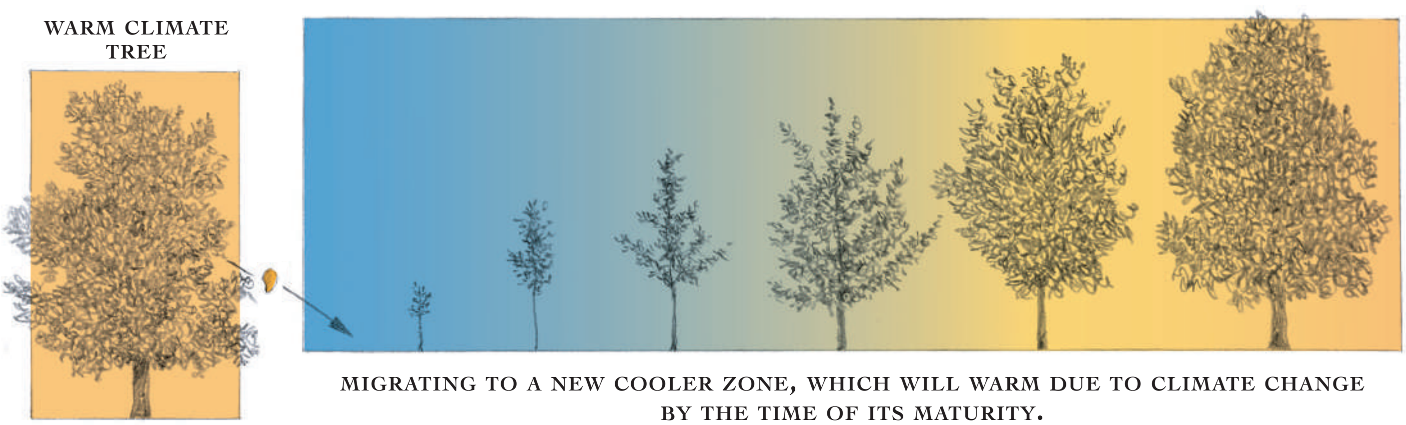
FUTURE CLIMATE-ADAPTED TREE SPECIES

By Alexandra Kosiba. Illustrations by Erick Ingraham.

This article is the second in a four-part series that focuses on climate change impacts and adaptation in forests. A companion series published last year focused on forest carbon. Alexandra Kosiba, a forest ecologist and tree physiologist, is an assistant professor of forestry at University of Vermont Extension. She specializes in climate change impacts to trees and forests and ways that foresters and landowners can incorporate climate change considerations in their decision-making and planning.

When we think about the impacts of climate change on our forests, it's crucial to understand that these changes will affect individual tree species differently. Some trees, in certain locations, will experience declines, while others will thrive. This variability stems from the unique physiology and ecology of each tree species, which determine the conditions in which the species grows and how it responds to environmental shifts. Consequently, as the climate changes, the composition of the forest community will also change.

To manage forests effectively in the face of climate change, we must grapple with several challenging questions. For instance, which species are most capable of adapting to changing conditions, and which ones may struggle? How might shifts in the forest community impact other objectives such as promoting wildlife habitat, carbon storage, flood prevention, and wood production? How rapidly can a forest change its tree species composition, and when is it appropriate to introduce new species? If we do choose to introduce new species, how far should we relocate these species within a forest to ensure their success?



