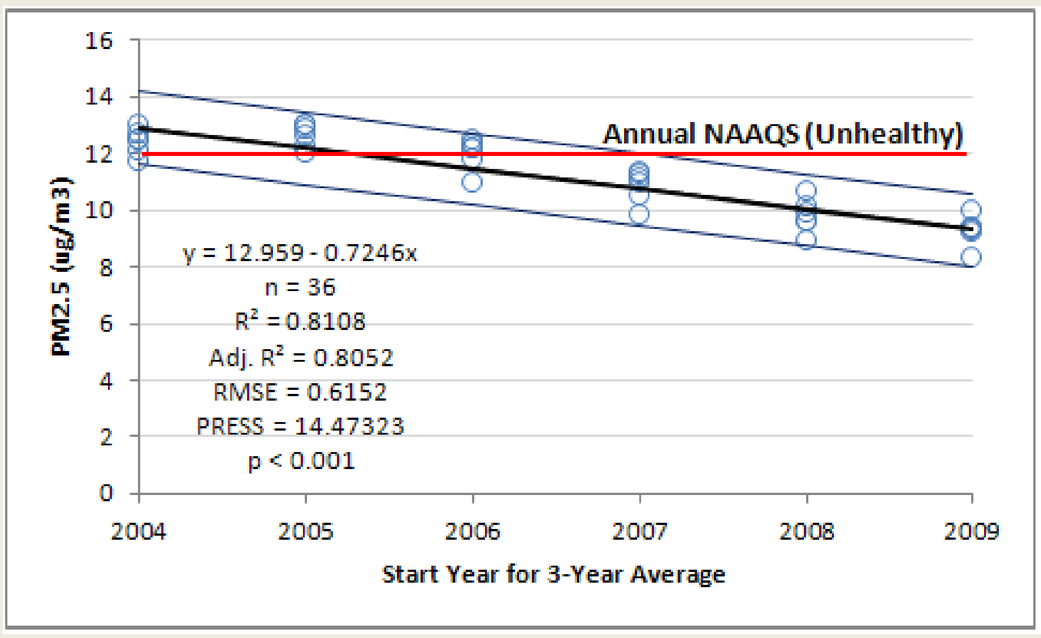
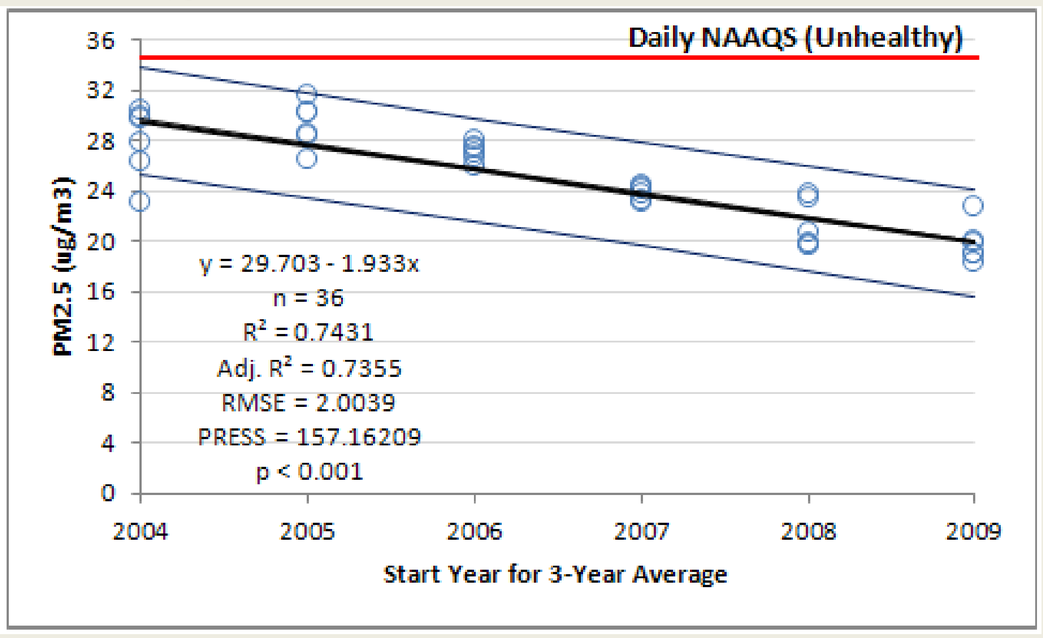
Air Quality Is Improving

