AN EARLY LOOK AT FOREST REGENERATION INDICATOR RESULTS FOR THE MIDWEST AND NORTHEAST UNITED STATES

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Abstract—Interacting regeneration stressors create challenges for policy makers and managers who are tasked with making decisions for restoring forest following major disturbances, such as harvest or catastrophic mortality. Concern over an aging forest, dwindling young forest habitat, and restoration of native forests in the midwest and northeast United States has resulted in the development of the regeneration indicator (RI), a new ecological health indicator derived from 25 years of measuring advance regeneration in Pennsylvania. The RI protocols were added to the Northern Research Station (NRS), Forest Inventory and Analysis (FIA) program sample plot design in 2012. Two case studies are presented that exemplify the scope of possible inferences from the existing data. The examples use two key variables—numbers of seedlings and browse impact—to highlight potential applications of this metric. Future research should focus on identifying issue-oriented geographic hot spots, further development of regeneration adequacy analytics, and integration with other publicly available geographic datasets.

INTRODUCTION

Multiple interacting regeneration stressors challenge wide-ranging policy and management decisions for restoring native forest ecosystems following major disturbances, such as harvest or catastrophic mortality. Some of the more complicated stressors are invasive plants, herbivory, and changing climate. Although it has been accepted as fact that tree regeneration determines future forest composition, structure, and health following stand replacement events, regeneration studies for subcontinental-scale forest landscapes are rare.

Concern over an aging forest, dwindling young forest habitat, and restoration of native forests in the midwest and northeast United States has resulted in the development of the regeneration indicator (RI), a new ecological health indicator derived from 25 years of experience measuring advance regeneration in Pennsylvania (McWilliams et al. 2012). The RI protocols include a suite of tree-seedling and browse impact measurements that were added to Northern Research Station (NRS), Forest Inventory and Analysis (FIA) program sample plot design in 2012 (McWilliams et al. 2015).

The goal of this paper is to demonstrate decisions for making inferences and observations using the RI data with examples that range from the substate to subcontinental scale. Only general guidance is offered because the of many prospective uses, sample sizes, and options for geographic applications preclude more complete recommendations in this short paper.

METHODS

In 2012, the NRS-FIA program began taking measurements for a suite of ecosystem health indicators collected during the leaf-on season. A 12-percent subsample of the core Phase 2 sample was selected randomly within estimation strata; the subsample plots are referred to as "Phase 2-plus." Each RI sample is coincident with Phase 2 and other Phase 2-plus indicator samples, including down woody material, vegetation structure, and soils.

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The vegetation structure measurements are collected on forested conditions and comprised of a vegetation profile, an invasive plant survey, and the RI. The vegetation profile includes estimates of percent cover by growth habit for four height classes and an aerial view of the subplot. The invasive plant survey is made up of percent cover estimates for 43 invasive plant species encountered on the subplot. The RI measurements are collected on microplots within the subplot and include a tally of all established tree seedlings at least 2-inches in length (or height) by species, assignment of each seedling to one of six height classes, and an assessment of root-collar diameter for large-seeded species. A browse impact code is also recorded based on conditions surrounding the sample plot. Details of plot, subplot, and microplot design are provided in USDA Forest Service 2012.

Two case studies exemplify the scope of possible inferences for data that range from small to large scales and to illustrate opportunities and limitations of analyzing results. The case studies use two key variables—numbers of seedlings and browse impact—to highlight reporting and research products.

The first case study presents estimates of seedlings in West Virginia. The estimates are based on 83 forested Phase 2-plus samples collected in 2012-2013. Population estimates for the six seedling-height classes were combined into three to take advantage of lower sampling errors associated with larger sample sizes of the wider range of heights. These traditional FIA sampling errors represent one standard error or a 68-percent confidence level.

The second case study is a geographic evaluation of browse impact comparing results for a variety of scales. The visualization includes RI data for 2012-2013 for Delaware (four samples), Maryland (19), and New Jersey (17) to represent minimum reporting options. These results are compared to the NRS-FIA region-wide data for 2012-2013 (1,711) and the full baseline data set for Pennsylvania (292) to provide context. Statistical confidence intervals for population estimates are used to suggest bounds for deriving logical conclusions from the results.

