Modeling Strategies for Adaptation to Coupled Climate and Land Use Change in the United States

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OBJECTIVES

To spatially predict future land use change and to incorporate those predictions under different scenarios into a set of coupled ecosystem and hydrology models that evaluate the combined impacts of climate and land use change. These models also simulate the influence of potential mitigation and adaptation actions by predicting land use change scenarios that incorporate a range of best management practices (BMPs). Land use BMPs could mitigate additional climate warming by increasing carbon sequestration via changes in primary productivity.

Spatial Predictive Modeling of Future Land Use Change

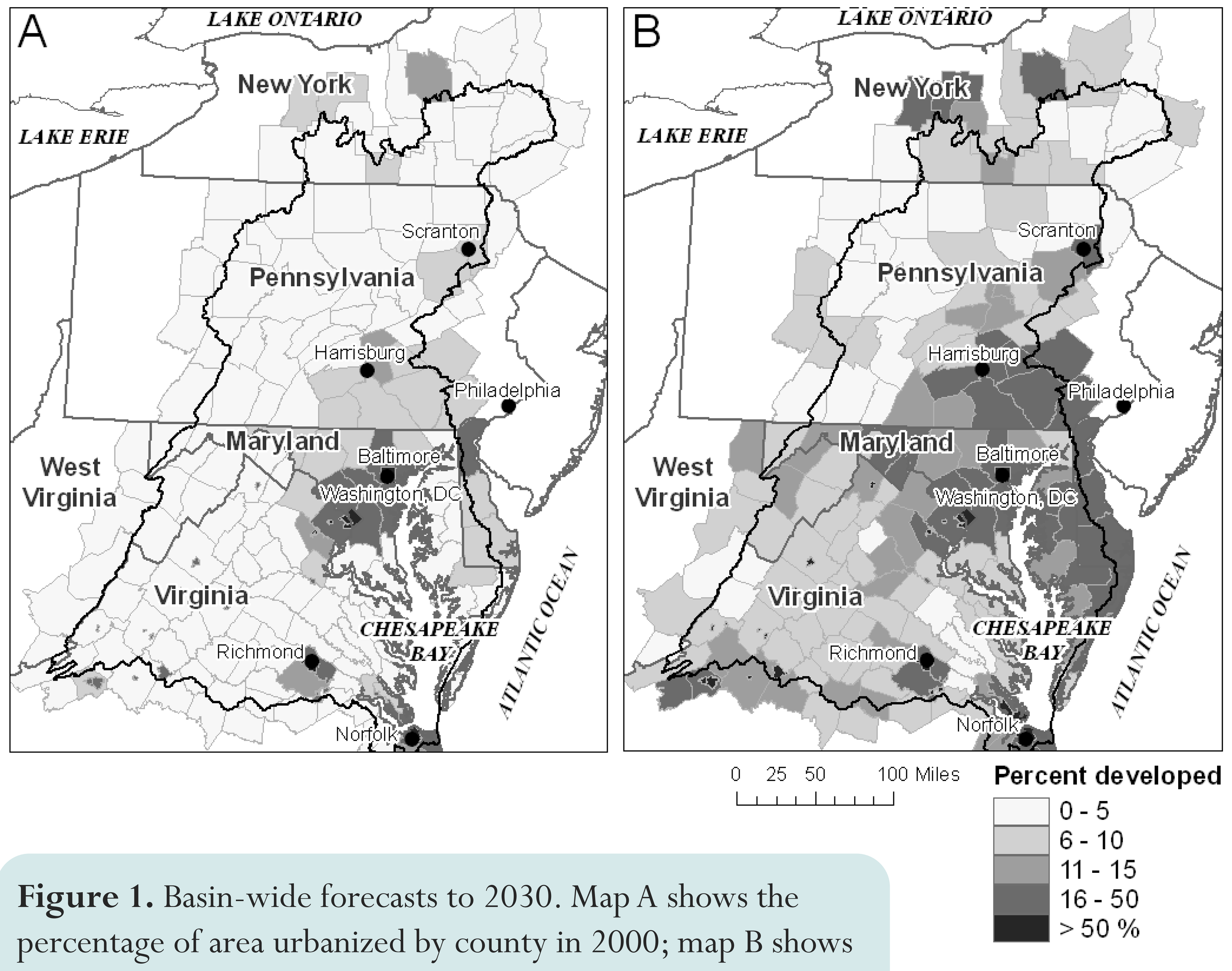


Figure 1. Basin-wide forecasts to 2030. Map A shows the percentage of area urbanized by county in 2000; map B shows the forecast for 2030 (from Jantz et al. 2010).

