Costs of Meeting Water Quality Goals under Climate Change in Urbanizing Watersheds: The Case of Difficult Run, Virginia

Jonathon M. Giuffria❖, Darrell J. Bosch❖, Dan B. Taylor❖, Nasrin Alamdari*

❖Department of Agricultural and Applied Economics , Virginia Tech, Blacksburg, Virginia, 24060

*Department of Biological Systems Engineering, Virginia Tech, Blacksburg, Virginia, 24060

Introduction

- ❖ Excess total Nitrogen (TN) loadings have been identified as one of the primary causes of degradation of the Chesapeake Bay.
- ❖ TN is often transported into water bodies via non-point source pollution, runoff from urban environments being an example.
- ❖ Climate change (CC) is expected to increase both mean TN loadings and the interannual variability of TN loadings within the Chesapeake Bay watershed, where increases in TN loading variability are more harmful than mean TN loading increases alone.
- ❖ There is little information regarding how TN loading abatement costs will change under conditions induced by CC.

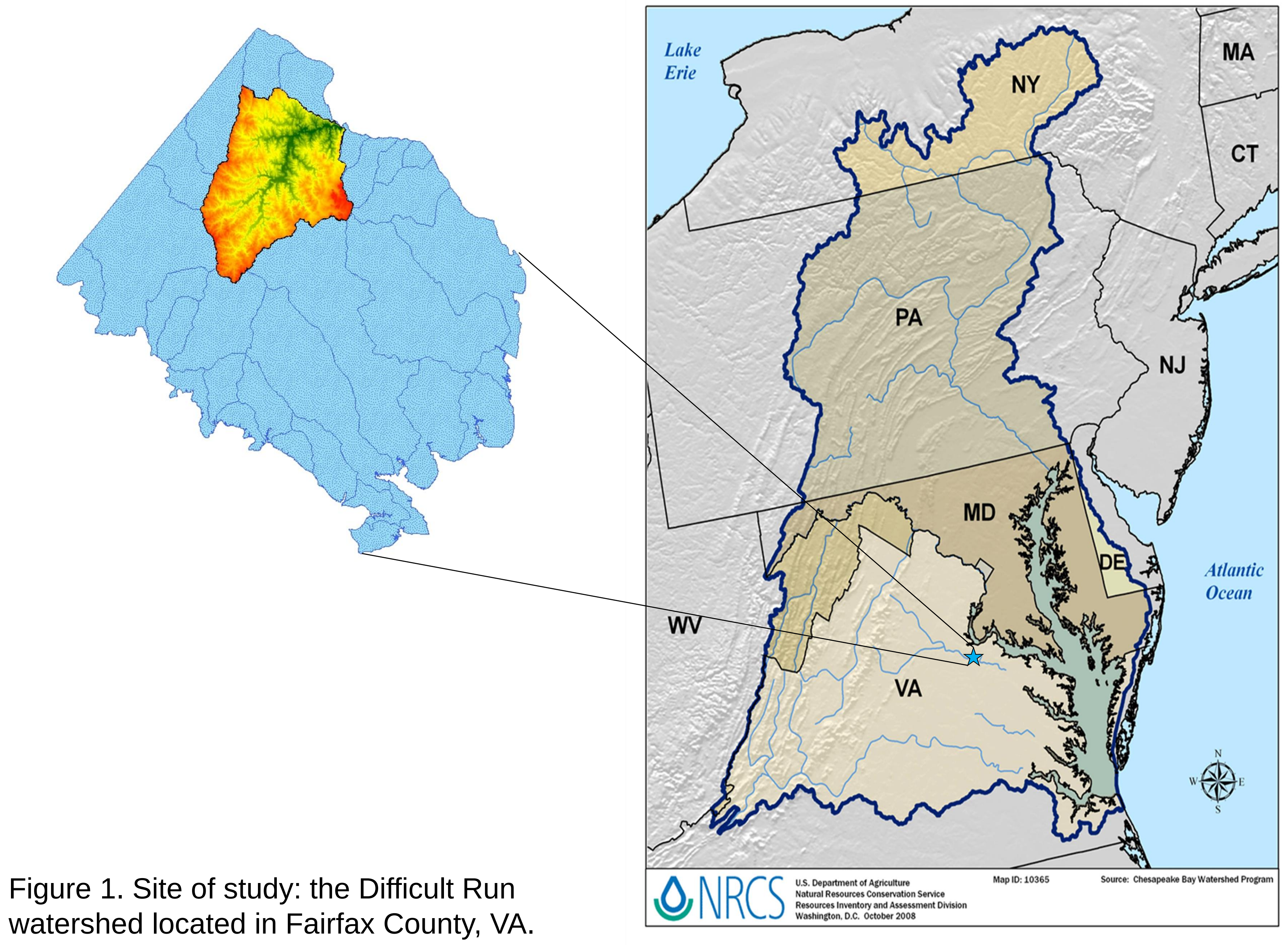


Figure 1. Site of study: the Difficult Run watershed located in Fairfax County, VA.

Objectives

- ❖ We sought to better understand how costs of TN loading abatement in urban environments change under CC relative to current climate conditions. Best Management Practices (BMPs) were used to control TN loadings.
- ❖ We used mathematical programming to estimate costs of abating mean interannual TN loadings under CC conditions relative to current climate conditions.
- ❖ We used risk programming to estimate the costs of abating interannual TN loadings variability for CC conditions relative to current climate conditions.

