BULLETIN

# Climate Change & Forest Productivity

JUNE 30, 2016 / BY JENNIFER HUSHAW

Considerable attention has been paid to understanding how climate change may alter the *abundance* and *distribution* of tree species, as discussed in our previous bulletin on modeling future forests, but an equally important consideration is how climate change may alter *productivity*. **Research suggests climate change has the potential to affect not just where, but how well our forests grow.** This bulletin highlights recent work by researchers at Virginia Tech, University of Maine, the US Forest Service, and others that estimates how productivity may shift as a result of changing climate.

## Productivity & Site Index

One measure of potential forest productivity is site index—defined as the average total height (in meters) that dominant and co-dominant trees attain at a specified base age in even-aged stands. Of course, this is based on the assumption that forests are even-aged and consist of a single species, which can be problematic in regions dominated by uneven-aged, mixed species stands, such as the eastern US. However, it is a commonly used metric that provides some utility. Researchers have responded to these known limitations by attempting to predict observed site index using site attributes like climate, topography, and soil characteristics.

## Study Overview

In a recent study published in the Canadian Journal of Forest Research (Jiang et al. 2015), researchers created models to predict site index (base age 50) for 20 eastern tree species (as well as hardwoods and conifers generally*) based on 15 soil and 37 climate variables. The models successfully predicted current site index values observed through USFS Forest Inventory and Analysis (FIA) data, which provides confidence in their ability to accurately represent on-the-ground conditions. Then they were re-run with future, rather than contemporary, climate data to estimate how site index would change under projected future conditions.

They utilized vegetation and site index data from the FIA program, contemporary (1961 to 1990) and future (2030, 2060, and 2090) climate data from the USFS Rocky Mountain Research Station representing four different future emissions scenarios, and soils data from the USDA Soil Survey Geographic (SSURGO) database.

The models were developed using a statistical technique (Random Forests—a classification and regression tree analysis) that has been shown to be very adept at analyzing these types of research questions and datasets. With the analysis they employed, they were also able to calculate confidence intervals to determine if the predicted changes in site index were significant or not.

## Results

Researchers used all climate and soil variables (to ensure maximum predictive accuracy) to generate maps of site index change. They found that site index may increase or decrease in the future, depending on the species and the geographic region in question. Although only the broad hardwood and conifer species groups were reported, models were generated for individual species as well.

## Key Findings

### CURRENT SITE INDEX:

- There was more variation in observed site index for conifers than hardwoods across the eastern US.
- The models that performed best at predicting site index included BOTH climate and soils data.
- Models that used *only* climate data to predict site index performed better than those using soils alone.
- Variables that were useful for predicting site index included:
    - Soil pH
    - Effective soil depth (especially for conifers)
    - Total available soil water capacity
    - Ratio of summer precipitation to total precipitation
    - Summer-winter temperature differential
    - Growing-season precipitation (April—September)
- For conifers, current site index showed a pattern of increasing from north to south.
- For hardwoods, current site index showed a pattern of increasing from north and west to southeast.

### FUTURE SITE INDEX:

- For conifers, there was a significant *increase* in average site index (+0.5 – +2.4m) over the 21st century.
- For hardwoods, there was a significant *decrease* in average site index (up to -1.7m) over the 21st century.
- Several regions showed contrasting results depending on the climate change scenario.
- Variables that were important for determining future changes in site index were related to:
    - The ratio of growing-degree-days to summer precipitation
    - The start and length of the frost-free season
    - Average and accumulated growing-season temperatures
    - Changes in moisture index or summer temperatures in combination with changes in midwinter ambient temperatures
- Under the lowest emissions scenario, more FIA plots showed a significant increase in site index and fewer showed a significant decrease, whereas the higher emissions scenarios consistently showed the opposite result—suggesting that there may be some overall benefit for forest productivity under moderate warming that disappears under higher levels of warming.

## Conclusion

This study is an example of the research being done to better understand how changing climate conditions will alter forest productivity. A key take-home is how different the forest response can be depending on the rate and level of warming, which is also a key area of uncertainty. This highlights the important ramifications of different climate trajectories and suggests that forest managers may want to keep their eye on those trends over time. In some cases, it may be beneficial to shift the species mix toward those projected to experience an increase in site index. However, these results should also be considered in conjunction with other research related to potential productivity changes, such as growth increases due to $CO_2$ fertilization or decreases due to extreme heat events. We will continue to monitor new and emerging research on this topic going forward.

**NOTE:** For those interested in a similar analysis for western US tree species, please see a paper by Weiskittel et al (2011) entitled Linking climate, gross primary productivity, and site index across forests of the western United States.

* Species comprising the hardwood and conifer species groups in this analysis:

| Hardwood | Conifer |
|---|---|
| White oak | Loblolly Pine |
| Yellow poplar | Shortleaf Pine |
| Quaking aspen | Eastern white pine |
| Northern red oak | Balsam fir |
| Sugar maple | Red pine |
| Red maple | Slash pine |
| Black oak | Black spruce |
| White ash | Tamarack (native) |
| Green ash | N. white cedar |
| Sweetgum | Virginia pine |

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## References

Jiang, H., Radtke, P.J., Weiskittel, A.R., Coulston, J.W., Guertin, P.J. 2015. Climate- and soil-based models of site productivity in eastern US tree species. *Can. J. For. Res*. 45: 325-342.

Weiskittel, A.R., Crookston, N.L., Radtke, P.J. 2011. Linking climate, gross primary productivity, and site index across forests of the western United States. *Can. J. For. Res*. 41: 1710-1721.