A fine-scale (30 m) regional urban modeling system, SLEUTH 3d, was used to forecast urban growth to the year 2030 throughout the Chesapeake Bay Watershed (CBW) and adjacent counties (Fig. 1). This model is based on the SLEUTH (Slope, Land cover, Exclusion, Urbanization, Transportation, and Hillshade) urban growth model but has been modified to include new functionality and fit metrics, as well as enhancing performance and applicability. The model was successfully calibrated for 15 individual sub-regions within the CBW based on our mapping of urbanization data for 1990 and 2000, accurately matching urban change within each sub-region.

The Spatially Explicit Regional Growth Model (SERGoM) was also used to produce housing density and impervious surface area (ISA) scenarios for the entire United States. Four housing density and ISA scenarios were produced for the period from 2010 to 2100 (Fig. 2). These ISA results wer used to determine changes to soil properties which were then used as a direct input to TOPS (the Terrestrial Observation and Prediction System).

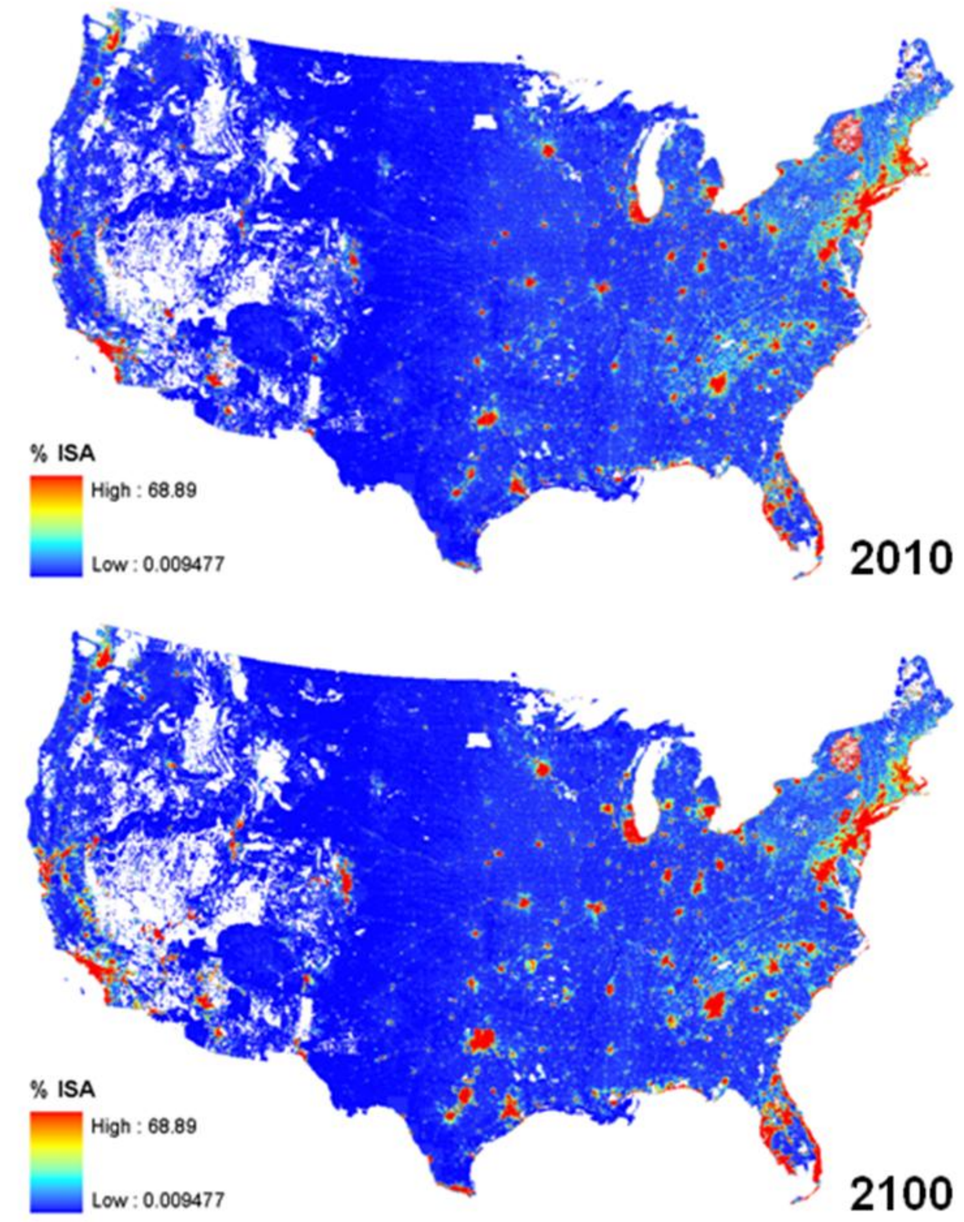
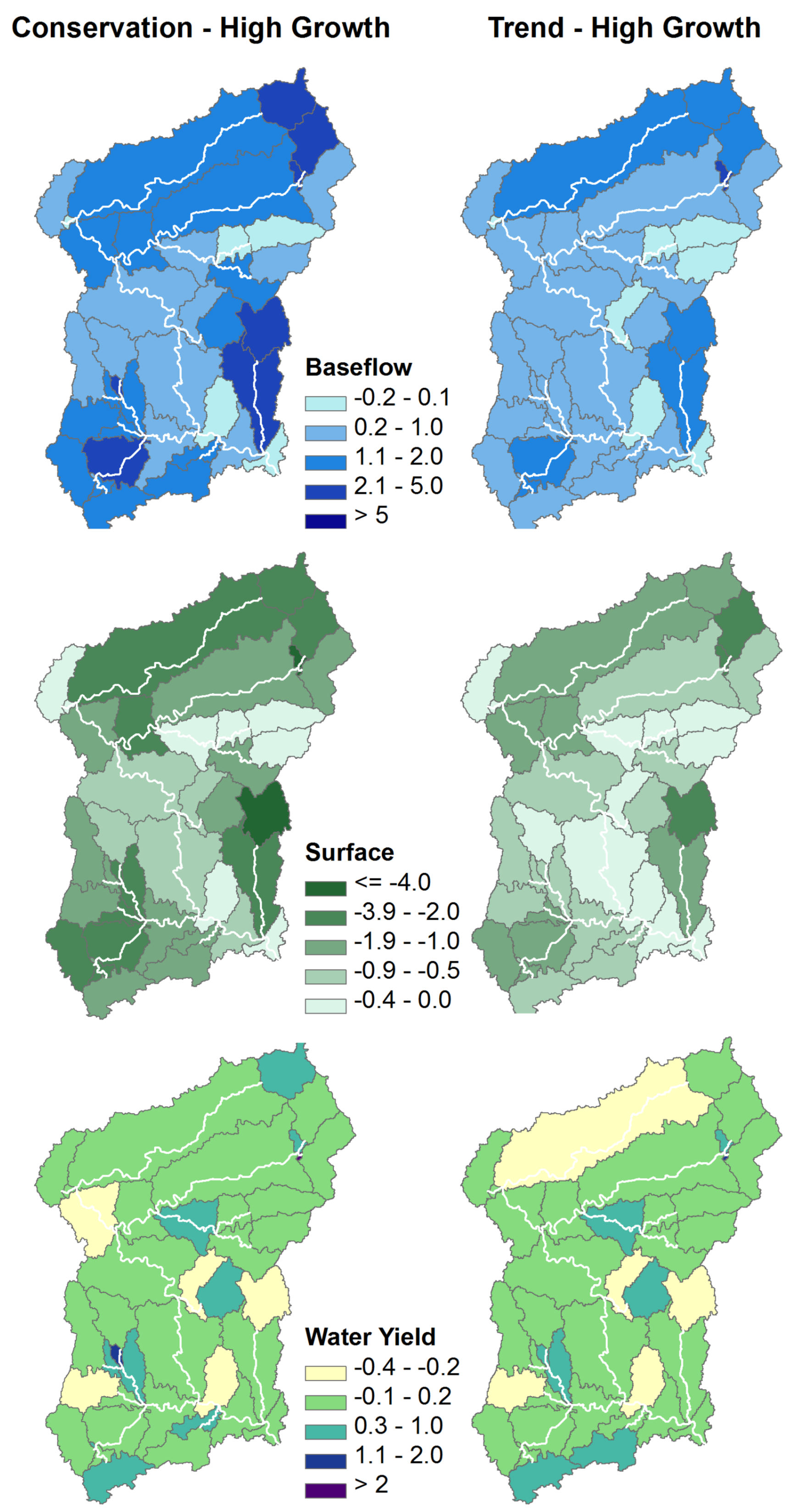


Figure 2. Predicted change in impervious cover across the U.S. from the year 2000 (left) to the year 2100 (right) based on predicted changes in population and associated housing growth (see Bierwagen et al. 2010).