RESULTS

In the Midwest and Northeast, large blocks of forest land are aging and subject to a plethora of stressors, which means stand-replacement disturbances will likely become more common. Estimates of the number of seedlings by height class, species, and spatial extent provide information for predicting future forest composition and prospective regeneration management challenges (Fig. 1a-c). Sampling errors for species and species groups range from 20 percent for the number of red maple seedlings to 70 percent for boxelder (see Appendix Table 1 for list of common and scientific names). The sampling errors exceed 25 percent for all species that comprise 3 percent or less of the total number of seedlings, suggesting a possible limit for taxa-specific inferences at these sample sizes. It is apparent that with only two inventory panels complete, nearly all of the estimates for species by height class lack statistical confidence needed for making inferences. The visualization of seedlings per acre across West Virginia clarifies spatial patterns of seedling development. The seedlings per-acre classes can be adjusted as needed for species, forest types, and regions of interest, subject to statistical confidence limitations.

Results displayed in a geographic context can facilitate the understanding of how and where deer browse has the most impact. The distribution of samples by browse impact for the NRS-FIA region provides a first look at general patterns of high versus low browse impact, e.g., Maine compared to central Pennsylvania (Fig. 2a). Figure 2b shows three states with relatively small sample sizes combined with the full baseline data set for Pennsylvania. Even though low sample sizes prevent rigorous spatial analysis for the three small states, including the Pennsylvania samples and the ecological province boundaries assists in observing broad browse impact patterns. For example, samples for western Maryland appear to follow the relatively nondescript patterns of the Central Appalachian Broadleaf Province. Combining the Outer Coastal Mixed province portions of the three small states suggests careful monitoring is needed because of the abundance of high browse impact samples.