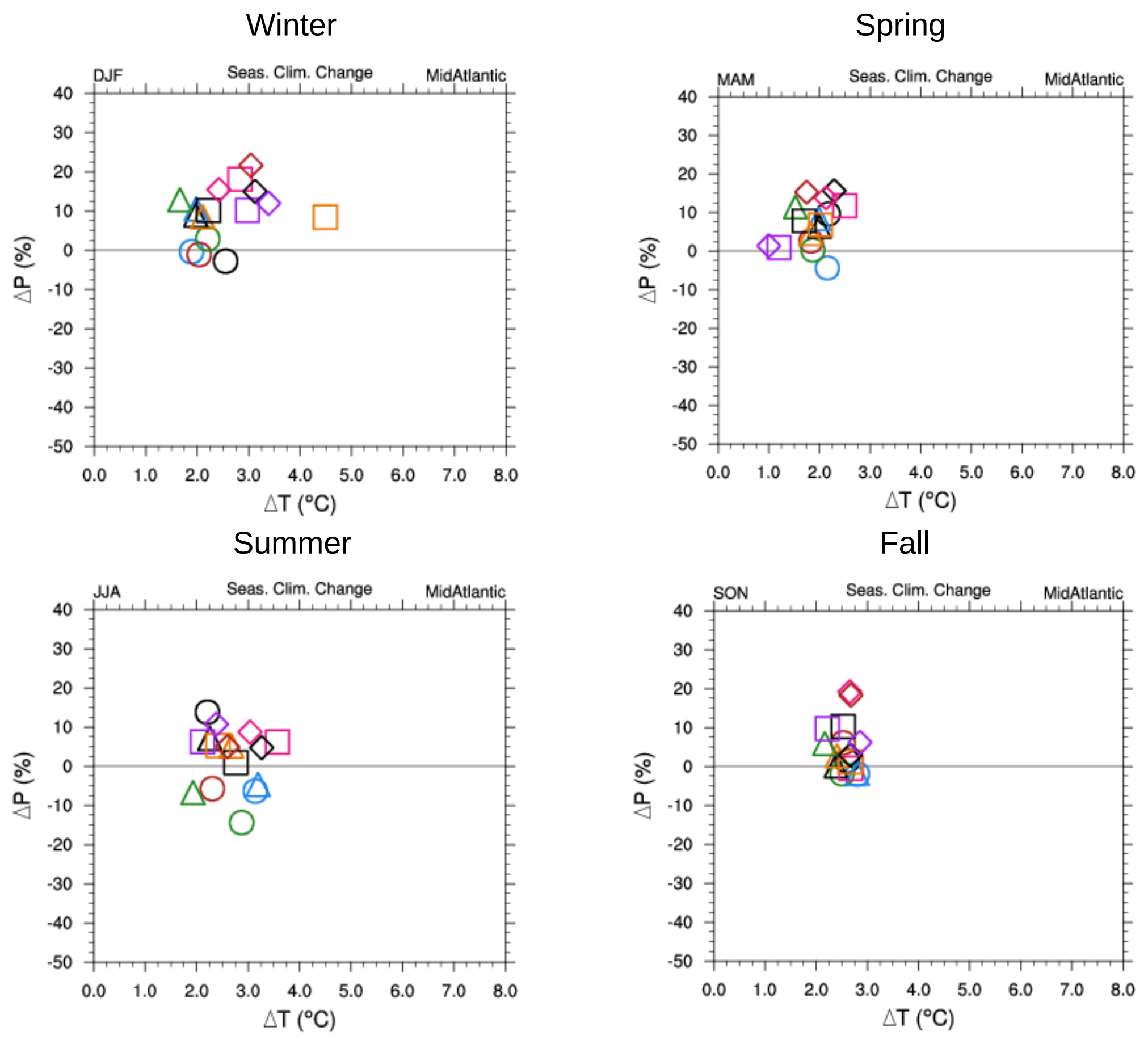