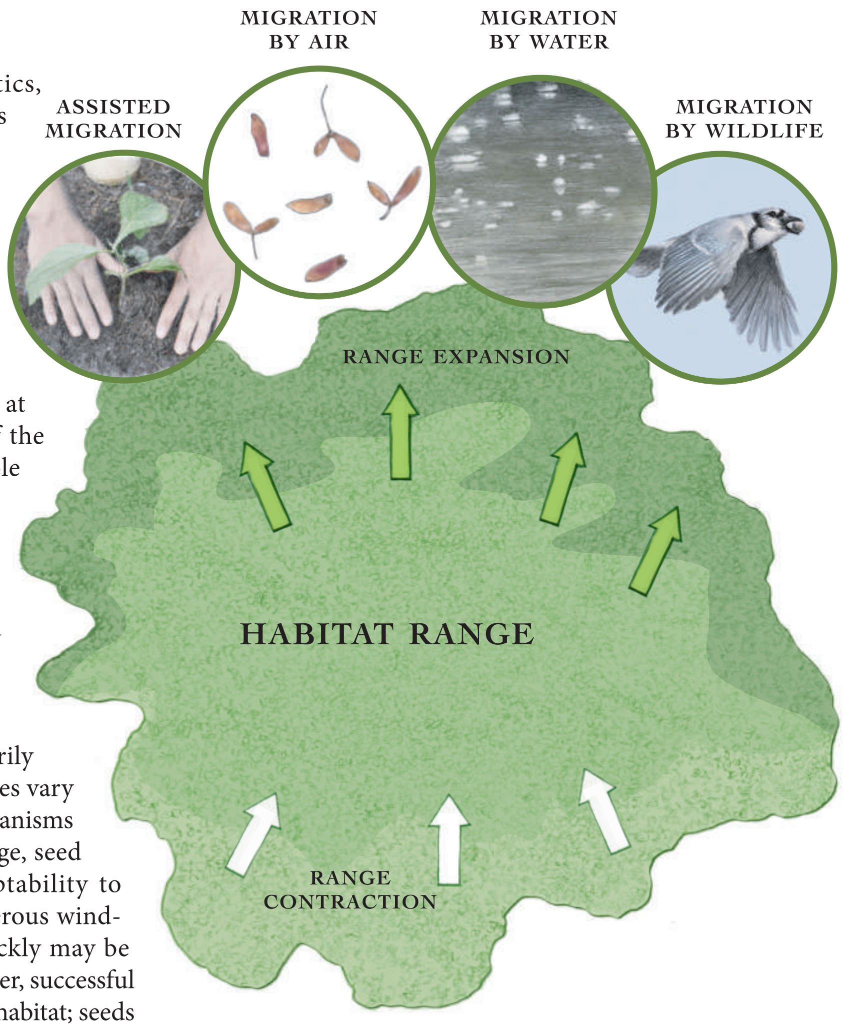
MIGRATING TO A NEW COOLER ZONE, WHICH WILL WARM DUE TO CLIMATE CHANGE BY THE TIME OF ITS MATURITY.

Trees on the Move

A combination of soil types, site characteristics, temperature tolerances, and precipitation levels collectively define a tree species' *habitat range* – the geographic area where all individuals of that species reside. As climate and environmental conditions change, the boundaries of this habitat range may contract or expand.

For instance, as temperatures rise, more of a tree species' seeds that disperse northward or to higher elevations may survive, allowing the species to establish in nearby areas. Conversely, at the southern edge or lower altitudinal limits of the habitat range, seeds may encounter less favorable conditions than in the past, leading to the decline and potential disappearance of the species from those areas. Scientists call these movements *range migrations*. More specifically, *range expansion* is when a species establishes in new habitats, and *range contraction* is when a species retreats from historical habitats.

Natural range expansion into new habitats is a process that spans multiple generations, primarily due to the slow maturation of trees. Migration rates vary among species, influenced by seed dispersal mechanisms (such as wind, water, or animals), reproductive age, seed production frequency and quantity, and adaptability to changing conditions. Species that produce numerous wind-dispersed seeds and reach reproductive age quickly may be able to move to new locations more rapidly. However, successful migration entails more than just arriving in a new habitat; seeds must find suitable conditions for germination, growth, and survival, including sunlight, water, and nutrients.



In the Northeast, a notable example of range migration is the recolonization of the region by trees following the last ice age. Starting around 12,000 years ago, pine, spruce, birch, larch, fir, and aspen began moving north into the tundra. Then came oak and hemlock. Later arrivals included beech, maple, and chestnut. Over millennia, northeastern forests developed and rearranged as species gradually migrated into the region, adapting to prevailing conditions along the way.