Hydrology under Land Use Change Scenarios



In the Upper Delaware River Basin, the urban development predictions generated by the SLEUTH model are converted to impervious cover estimates and used as inputs to a hydrological model, SWAT (the Soil Water Assessment Tool), to predict changes to baseflow, surface runoff, and total water yield. Three possible development scenarios are used: high growth, trend, and conservation for the year 2030. The model results confirm that increased development reduces the amount of precipitation infiltrating the ground, hence reducing the baseflow while adding to the amount of surface flow. The high growth scenario shows more severe changes than the conservation scenario (Fig. 6).

Figure 6. The modeled differences in baseflow, surface flow, and total water yield for the high growth scenario minus the conservation scenario on the left and the high growth scenario minus the trend scenario on the right.

TOPS Predictions under Climate Change Scenarios

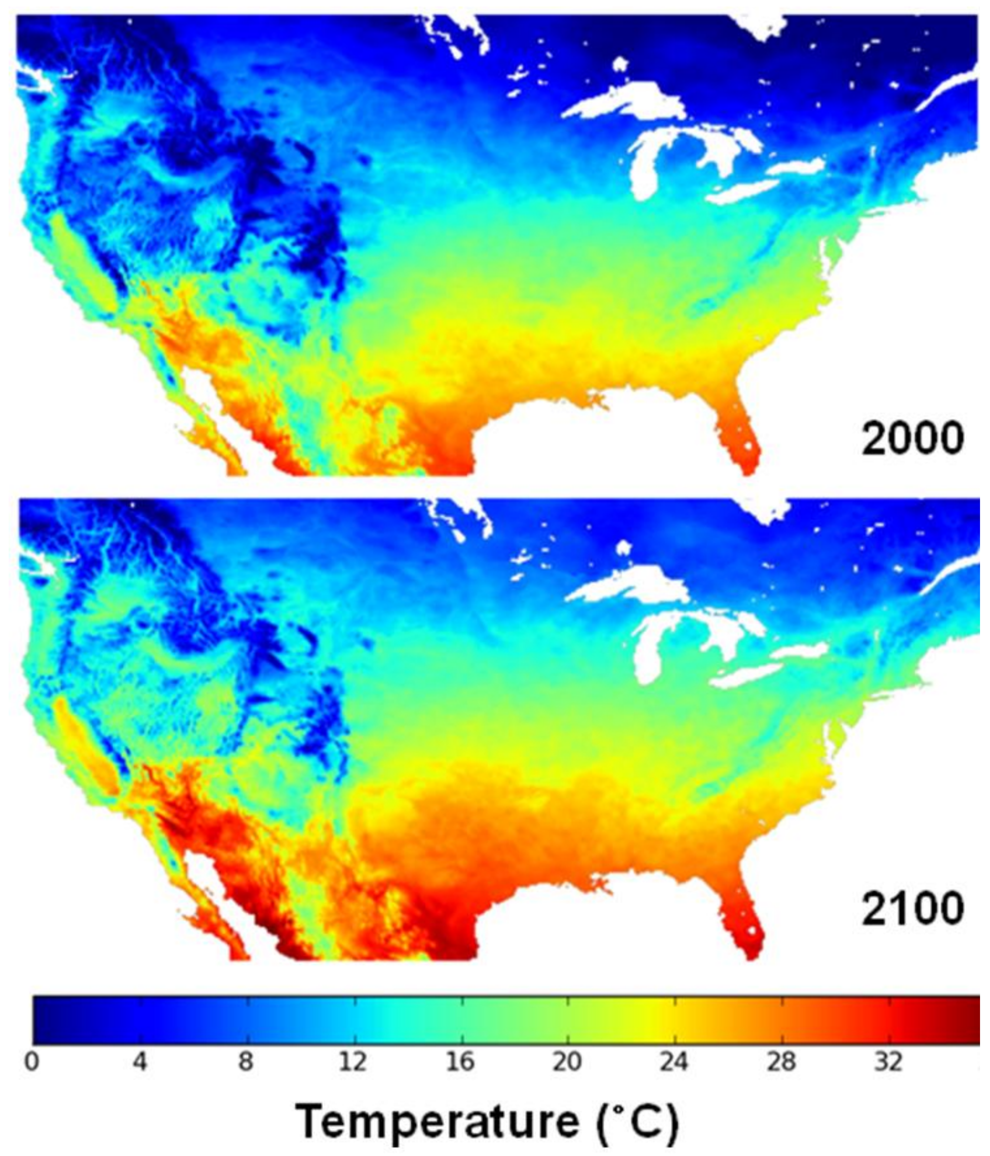


Figure 5. Sample climate forecasts from the GFDL CM2.0 A1B scenario showing changes from 2000 to 2100. These downscaled forecasts are being used to drive TOPS.