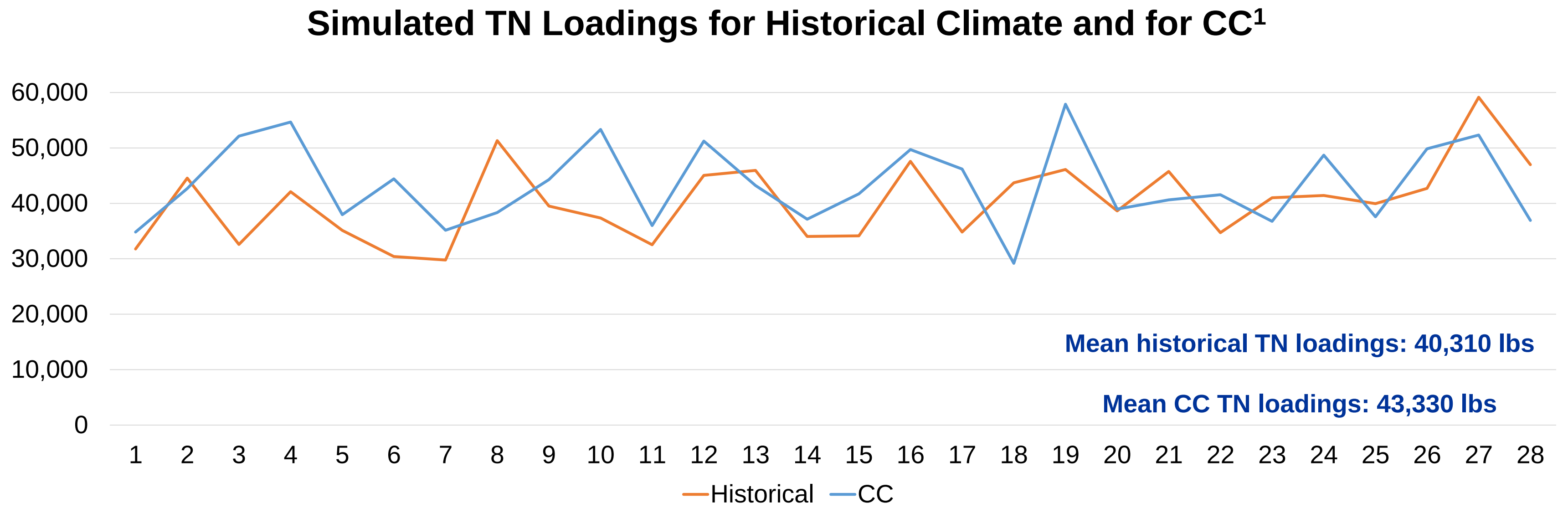