In contrast, range contraction can happen more quickly. Factors such as changes in temperature and precipitation, declines in snowpack, alterations in rainfall seasonality, soil drying, insects and diseases, competition from other plants, and heavy browsing by deer can all decrease seedling survival. When these stressors coincide with losses of older, seed-producing trees – such as mass infestations of invasive insects triggered by warming winters – a tree population may rapidly decline in part of its habitat range.

Over time, expansion at the leading edge and retreat at the opposite side can shift an entire tree species' habitat range across the landscape. These shifts, along with changes in other tree species' habitat ranges, shape forest communities.

Future-adapted Tree Species

In the Northeast, there are now more than 100 different native tree species, each with its own unique habitat range. While no two species have identical habitat ranges, we can categorize the region's trees into three broad groups to help us understand potential range shifts in response to climate change.

The first group comprises tree species with current habitat ranges that extend farther north, such that the Northeast sits along the southern end of their range. Species in this group include balsam fir, white spruce, quaking aspen, paper birch, northern white-cedar, pin cherry, black ash, and tamarack (larch). A warming climate poses challenges for this group because they are adapted to colder locations. Consequently, their ranges may contract northward or to higher elevations. We're already observing such shifts for species such as balsam fir, northern white-cedar, paper birch, and quaking aspen[1].

The second group includes species with the center of their habitat range in or near the Northeast, such as sugar maple, white pine, eastern hemlock, American beech, red maple, and yellow birch. These species may exhibit varied responses to climate change due to their wide distribution across the region.

The third group includes species with ranges extending south, with the Northeast being historically at the northern limit of their range. Examples include white oak, shagbark hickory, tulip poplar, eastern red-cedar, red oak, bitternut hickory, black cherry, and American sycamore. These species, adapted to warmer and more southerly areas, may expand their ranges farther into the region due to climate change.

Additionally, there is a fourth group to consider: species native to the mid-Atlantic states whose ranges do not currently extend into New England and New York. As the climate warms, these species may find new suitable habitat. This group includes more than 30 tree species, such as loblolly pine, pecan, eastern redbud, honey-locust, Virginia pine, and pawpaw.

Tree species likely to thrive and expand their range in the Northeast under future climate conditions are considered future *climate-adapted.* However, there's significant variation in suitability for different growing conditions within this group. For instance, the suite of tree species best suited to the future conditions in southwestern Connecticut differs from those for northern Maine. Factors such as soil, site characteristics, management goals, and future temperature and precipitation are essential considerations.

The Climate Change Tree Atlas

To offer insights into potential future habitats for tree species in the eastern United States amid changing climate conditions, the USDA Forest Service has developed a freely accessible online tool called the *Climate Change Tree Atlas*[2]. By analyzing data from 85,000 Forest Inventory and Analysis plots, scientists identified the current distribution of each tree species based on factors such as elevation, soil, and climate. Using future climate projections and statistical models, they predict potential suitable habitats for each tree species by 2100.

