

Biophysical Feedbacks on the Regional Climate System

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Experiments with coupled atmosphere/biosphere models indicate that land degradation leads to a reduction in rainfall, evapotranspiration, soil moisture and runoff, and an increase in surface temperature and near surface winds. This talk discusses studies that have investigated the feedback of degradation in forest and other ecosystems on regional climate in the Sahel, the central U.S., South America, and East Asia.

Sahel Experiment

Why has the African Sahel experienced persistent drought from 1990 to the present? The explanation supported by the research discussed here is that desertification and land degradation are the cause. As the land cover of the Sahel changed from savannah to shrubs with bare soil, the albedo did not change significantly, but the leaf area index (LAI), vegetative cover, soil condition, and stomatal resistance were significantly altered.

[Insert Figure 1, monthly mean precipitation over Sahel - a) observations and b) model]

In the Sahel study, a coupled model produces anomaly patterns consistent with the long-term drought observed in the region (see Figure 1). The simulated climate anomaly in the Sahel is not limited to the specified degradation area and the summer rainy season, but extends to the south and into the autumn months of October, November and December.

How does land use/land cover change result in the Inter Tropical Convergence Zone (ITCZ) shifting to the south? Moisture flux convergence reduces convective heating in atmosphere, such that total heating is reduced above 700 mb. The resulting cooling of the upper atmosphere and warming of the lower atmosphere produces a pushing motion that pushes the monsoon to the south, moving the ITCZ away from the Sahel. As a result, the Sahel region only has one rainy season in a year when it used to have two.

Naturally, river discharge is also affected. Runoff increases in the early stages of land degradation, but later decreases, as is seen, for example, in data of river discharge on the Oubanqui River (see Figure 2).

[insert Figure 2 - river discharge on the Oubanqui River]

East Asia Experiment

In the East Asian simulation, like the Sahel study, a coupled model produces anomaly patterns consistent with the long-term drought observed in the region. In the East Asian study, the degradation of the Mongolian and Inner Mongolian grasslands produces a rainfall anomaly extending far to the south of the degraded area. In the change from grassland to desert, while the albedo did not change much, the vegetative cover and LAI changed a great deal. In China in the summer time there is a cooling effect from atmospheric aerosols, but in Mongolia it is warming. Similar to the effect seen in the Sahel, there is cooling in the upper atmosphere and warming in the lower; a sinking motion pushes the air flow to south, reducing precipitation in the north of China and increasing it in the south.

[insert Figure 3, shows how land degradation leads to less rainfall]

Central U.S. Experiment

In the central U.S., the regional climate is also very sensitive to the surface vegetation conditions but the simulated anomalies are mainly limited to within the area where the land conditions are changed. Over the U.S., the model produces rising temperatures and reduced precipitation over agricultural area of central U.S. following the harvest, thus reflecting a seasonal pattern.

South American Experiment

In South America, two deforestation scenarios are tested: clear cut and secondary forest. Experiments show the secondary forest case produces less precipitation and warmer temperature within two scenarios.

In all four of the experiments discussed above, changes in the hydrological cycle were the most important in producing the climate anomalies, in contrast to the conventional view that radiative effects dominate.

Conclusions

Modeling experiments for four continents using coupled atmosphere/biosphere models show that large-scale land degradation/land cover change can result in regional climate change, with increases in surface temperature, reductions in summer rainfall and soil moisture, and changes in runoff. These changes may lead to serious effects on the ecosystem.

The impact is not only limited to the degraded areas in the monsoon regions, but extends to other areas through interactions between land surface processes and large-scale circulation. Each continent shows different characteristics in land/climate interaction due to the differences in regional conditions. The spatial and temporal scales also play roles.

While early studies consider the albedo/radiation interaction as a primary driven process in land/atmosphere interaction, we now realize that an evaporation/convection driven process chain is probably more important.

Adequate simulations of climatic mean conditions are important for realistic assessment of the land surface impact on the climate. Validation of atmospheric models and land surface models are necessary and observational data are crucial.