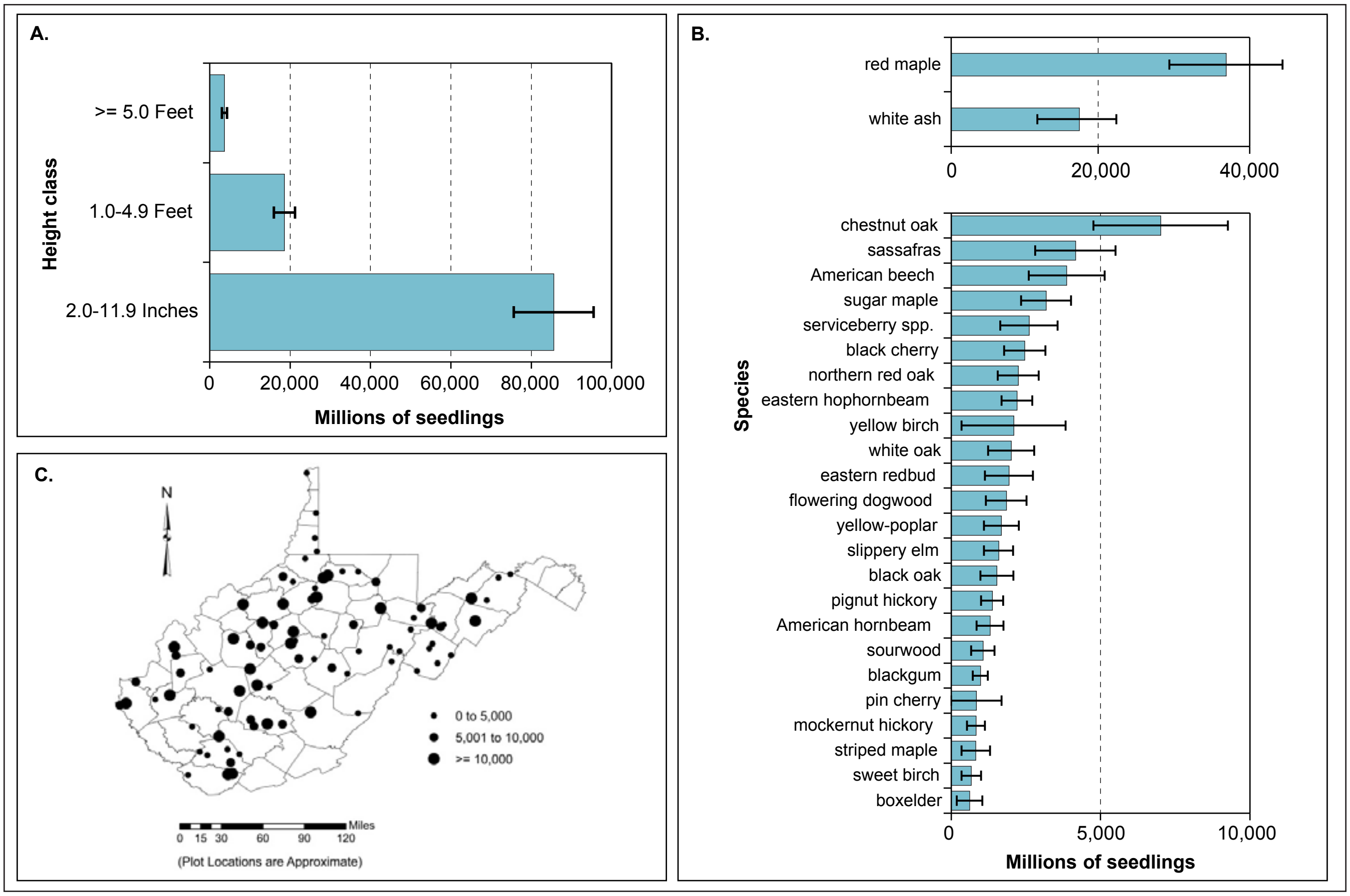

Figure 1—a) Number of seedlings by height class; b) Number of seedlings ranked by species for species with at least 1 percent of the total number of seedlings; and c) distribution of forested Phase 2-plus samples by the average number of seedlings per acre, West Virginia 2012-2013. Error bars represent 1 standard error or a 68-percent confidence interval.

DISCUSSION

The RI results provide meaningful insight into the character and abundance of the seedling component for the NRS-FIA region; however, it is clear that caution is needed for making inferences. The relatively small sample size at the regional level means that some states, study regions, and variables have sample sizes that limit the ability to make inferences. Consequently, reporting templates for West Virginia and Maryland would be quite different because analyses need to be tailored to fit statistical limitations. Presenting the results with error bars and geographic distributions for the major variables of interest provides insights for the smaller states. It becomes obvious that more information is needed for taxa-specific abundance (numbers of seedlings) and structure (seedling height). These attributes are critical for understanding the future status of forest ecosystems following stand-replacement disturbance.

These results reflect only two of the seven panels of measurements that will eventually comprise the first full baseline data set for the RI. Completion of the baseline data set in 2018 will improve the level of statistical confidence in the estimates and facilitate more detailed studies.