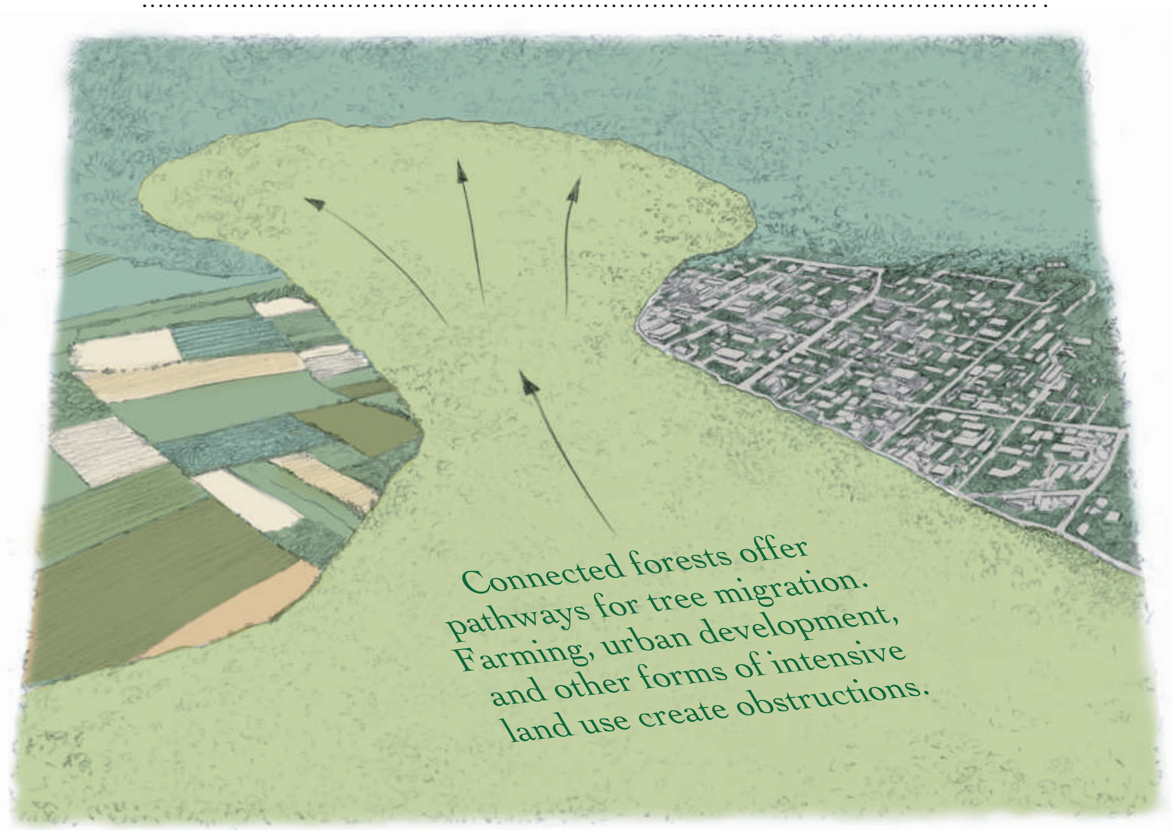
A tree species' future success isn't solely determined by changes in temperature and precipitation patterns. Individual tree species have certain traits that can contribute to their migration rates, as well as to their adaptability or vulnerability to disturbances and stressors. To provide insights to the potential of each species to reach new suitable habitats, the *Tree Atlas* uses a species' past migration rate to assess the likelihood that the species will be able to migrate to these new locations. Understanding these traits can inform conservation strategies and management practices to promote resilient forest ecosystems.

Additionally, traits such as fire tolerance and resistance to windthrow could contribute to a species' adaptability, while susceptibility to pests and diseases and sensitivity to animal browsing, for example, could hinder a species' future success. The *Tree Atlas* rates the traits of each species based on their positive or negative effects on adaptability compared to other species. For instance, balsam fir receives a negative adaptability score due to its susceptibility to pests and wood rot fungi, while eastern cottonwood gets a positive rating for its ability to endure prolonged flooding. Among our native species, red maple has the highest adaptability score, while black ash ranks the lowest. These adaptability scores can help us better understand how likely it is for a species to persist given a combination of stressors.

It's important to acknowledge that while the *Tree Atlas* aids decision-making, it doesn't encompass all aspects of tree physiology and ecology that influence species' responses to climate change. For example, there is considerable variability in traits within a species, leading to differences in growth, site tolerances, and adaptability among individuals. Natural selection can drive adaptations to new conditions, and some species can hybridize with related ones, producing offspring with beneficial traits for rapid adaptation.

For summarized lists of *Tree Atlas* species projections for different regions, see the Climate Change Response Framework[3]. Keep in mind that the reliability of the *Tree Atlas* projections varies by species, indicated by a reliability score. Generally, widely distributed species have higher reliability, while rare ones have lower reliability. Despite lower reliability, the model still offers insights into future changes, albeit with less confidence.