TOPS is also used to determine the terrestrial effects of changing climatic conditions. Future climate scenarios are generated using three models (GFDL CM2.0, GISS-ER, and CCSM3.0) to produce forecasts for temperature and precipitation (Fig. 5). Vapor pressure deficit and solar radiation are further derived.

The climatic predictions are input to TOPS to generate 1km surfaces for the Eastern U.S. for baseline runs for the period from 2001-2010.

TOPS Predictions under Land Use Change Scenarios

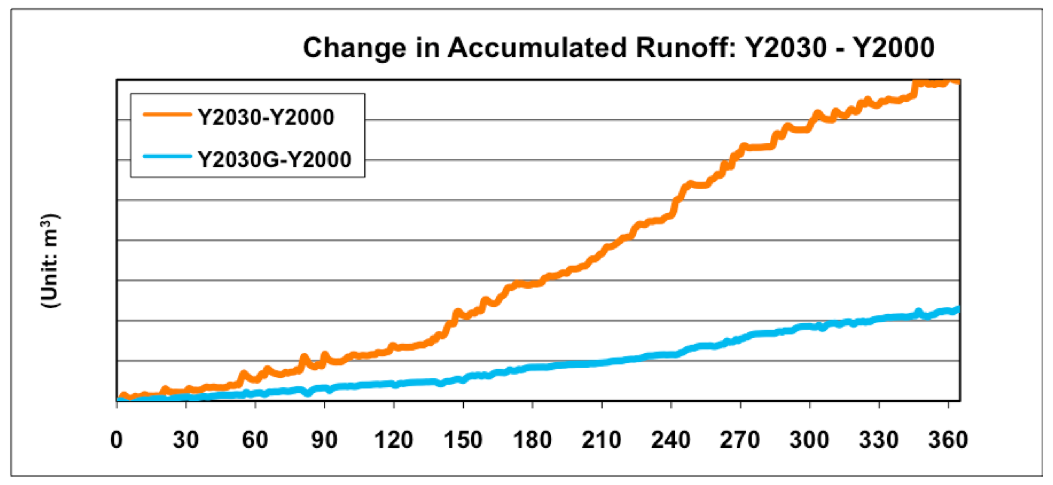


Figure 3. Predicted change in average daily runoff over the four year simulation period expressed as the difference between the forecast (2030) and baseline (2000) scenarios.

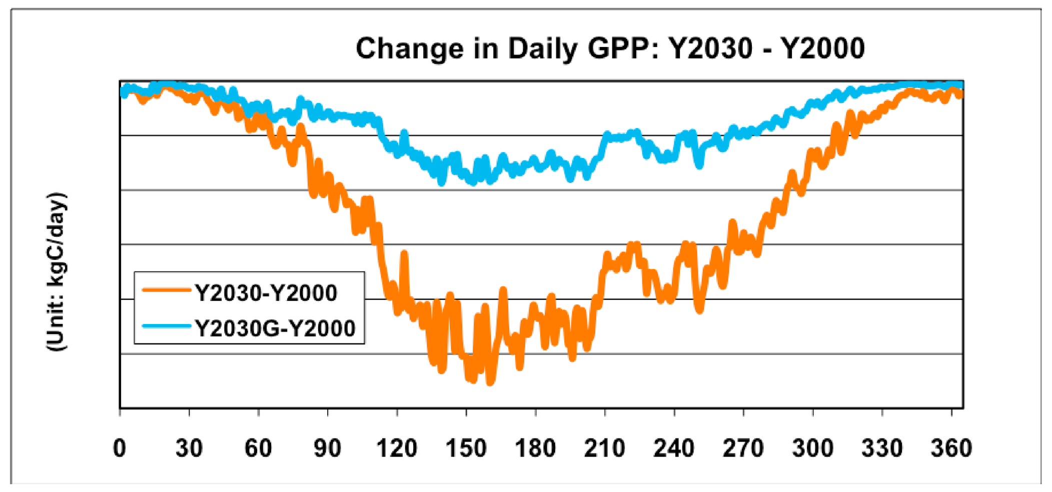


Figure 4. The difference between the baseline (2000) and forecast (2030) scenarios average cumulative runoff over the four-year simulation periods.

TOPS is able to quantify the potential for significant impacts to occur as a result of land use change and increasing urbanization (i.e. increased impervious surface area). Simulations conducted in the Chesapeake and Delaware watersheds show the impact of land use change on runoff and gross primary production (GPP) (Fig. 3 and 4). TOPS was also used to estimate various water (evaporation, transpiration, stream flows, and soil water), carbon (net photosynthesis, plant growth) and nutrient flux (uptake and mineralization) processes.

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