Fine Particulate Matter ($PM_{2.5}$) Concentrations





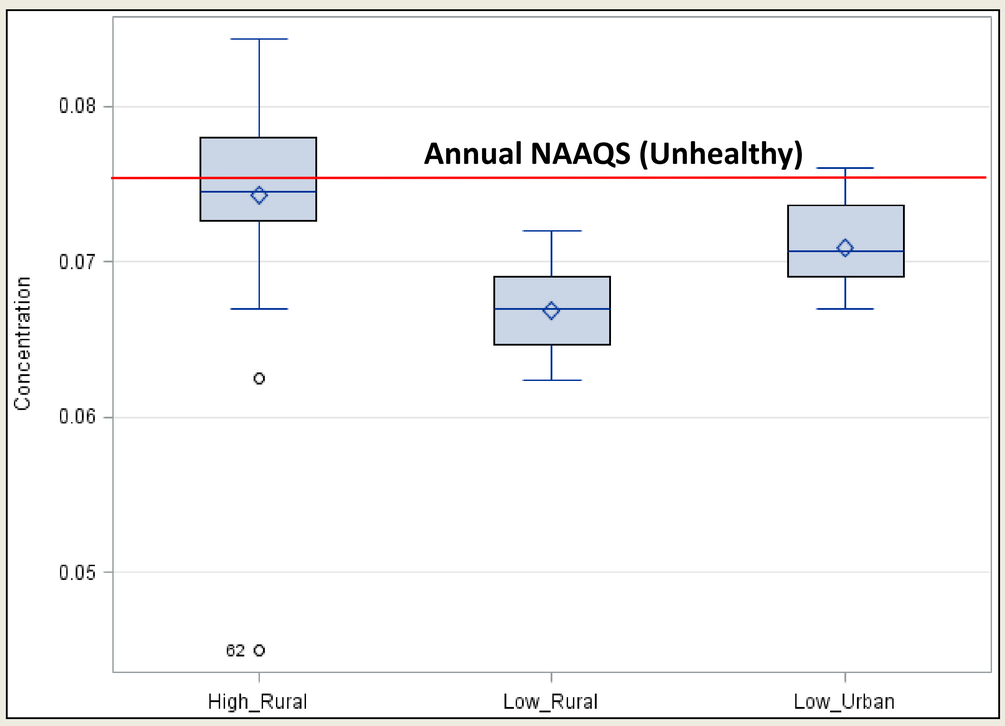
Statistical trend in the 3-year average of the mean annual $PM_{2.5}$ concentrations (left) and the 3-year average of the 98th percentile daily (24-hour) concentrations of $PM_{2.5}$ (right). The open circles (blue) are the results at each of the six ambient monitoring sites near the National Forest. The black line shows the downward trend in $PM_{2.5}$, while the blue lines are the 95 percent confidence intervals for the trend estimate. The red line shows the current National Ambient Air Quality Standard (NAAQS) for the annual (12 ug/m^3) and daily (35 ug/m^3) NAAQS.

There are two different averaging periods for the $PM_{2.5}$ NAAQS. The form of the annual NAAQS was established by EPA as the annual arithmetic mean, averaged over 3 years, from single or multiple community-oriented monitors. In December 2012, the EPA lowered the annual standard from 15 micrograms per cubic meter (ug/m^3) to 12 ug/m^3. The left figure above shows there is a highly significant ($p < 0.001$) decrease in the rolling three year averages in fine particulate concentrations. By 2009, the 95 percent confidence interval for $PM_{2.5}$ concentrations representing the Forests was 8.0 – 10.6 ug/m^3, which is below the current annual NAAQS of 12 ug/m^3.

The annual NAAQS is designed to protect the health of people from the chronic (day to day) effects of fine particulates, while the daily NAAQS is implemented to protect the health of people from acute (high) concentrations of $PM_{2.5}$. The daily NAAQS is 35 ug/m^3 and is based upon the 3-year average of the annual 98th percentile $PM_{2.5}$ concentration. The right figure above also shows there has been a highly significant decline ($p < 0.001$) in the daily fine particulate matter concentrations. The three year (2009 – 2011) average for the final period had a 95 percent confidence interval of 15.8 – 25.2 35 ug/m^3, which is well below the daily NAAQS of 35 ug/m^3.