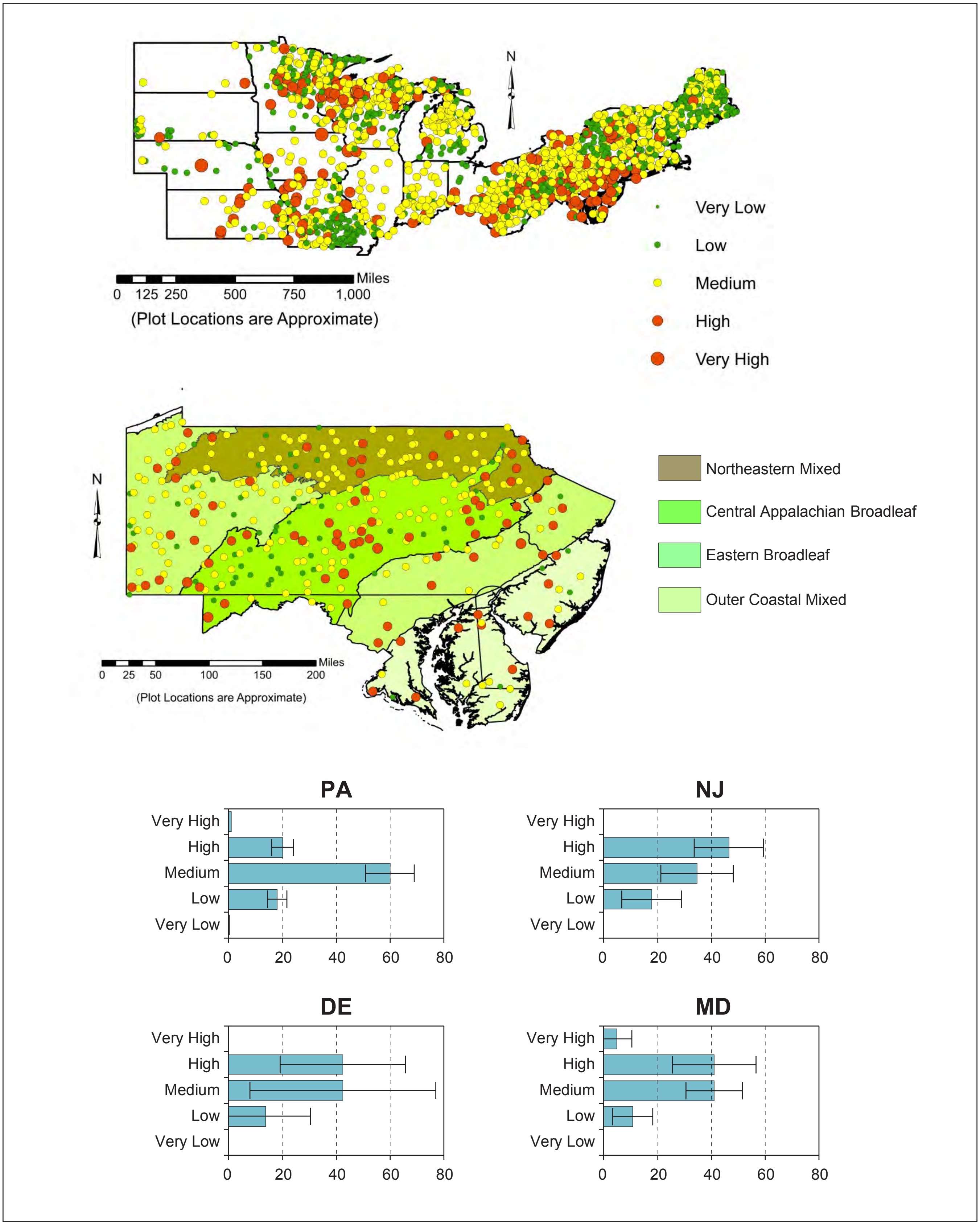

Figure 2—a) Distribution of forested Phase 2-plus samples on forest land by browse impact, b) distribution of forested phase 2-plus samples and by browse impact and ecological province (Cleland et. al. 2007), NRS-FIA states, US, 2012-2014. Error bars represent 1 standard error or a 68-percent confidence interval. (Note: results for Pennsylvania are for 2010-2014).

FUTURE WORK

As with any new ecological health indicator, there are numerous research extensions and applications to enhance the utility of science products. Future research should focus on an analysis of composition and structure of the seedling component as the data set expands and a geospatial analyses to identify high-risk areas, such as forest types with poor regeneration or areas with high browse impact.

Research is also needed to address the viability, or adequacy, of the regeneration process. While analytics that adjust existing regeneration guidelines to reflect browse impact have been applied for the mid-Atlantic States (McWilliams et al. 1995), similar analytics for the Central, Lake, and New England States are needed. Once complete, such metrics will facilitate a seamless and transparent assessment of regeneration adequacy for the major forest types of the Northeast and Midwest. This is a critical need due the aging of mixed oak and northern hardwood forests of the region and regeneration stress factors that interact to make regeneration difficult.

Modern resource questions often require multivariate studies that combine geographic data to better understand complex relationships. There are many research opportunities to integrate the RI data with other publicly available geographic datasets. For example, tree-species migration studies would benefit from including soils (USDA Natural Resource Conservation Service 2015), climate (NOAA National Weather Service 2015), and disturbance (USDI Geological Survey 2015).

The RI was designed to supplement NRS-FIA's vegetation profile and invasive plant survey information. Combining results from these three components of the vegetation structure measurements provides a fuller appraisal of the forest understory that will better address emerging issues, e.g., the status and condition of new forest communities (Royo and Carson 2006). In turn, this should improve our ability to evaluate sustainability of future forest values in the Midwest and Northeast.

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APPENDIX

Table 1—Common and scientific names of FIA tree species.

Species Common name	Scientific name[1]
American beech	*Fagus grandifolia*
American hornbeam	*Carprinus caroliniana*
black cherry	*Prunus serotina*
black oak	*Quercus velutina*
blackgum	*Nyssa silvatica*
boxelder	*Acer negundo*
chestnut oak	*Quercus prinus*
eastern hophornbeam	*Ostrya virginiana*
eastern redbud	*Cercis canadensis*
flowering dogwood	*Cornus florida*
mockernut hickory	*Carya alba*
northern red oak	*Quercus rubra*
pignut hickory	*Carya glabra*
pin cherry	*Prunus pensylvanica*
red maple	*Acer rubrum*
sassafras	*Sassafras albidum*
serviceberry spp.	*Amelanchier spp.*
slippery elm	*Ulmus rubra*
sourwood	*Oxydendron arboreum*
striped maple	*Acer pensylvanicum*
sugar maple	*Acer saccharum*
sweet birch	*Betula lenta*
white ash	*Fraxinus americana*
white oak	*Quercus alba*
yellow birch	*Betula alleghaniensis*
yellow-poplar	*Liriodendron tulipifera*

[1] USDA Natural Resources Conservation Service, 2014.