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A Multi-Scale Approach to the Forecast of Potential Distributions of Invasive Plant Species

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Controlling and preventing the spread of invasive plant species are common goals among ecologists and natural resource managers. Because these goals often are most successful when initiated early in the invasion process, the ability to predict where invasives will spread is crucial. The objective of this research project is to explain the distribution and abundance of invasive plants across the northeast United States as a function of climate and land use, and then forecast their future spread across the region to mid-21st century. To achieve reliable predictions on invasive species spread, the investigators propose a comprehensive approach that will take into consideration the major variables that will shape plant invasions in the next few decades (i.e., climate change, land use change, and the effects of elevated atmospheric CO_2).

The investigators will integrate experiments with predictive modeling to study plant invasions by focusing on the factors affecting their establishment and spread at four spatio-temporal scales: (1) regional-level, in which distributional ranges, based on the response to climate, will indicate the broad tolerance limits of each species; (2) landscape-level, in which incorporating the structure and composition of the landscape will inform predictions on the land use attributes that promote the spread and population growth of invasive species; (3) local-level, in which local site attributes (e.g., habitats, microclimates, soils, biotic interactions, etc.) will inform of establishment thresholds for these species; and (4) individual-level, in which changes in drought and shade tolerance will be examined under elevated atmospheric CO_2. The focus is to identify where specific species could establish and increase in abundance as successful invaders now and in the future.

An integral component of this project is to incorporate education and outreach for the public at large, professionals, and scientists. The investigators will use as a model the outreach and networking tools that they have implemented through the IPANE project (Invasive Plant Atlas of New England). The IPANE project has developed extensive educational and outreach materials on invasive species through its Web site, IPANE.org. Output from this project will be incorporated on model-prediction Web sites. The investigators plan to present the results of this research at regional, national, and international meetings of relevant scientific societies (e.g., the Ecological Society of America) each year during the course of the project. It is anticipated that the results of the research will be published in peer reviewed journals that focus on ecology, climate change, invasive species, and related issues (e.g., Ecological Applications, Biological Invasions, Global Change Biology, etc.). The investigators also will consider submitting articles, when appropriate, to high-profile general science journals.

Using the IPANE data set (species presence/absence, canopy closure, habitat type, etc.) with climate and land use and land cover (LULC), hierarchical Bayesian (HB) models will be constructed to predict potential distribution of selected invasive species. This approach provides for the specification of uncertainty in model components, as well as the predictions, and accepts prior knowledge and data from multiple sources. Regional predictions of future climates, focusing on projected changes in temperature and soil moisture, then will be incorporated. The climate models will be identified with co-PI Wang after examining the temperature and soil moisture changes projected by each of more than 20 global climate models (IPCC AR4). Climate projections from the North American Regional Climate Change Assessment Program (NARCCAP) also will be examined using forecasts for the middle of the 21st Century. The investigators will develop predictive LULC-change models, using LULC-change data from co-PI Civco. Co-PI Gelfand will develop and implement the LULC change models for the region. To evaluate the process of successful establishment of invasive species, in the context of new climates, varying establishment factors, and new biotic environments, the investigators will conduct a large-scale transplant study of invasive plant species across the region; this includes planting sites from southern Connecticut to northern Vermont. Demographic variables will be estimated as functions of environmental covariates using R and OpenBUGS software. Co-PI Reid will implement a CO_2 enrichment

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experiment with representative invasive and native species, grown under ambient and elevated (mid-21st Century) CO_2, under an array of watering and light levels; this allows quantification of the potential demographic advantage that projected elevated CO_2 levels may bring to some species.

The major objective of this project is to provide potential distribution maps and site information on potential establishment and abundance of invasive plant species across the region now and in the future. Predictions based on experimental data will reflect realistic plant responses to environmental conditions. This model approach will provide measurements of the uncertainty in predictions, one of the advantages of using statistical hierarchical Bayesian models. These models will be evaluated in part using Deviance Information Criterion and cross validation analyses. Data documentation, data files, and model descriptions will be made available through the IPANE Web Site. Periodic self-evaluation will be conducted by the project PIs. Independent evaluation of the project will come from peer reviews of manuscripts submitted for publication.

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