Ground-level Ozone Concentrations

Data obtained from 14 ozone monitoring sites within or near the Nantahala and Pisgah National Forests were summarized to evaluate how the 3-year averages compare to the current National Ambient Air Quality Standard (NAAQS) of 0.075 ppm. The monitoring sites were categorized by their elevation [High (≥2500 feet above sea level (a.s.l.)) or Low (<2500 feet a.s.l.)] and if they were located in a rural setting or within or adjacent to an urban area. The monitoring sites were classified into the following three categories: High_Rural (n = 7), Low_Rural (n = 4), or Low_Urban (n = 3). The figure to the right shows the results when all of the 3-year averages are combined. Both low elevation categories had at least 75 percent of the 3-year averages below 0.075 ppm; while some of the 7 high elevation monitoring sites had 3-year averages above 0.075 ppm. Even though there is variability in the results, there has been a significant ($p < 0.0021$) decline in ozone concentrations at the high elevation sites with the 3-year averages declining about 0.002 ppm for each time period (figure not shown). The three year (2009 – 2011) average for the final period had a predicted mean of 0.071 ppm and a 95 percent confidence interval of 0.0583 – 0.0819 ppm. A majority of the Nantahala and Pisgah National Forests does meet the current ozone NAAQS; however, there could be some high elevation locations where ozone may be greater than the NAAQS of 0.075 ppm.



Boxplots of the ozone monitoring results for the maximum 8-hour averaged for 3-years. The data began in 2004 and ended in 2011. The 14 monitoring sites were categorized as high elevation if they were ≥ 2500 feet above ground level (a.s.l.), while low elevation sites were <2500 feet a.s.l. Urban sites were within or adjacent to densely populated areas, while monitoring sites in rural areas were sparsely populated. The red line shows the current National Ambient Air Quality Standard (NAAQS) for ozone of 0.075 parts per million (ppm).

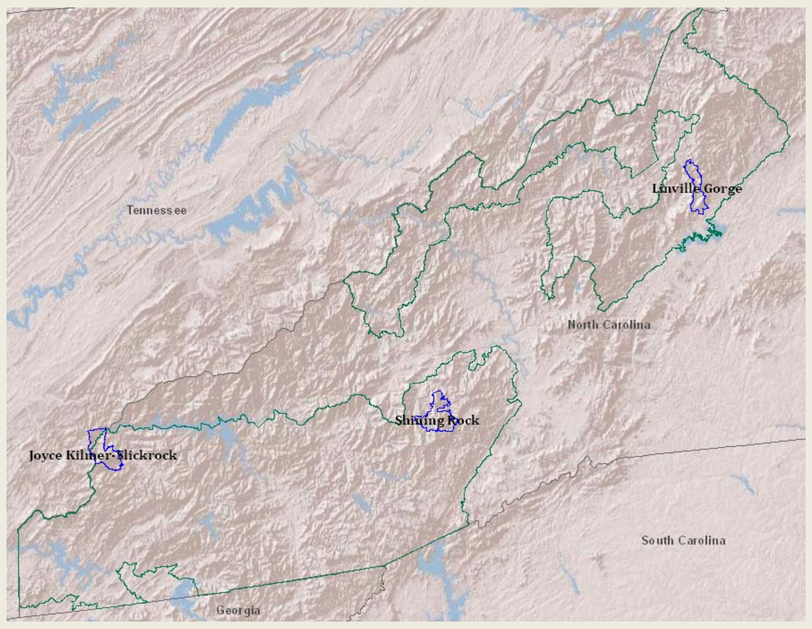
Ambient Air Quality and Climate Change

Carbon dioxide is the primary greenhouse gas trapping Earth's heat and causing an increase in global temperature, but ground-level ozone is also a greenhouse gas. The decreases in ground-level ozone within the National Forests are likely to contribute to an undefinable decrease in temperature. However, the major component of fine particulate matter is sulfates. Sulfates reduce the amount of solar energy reaching Earth and therefore have a cooling effect. Consequently, the decrease in sulfate fine particulate matter is likely to cause an undefinable increase in temperature within the National Forests.

