

## **Land cover and land use change as climate forcing: from historical conjecture to modern theories**

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Terrestrial ecosystems influence climate through physical, chemical, and biological processes that affect planetary energetics, the hydrologic cycle, and atmospheric composition. Human activities have converted large regions of the world from natural forest, grassland, and savanna ecosystems to managed cropland and pastureland. These anthropogenic changes in land cover and land use are increasingly being recognized as an important climate forcing, both over the historical era and through the 21st century. Forests have a lower albedo than croplands or pasturelands, especially in snow-covered lands, and it is generally accepted that deforestation increases surface albedo. Forests can also sustain high rates of evapotranspiration. Climate model simulations indicate that tropical deforestation warms climate, because the warming associated with reduced evapotranspiration offsets the cooling from the higher surface albedo of pasturelands. Boreal deforestation cools climate, primarily from higher surface albedo. In mid-latitudes, higher albedo following conversion of forest to cropland or pastureland leads to cooling, but changes in evapotranspiration can enhance or mitigate this cooling. The greatest uncertainty is in mid-latitudes and is associated with evapotranspiration. Anthropogenic land cover and land use change releases carbon to the atmosphere. An understanding of the combined biogeophysical (albedo and evapotranspiration) and biogeochemical (carbon cycle) effects of anthropogenic land cover and land use change remains elusive. The dominant competing signals from historical deforestation are an increase in surface albedo countered by carbon emission to the atmosphere. Climate warming over the twentieth-century may be less than that expected from greenhouse gases alone, primarily from increased albedo with loss of extratropical forests. Carbon emission from land cover and land use change dampens this biogeophysical cooling. Anthropogenic land cover and land use change can be regionally significant relative to other climate forcings, but the uncertainty is large. Models differ in response of albedo and evapotranspiration to land cover change and in representation of wood harvest, an important term in the land use carbon flux. Interdisciplinary science that integrates knowledge of the many interacting climate services of ecosystems with the impacts of global change is necessary to identify and understand ecosystem feedbacks in the Earth system, to quantify the potential of ecosystems to mitigate climate change, and to devise effective policies to manage the Earth system.