1 Fei et al. 2017. Divergence of species' responses to climate change. Science advances, 3(5).
2 https://www.fs.usda.gov/nrs/atlas/tree
3 https://forestadaptation.org/learn/resource-finder/climate-change-projections-individual-tree-species-new-england-and-northern and https://forestadaptation.org/learn/resource-finder/climate-change-projections-individual-tree-species-mid-atlantic-region



Barriers to Tree Migration

As noted above, numerous factors influence a tree species' ability to migrate, including land use changes, how quickly trees within that species attain reproductive age, seed viability, competition from other plants, weather patterns, herbivory, and insects and diseases. This means that even if a location offers suitable habitat for a tree species in the future, that species may not be able to become established there.

An unprecedented challenge trees face is that the climate is changing much faster than historical migration rates. Researchers estimate that following the last ice age, tree migration rates averaged less than 350 feet per year[4]. To match projected rates of climate change, trees may need to migrate much faster – up to 5 miles per year. Compounding this difficulty is the fragmentation of the landscape due to roads, farm fields, densely settled areas, and other intensive developments, which act as barriers to migration.

Given these obstacles, there is a substantial risk that certain tree species, particularly rare or uncommon ones, may fail to migrate to favorable locations quickly enough, and could experience population fragmentation and extirpation in parts of the Northeast. Widely distributed species such as sugar maple are unlikely to face complete habitat loss, but rapid climate change could lead to shrinking habitat ranges and declines in areas where they were once abundant.

Beyond the risk to individual species, there is concern that change is happening so rapidly, accompanied by numerous other stressors, that currently abundant tree species could decline faster than new species are able to establish, jeopardizing the forest's ability to sustain habitat and ecosystem services, including carbon storage and sequestration.

Assisted Migration of Tree Species

To address the impacts of rapid climate change on forests and individual tree species, some conservation groups, forest managers, and scientists are experimenting with assisted migration – planting tree species at new growing sites in anticipation of changing climate conditions. There are three general approaches.

Assisted population migration involves planting trees in new locations within a species' existing habitat range. This strategy is primarily used to enhance the resilience and adaptation of a forest to expected future conditions. An example of assisted population migration is collecting red oak acorns from a low elevation site and planting them at a higher elevation. In this scenario, red oaks growing at the lower elevation are adapted to a slightly warmer climate than currently exists at the planting

4 Aitken et al. 2008. Adaptation, migration or extirpation: climate change outcomes for tree populations. Evolutionary applications, 1(1), pp. 95–111.

location. Therefore, they may be better suited to the future conditions of the planting site.

Assisted range expansion involves planting trees in suitable areas just north of the species' current range in order to accelerate natural migration. This strategy may help to transition the species' composition of a forest to include a greater proportion of future climate-adapted species. An example is planting tulip poplar in a northern Massachusetts forest, just north of its current range.

Assisted species migration involves moving species far beyond their current range and what natural dispersal would allow over many decades. This strategy can help to conserve species with narrow habitat ranges or low migration potential. An example is planting Virginia pine in southeastern New York. Although the *Tree Atlas* projects some areas with future suitable habitat for Virginia pine in southeastern New York by the end of this century, there is a very low likelihood that the species will be able to migrate to this area without human intervention. Compared to other forms of assisted migration, this strategy has the highest risk of failure and potential for unintended consequences, such as inadvertently moving tree-infesting insects and diseases to new areas.

There are several challenges to assisted migration. Monitoring has revealed that although locally adapted trees may not always be well positioned for the future, they often outcompete transplanted young trees. Planting trees is also labor-intensive and costly, and these trees may require significant upkeep before they become established. Some evidence suggests that planting seeds, rather than nursery-grown seedlings, may be more effective in balancing costs and success.