Figure 2. Seasonal increases in precipitation and temperature predicted by the North American Regional Climate Change Assessment Program (NARCCAP) – symbols representative of different Regional Climate Models (RCMs) under A2 climate scenario.

Data

- ❖ We simulated TN loadings for the watershed using EPA's Stormwater Management Model (SWMM) 5.1.010.
- ❖ CC data were simulated using a modified Mid-Atlantic regional climate model (RCM) adapted from NARCCAP.
- ❖ We derived geospatial attributes of the watershed using ArcMap by ESRI.
- ❖ BMP attributes and costs were based on government manuscripts and current BMP literature.



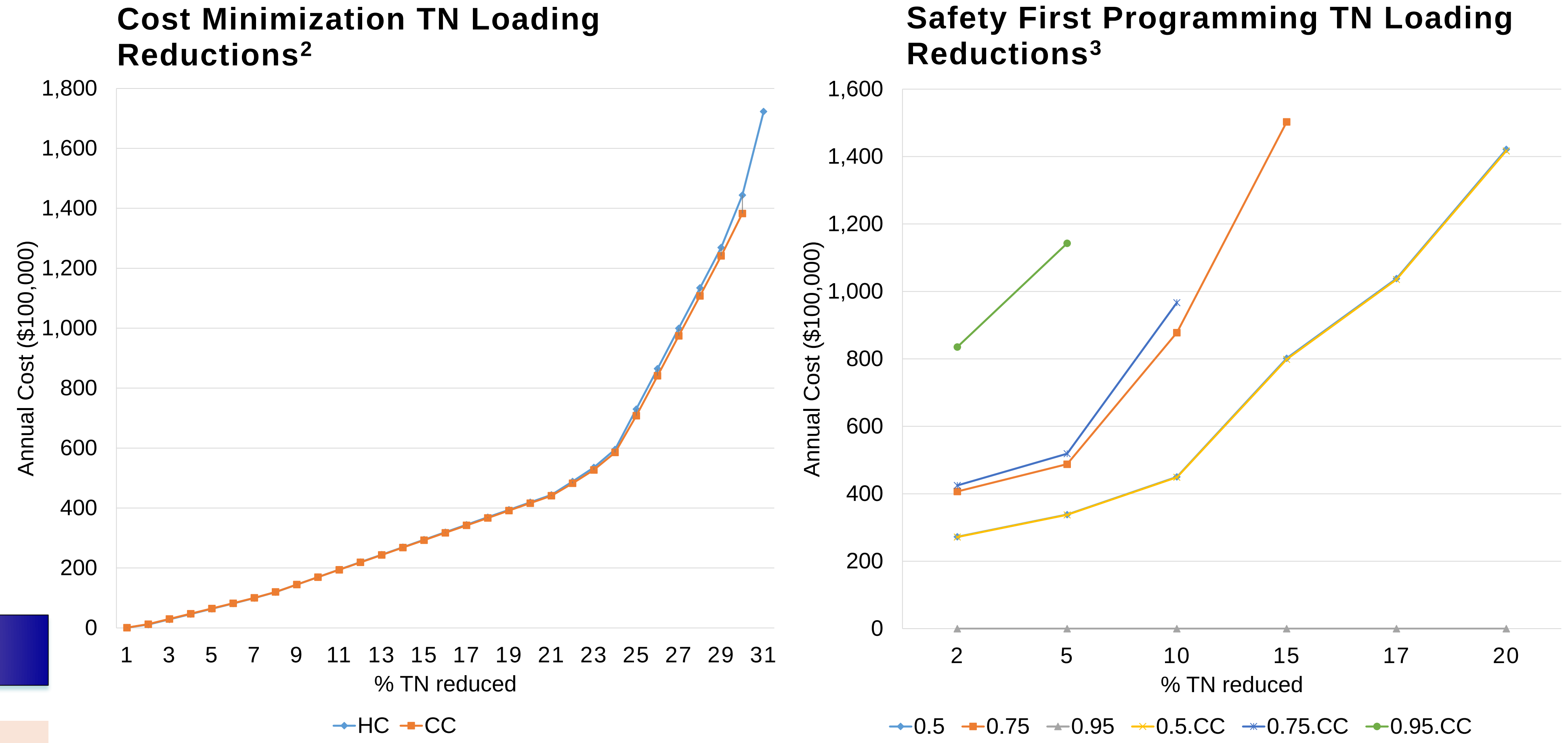
[1] Along the horizontal axis are the years spanning across each climate – historical climate being modeled from 1971-1998 and CC being modeled from 2040-2068.

