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Assessing the Impact of Climate Change and Land Use Variation on Microbial Transport Using Watershed Scale-modeling

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Objective

To use watershed modeling to predict the impacts of future climate change and land management scenarios on microbial water quality.

Introduction

The scientific community accepts that global climate change (CC) will affect the dispersion of microbial organisms in the environment. Risks posed by the transport of these organisms to future communities may be very different than those posed today. A shift in health risks may also be linked to climate driven land-use change, which may alter both microbial loadings to receiving waters and human exposure pathways[1]. Uncertainty surrounding microbial fate and transport renders the assessment of CC effects on waterborne pathogens complex and difficult to forecast.

Methods

Pigg river watershed, located in southwest Virginia, was chosen as the study location for model development using the Hydrologic Simulation Program in Fortran. Calibration and validation, of hydrology and bacteria, was initially carried out using data from the watershed (hydrology-calibration: 1989-1995, validation: 1984-1989; bacteria-calibration: 1994-1998, validation: 1995-2005).

Climate modeling data from the Consortium of Atlantic Regional Assessments project (CARA) is used for CC projections (http://www.cara.psu.edu/). Predictions at Rocky Mount National Climatic Data Center station (located in the watershed) were used to develop scenarios reflecting the potential range of variations in temperature and precipitation in Pigg river watershed by 2050. CARA data are expressed as changes relative to a base period (1971-2000), averaged for each season of the year, and interpolated spatially from the original grid resolution to 1/8 degree resolution.

Future residential development scenarios for the watershed are derived from the Integrated Climate and Land-Use Scenarios project[2], CARA population estimates and county comprehensive plans. Variations in agricultural production and land use are designed to replicate increases in demand based on information from peer reviewed literature, CARA forecasts and county comprehensive plans. Wildlife populations are adjusted to reflect increasing residential and agricultural land use areas.

Results

Model simulation of hydrology was satisfactory, producing a Nash Sutcliffe Efficiency of 0.44 for the calibration period and 0.57 for the validation period. For bacteria simulation, the predicted concentrations met criteria for assessing bacteria calibration endpoints[3].

Climate predictions suggest an annual increase in temperature of 12% and an increase in precipitation of 13%. Seasonally, temperature is projected to increase in Winter (+42%), Spring (+15%), Summer (+2%) and Fall (+51%). Precipitation is expected to increase in Winter (+19%) and Fall (+51%), but decrease slightly in Spring (-2%) and Summer (-3%).

A greater proportion of annual precipitation is likely to occur in larger magnitude events. This will contribute a greater fraction to direct runoff and cause increases in sediment erosion and bacteria transport. Concurrent increases in human population and agricultural production will intensify microbial contamination of water resources. Preliminary findings suggest an increased risk to human health due to direct consequences of CC.

Conclusions

Current water quality standards are sufficient to maintain the quality of water. However, unless realistic adaptation measures are incorporated into water policy, previous remediation efforts to reduce microbiological contamination of water bodies could prove inadequate and the potential threat posed to humans from exposure to waterborne pathogens may be amplified. Results of watershed-scale microbial load modeling can inform the adoption of pollution control measures required to protect human health and aid development of new water policy.

Keywords

Microbial transport; Climate change; Modeling; Water policy

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