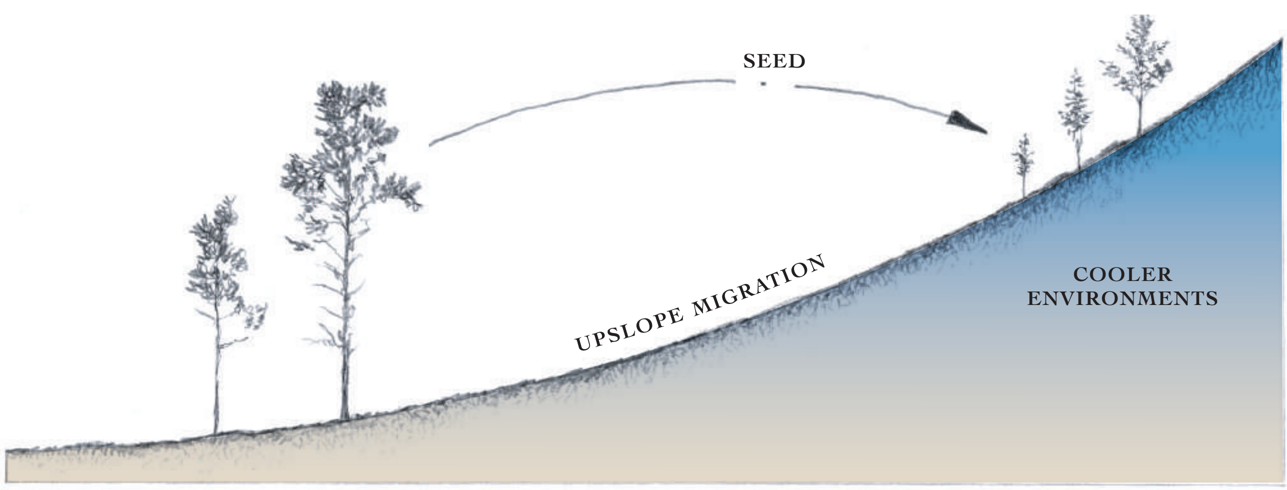
One key obstacle to assisted migration lies in the collection of the seed source, whether for direct planting or to grow seedlings. Given the trait variability within a species, it is crucial to select seeds originating from a variety of locations to enhance resilience to future conditions. Ideally, seeds should be sourced from locations that match the expected future climate of the planting site so that the seedling can both tolerate the current conditions as well as thrive in the future. However, implementing this approach can be difficult. Currently, most plant nurseries do not specify seed origin, and the overall availability of planting stock for many tree species is limited.

One of the biggest challenges with assisted migration is that the planted tree needs both to survive current conditions as well as future conditions that may be significantly different. Trees are unlikely to grow well if planted too far north from their origin, primarily due to their intolerance of cold temperatures. For example, U.S. Forest Service climate models indicate that by 2100, northern New Hampshire will have suitable habitat for pignut hickory, a species with high wildlife food value. However, northern New Hampshire is currently classified as belonging to a hardiness zone 3 (minimum winter temperature of -35 degrees Fahrenheit), and pignut hickory is only hardy to zone 5 (minimum winter temperature of -20 degrees F). As a result, planted pignut hickory in northern New Hampshire would likely suffer from cold injury in winter and may not survive long enough to experience more favorable climate conditions.

