommendation #1). In response, national legislative bodies will need to recognize this issue and propose and approve necessary laws that would allow nations to have cohesive actions that are consistent with their priorities. This could be achieved by using existing platforms of international treaty negotiations. Individual countries will need to develop national policies to resolve this issue (Translation of international treaties and protocols into national policies and actions) with consideration of their current socio-economic environment.

Policy implementation and its impacts can be determined by periodic assessment of the trajectory of the resulting LULCC, changes in the structure of the landscape and their spatial scales (further details are provided in recommendation #3). It needs to be recognized that the biogeophysical impacts vary from region to region, e.g., changes in
tropical forest cover will have different climate consequences compared to changes in
temperate or boreal forests. Hence, region specific rules and actions need to be adopted.

Developing countries may need additional help in the process of translation of
treaties and protocols. International bodies such as the U. N. and linked entities or
developed countries may offer help to overcome difficulties in devising workable and
effective policies and their implementation so that these mismatches are removed.

2) Updating international protocols to reflect advancement in Climate-LULCC science
for effective policies.

It is critical that international protocols stay current as new scientific knowledge
of climatic impacts of LULCC comes to light [for example, the increased recognition of
biogeophysical impacts of LULCC by the IPCC (Stocker et al. 2013)]. Increased
surveillance and monitoring from ground-based measurements and satellite observations
(further discussed below) can provide objective evidence of the connections between
LULCC and climate (e.g., localized warming and drying). More aggressive acquisitions
of high-resolution satellite imagery, for example, are resulting in more timely evidence of
the impacts of land change events on both human and natural systems (Roy et al. 2014).
State-of-the-art mesoscale models using more accurate representations of surface
conditions (e.g., land cover properties, topography) along with realistic scenarios can
help understand the outcomes of policy options (Lawrence and Vandecar, 2015). These
actual and scenario-based assessments need to be communicated and subsequently
translated into the national policies for effective mitigation and adaptation strategies.
Again, this can be achieved by continued collaboration among various international bodies and national entities and by using established protocols and procedures.

3) Continued investment in the measurement, data base development, reporting, and verification activities associated with LULCC, LULCC relevant climate monitoring, and emissions reductions linked to land use practices.

In this era of limited government funding for new initiatives, we need to start with leveraging current and largely successful approaches such as satellite observation of LULCC. Specifically, for example, continuation of Landsat, Terra, Aqua, Sentinel, and other similar satellite missions by various nations and space agency policies that allow free access to Earth observation data are needed for international transparency for monitoring LULCC (De Sy et al. 2012; Herold and Johns, 2007). These activities should include data base development and easy access to quality assured data. Spaceborne observation and monitoring platforms could be particularly useful for developing nations where historical data may not be available (Herold et al. 2011). We recognize that processing and analysis of the data still require resources and budgetary support. However, the level of funding needed for these steps are much smaller in an already constrained national budgets. As shown in Brazil’s approach to the reduction in deforestation, monitoring transparency and appropriate policies can lead to significant reductions in adverse LULCCs (Instituto Nacional de Pesquisas Especias, 2013).

In addition to utilizing data from existing in-situ and spaceborne climate monitoring platforms, new in-situ monitoring networks need to be established in regions
where rapid LULCC is currently underway. This effort could be undertaken in selected areas such as the Amazonia, Costa Rican cloud forests, Southeast Asian tropical forests, and near rapidly growing urban and agricultural areas and then expanded to other regions. This effort could consider collaborating with existing coordinated national and international efforts [e. g., Fluxnet (Baldocchi et al. 2001)]. Mitigation of the diverse range of effects on climate from LULCC can also begin with existing local policies and practices of land management devised for conservation efforts. For example, in the U.S. and China, there are certain government policies [e. g., Grain for Green Project (Fan et al. 2014)] that encourage farmers from selected regions to adopt conservation practices that may also reduce biogeophysical and biogeochemical effects on climate. Wherever needed, these policies could be further expanded so that specific emission reduction policies can be adopted and implemented. It is also critical that the local-level implementation requires simple and straightforward policies (Höhne et al. 2007).

4) Reducing deforestation and forest degradation in developing countries under REDD+ is an important step. However, developed countries that are not covered under this protocol, need to be included.

Again, existing international platforms can be used to initiate the discussions. Negotiation of actual individual national level actions, to be adopted by developed countries, can begin subsequently. A major requirement underpinning the implementation of these protocols is an *a priori* assessment of the LULCCs that will result from their implementation. This assessment should include: a) an analysis of the
extent, type and intensity of the resulting changes, b) what are the likely biogeophysical and biogeochemical feedbacks on the climate system at different spatial scales, and c) what are the risks and consequences for the regional environment and communities. This assessment should follow similar rigor to that applied for greenhouse gas accounting. Another important aspect of REDD+ implementation is that all relevant parties need to be aware of potential and unintended danger of ‘recentralization’ of forest governance (Phelps et al. 2010). This awareness is particularly critical for developing nations because many of them have spent many decades overcoming the legacy of centralized colonial and post-colonial governance in all aspects of national life. This decentralization effort is still ongoing or is in the process of taking roots in governance for many of these countries. Hence, REDD+ implementation should not interfere, disrupt, or set examples that are counterproductive to decentralization efforts. We suggest that these steps will make current national policies and international protocols and conventions more effective. This, in turn, would reduce negative climatic impacts arising from LULCC, whether planned or inadvertent.

Acknowledgements: The Authors would like to thank three anonymous reviewers for their valuable suggestions which helped to improve this manuscript.
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Figure 1. Land use land cover change during various time periods. Pasture or crop lands are presented as a fraction. Source of the data is http://luh.unh.edu. Refinement of the data has continued (e.g., much of central Australia is ungrazed or low density grazing and shown as pasture). (Source: Pielke et al., 2011)
Figure 2. LULCC in the Amazonian central Bolivia observed by Landsat satellite: a) Intact forests (green color) prior to deforestation (light color) on 7 November 1986, b) after deforestation on 29 August, 2013. Each image is 185 x 185 km. The river on the western side of the images is the Rio Grande O Guapay, an upper tributary of the Amazon River.
Figure 3. LULCC in Fort McMurray, Alberta, Canada region showing the growth of tar sands/oil and gas mining. Fort McMurray is in the bottom center of the image (on the fork of the rivers), and the mining areas are all to the north. Land use expansion of 50 miles is due to the energy policy. The images are from: a) Landsat 5 on July 24, 1984 and b) Landsat 8 on September 28, 2014. Each image is 185 x 185 km.