

# Land use and land cover tools for climate adaptation

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**Abstract** Land use and land cover interact with atmospheric conditions to determine current climate conditions, as well, as the impact of climate change and environmental variability on ecological systems. Such interactions are ubiquitous, yet changes in LULC are generally made without regard to their biophysical implications. This review considers the potential for LULC to compound, confound, or even contradict changes expected from climate change alone. These properties give LULC the potential to be used as powerful tools capable of modifying local climate and contributing significantly to the net impact of climate change. Management practices based modifications of LULC patterns and processes could be applied strategically to increase the resilience of vulnerable ecological systems and facilitate climate adaptation. These interventions build on the traditional competencies of land management and land protection organizations and suggest that these institutions have a central role in determining the ecological impact of climate change and the development of strategies for adaptation. The practical limits to the use of LULC-based tools also suggest important inflection points between manageable and dangerous levels of climate change.

## 1 Introduction

Human activities have altered climate on a global scale and driven atmospheric concentrations of greenhouse gases (GHGs) outside the range experienced over at least the last 400,000 years (Houghton et al. 2001; AGU 2003). Climate change exacerbates threats to imperiled species, (Hansell et al. 1998; McLaughlin et al. 2002), alters community interactions (Stenseth et al. 2002; Zavaleta et al. 2003), and reduces the availability of suitable habitat (Thomas et al. 2004). Observed and projected rates of climate change suggest that many species will need to adapt rapidly within fragmented, human-dominated landscapes (Hannah et al. 2002). Reductions in atmospheric GHG concentrations and management of global carbon budgets

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may slow the pace of change, but they will not be sufficient to maintain biodiversity in the face of climate change (Noss 2001). Significant climate changes may have already occurred, and potentially dangerous changes are possible regardless of near-term mitigation actions (Mastrandrea and Schneider 2004).

The impact of global climate change is mediated at regional and local scales by biophysical processes associated with land use and land cover (LULC). In this paper, we take an expansive view of these processes to include all aspects of land management that maintains or alters the biophysical properties of the Earth surface. We review the role of LULC in contributing to the impact of global climate change on local and regional environmental conditions, species persistence, community composition, and ecosystem processes. The following sections discuss the biophysical consequences of LULC at local and regional scales, review the ecological implications of interactions between LULC and climate, and highlight opportunities for the development of LULC-based tools for climate adaptation.

## 2 Biophysical consequences of land use and land cover

In comparison to their atmospheric counterparts, LULC receive relatively modest attention a driver of climatic change (Pielke et al. 2002). However, these processes play a significant role in determining climate at local, regional, and global scales (Brovkin et al. 1999; Kalnay and Cai 2003; Matthews et al. 2003; Myhre and Myhre 2003) and, consequently, the effectiveness of climate policy (Marland et al. 2003). Recent studies demonstrate that LULC activities have ecologically-important impacts on biophysical conditions such as soil moisture availability (Li et al. 2000), length of growing season (White et al. 2002), diurnal temperature range (Stone and Weaver 2003; Balling and Cervený 2003), temperature extremes (Shine et al. 2002; Marshall et al. 2003), precipitation patterns (Changnon 2003), and severe storm frequency (Rozoff et al. 2003) (Table 1). Biophysical processes associated with common LULC activities can alter the net impacts of global climate change on specific ecological systems at local and regional scales. The following examples illustrate instances of strong interactions between LULC and ecologically-important aspects of climatic conditions.

### 2.1 Changes in energy budgets

Land surface energy budgets describe the balance between incoming energy, such as solar radiation, and outgoing fluxes, including long wave (thermal) radiation and evapotranspiration (Oke 1987). LULC activities alter energy budgets when they change physical properties, such as albedo, soil moisture, roughness, humidity, and evaporation rates. In many cases, these processes generate local and regional forcings sufficient to compound or confound larger scale climatic change.

Examples of these interactions are becoming more frequent, and the following cases provide a sample of processes and places. In West Africa, vegetation type and canopy structure have greater influence on land-surface energy budgets than short-term fluctuations in rainfall (Fuller and Ottke 2002). In tropical forests, deforestation shifts atmospheric circulation patterns, suppresses cumulus cloud formation, and changes the height of cloudbanks (Roy and Avissar 2002; Nair et al. 2003). In the Great Lakes region, land use change could drive increases in stream run-off and significantly compound climate-driven increases in stream flow (Barlage et al. 2002). In Japan, experiments show that tree density controls the rate of snowmelt and the duration of the snow-free growing season (Suzuki and Ohta 2003).