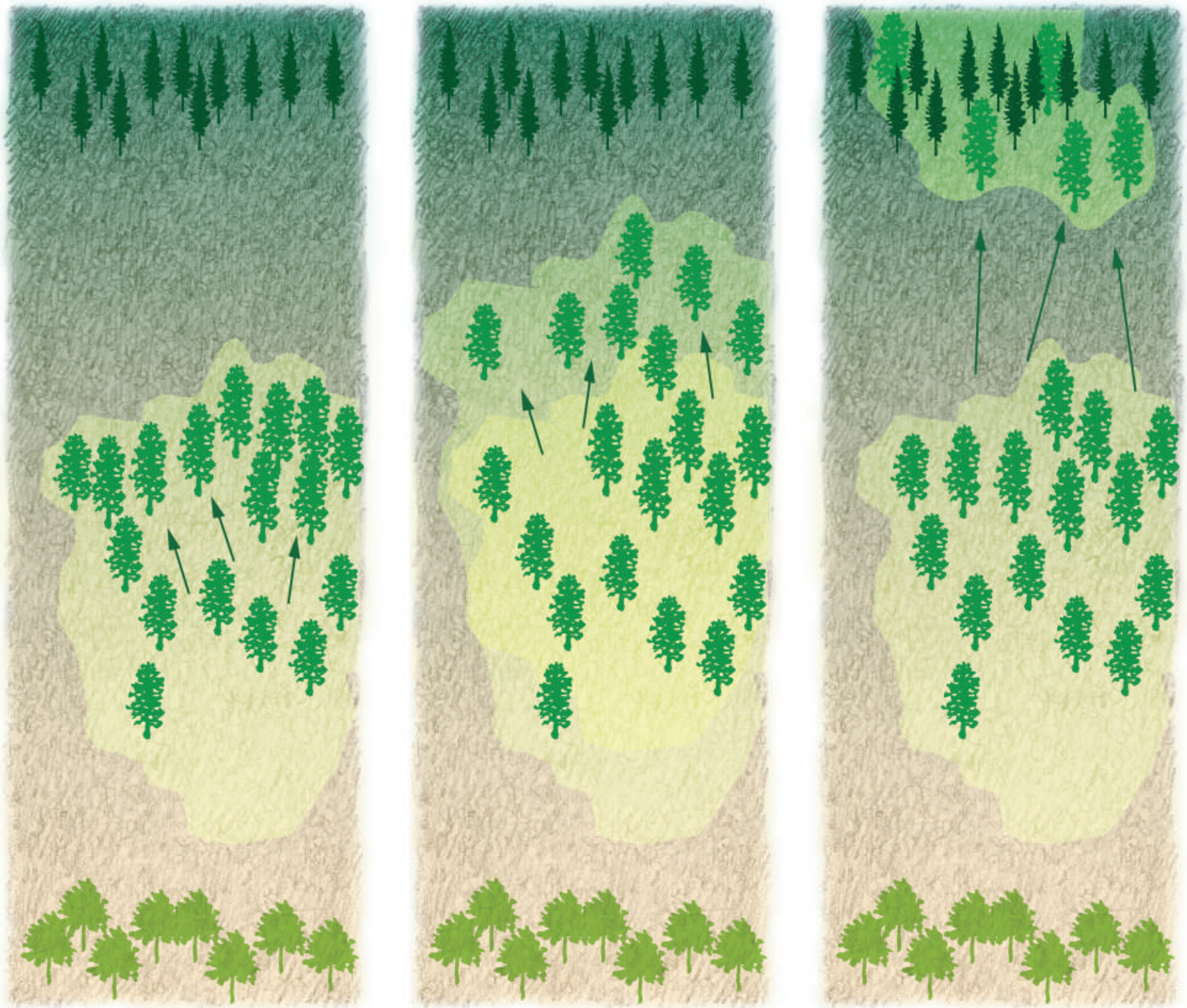
Managing Forests for the Future Climate

Understanding the effects of climate change on forest communities is essential for informed decision-making in forest management. By combining traditional forestry knowledge and practices with emerging climate science, we can enhance the resilience of forest ecosystems. One strategy is to identify and promote future climate-adapted tree species.

The *Tree Atlas*, and the "Climate at a Glance"[5] site described



5 ncei.noaa.gov/access/monitoring/climate-at-a-glance



in the prior article in this series, can help forest managers plan, manage, and plant for the future. However, specific site conditions and local factors are also important for selecting future climate-adapted species. Analyzing the tree composition of similar sites located at lower elevations or to the south can provide valuable insights into which species might succeed at your site in the future. Also keep in mind that because of the complex topography and weather patterns in the Northeast, certain locations such as north-facing slopes and cold air drainages may naturally remain cooler than their surroundings, supporting current tree species communities in the long term. Seeking the advice of a professional in your area, such as a forester or ecologist at your state forestry agency or local extension office, is an important next step.

The cascading impacts of these forest changes on other parts of the ecosystem are still uncertain. It is unclear how these shifts will affect the ability of our forests to sequester and store carbon, or to continue to provide many other essential ecosystem services. However, one thing is clear: greater greenhouse gas emissions stress trees more, forcing their ranges to shift larger distances and putting forests at greater risk. Despite this uncertainty, as forest stewards, we have enough information to be proactive and consider future tree communities in our management plans. We are wise to do so to ensure that our future forests continue to provide critical benefits to both nature and people.

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