Figure 3. Simulated Nutrient Loadings for the Difficult Run Watershed

Methods

- ❖ We estimated applicable watershed area to which BMPs may be applied using a Geographic Information System (GIS).
- ❖ We estimated costs of abating mean loadings for both climate scenarios using a Cost Minimization model to minimize the total annual cost of BMPs subject to a TN loadings constraint.
- ❖ We estimated costs of controlling variability of TN loadings for both climate scenarios using Safety-First probabilistic constraints. We set the maximum allowable amount of TN loadings within the watershed as well as the allowable probability of exceeding the maximum.

Results



[2] HC is the annual cost estimate for TN abatement under historical climate conditions. CC is the annual cost estimate for TN reductions under climate change.

[3] Line segments designated by 0.5 (0.75, 0.95) indicate the costs incurred for varying % TN reductions when there is a 0.5 (0.75, 0.95) probability of meeting the designated reduction under historical conditions. If the probability of success is followed by ".CC", the resulting line segment depicts the cost schedule under altered climate conditions induced by CC.

Figures 4 & 5. Optimal Cost Schedules for TN Abatement in the Difficult Run Watershed.

Average Percent Increases in Cost Estimates under CC

Cost Minimization	**0.6%**
Safety First Programming	**2.1%**

Conclusions and Discussion

- ❖ TN loading abatement costs increased under CC. The percent increase in costs from historical climate conditions to CC conditions for TN loadings variability abatement was greater than the percent increase in costs for controlling for mean TN loadings.
- ❖ Urban stream restoration was the most cost effective BMP followed by Low Impact Development. Where structural BMPs have long lifespans, policy makers may wish to front-load more BMP implementation today in order to account for increased TN loads in the future.
- ❖ Our analysis did not account for changes in land use and impervious surface. If these changes are included, we can predict there will be more TN export and higher subsequent control costs.
- ❖ Although not shown, sediment and Phosphorus control costs increased substantially under CC relative to TN control costs for both math models.

Acknowledgements

The National Science Foundation's Water, Sustainability, and Climate Initiative, grant # CBET-1360280 funded this study.

Costs of Meeting Water Quality Goals under Climate Change in Urbanizing Watersheds: The Case of Difficult Run, Virginia

Jonathon M. Giuffria❖, Darrell J. Bosch❖, Dan B. Taylor❖, Nasrin Alamdari*

❖Department of Agricultural and Applied Economics, Virginia Tech, Blacksburg, Virginia, 24060
*Department of Biological Systems Engineering, Virginia Tech, Blacksburg, Virginia, 24060

Author Contact: Darrell Bosch, tel. 540-231-5265, bosch@vt.edu

Selected Poster prepared for presentation at the 2016 Agricultural & Applied Economics Association Annual Meeting, Boston, MA, July 31- Aug. 2.