Best available data as of December 2012. Maps may have been develop from different data sources, accuracies and modeling results are subject to change without notice.

Air Resource Management

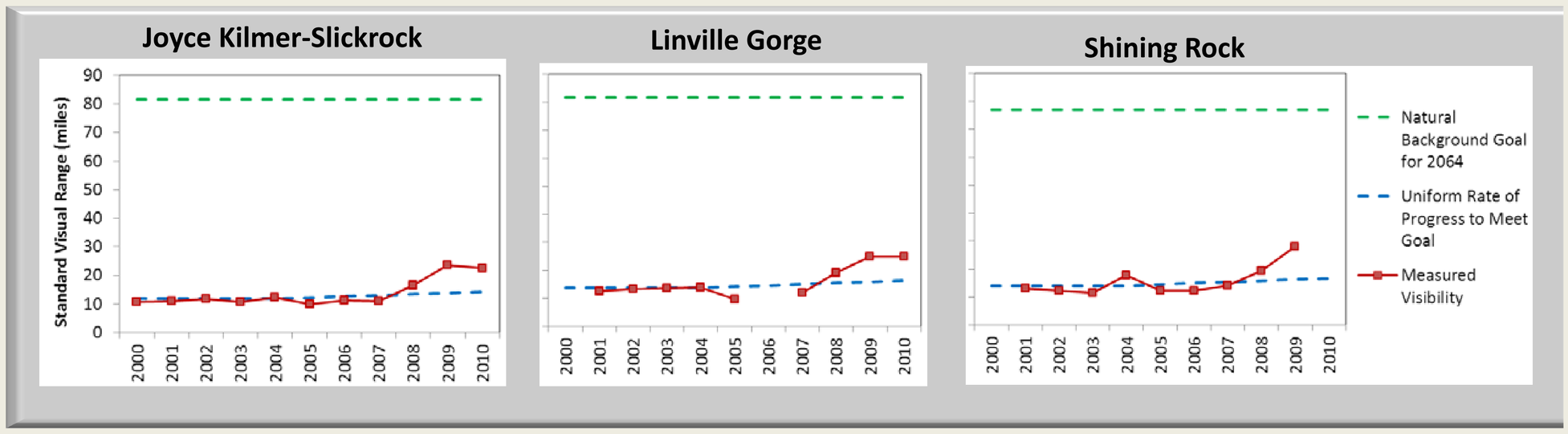
Visibility Is Improving



The USDA Forest Service is cooperating with the North Carolina Division of Air Quality, the Tennessee Division of Air Pollution Control, and other air regulatory agencies to identify air pollution emission reduction strategies to achieve natural background visibility (figure right) at the three federally mandated Class I areas. The Class I areas managed by the National Forests in North Carolina include: Joyce Kilmer – Slickrock, Linville Gorge, and Shining Rock Wilderness (figure above).

In Section 169A of the 1977 Amendments to the Clean Air Act (CAA), the United States implemented a program for protecting visibility in federally mandated Class I areas by "… prevention of any future, and the remedying of any existing, impairment of visibility in mandatory Class I Federal areas, which impairment results from manmade air pollution." The Forest Supervisor of the Nantahala and Pisgah National Forests has been delegated the Federal Land Manager responsibilities and fulfills their role under the CAA Amendments of 1977. The Federal Land Manager provides critical information to prevent further visibility degradation by advising the state or local air regulatory agencies in the region if a proposed new large source of air pollution may have an adverse impact to visibility or any other Air Quality Related Values (AQRVs). In Section 169B of the 1990 CAA, the Environmental Protection Agency was directed to issue regional haze rules to remedy any existing impairments to visibility in mandatory Class I areas. The USDA Forest Service has cooperated with the state and local air quality agencies with the Regional Haze program in two ways. First, USDA Forest Service staff participated and provided technical advice to the regional haze planning organization (Visibility Improvement State and Tribal Association of the Southeast), and the Federal Land Manager submitted comments to the state air quality agencies regarding the modifications to their state implementation plans to comply with the regional haze rules. Second, USDA Forest Service staff, in cooperation with others, has conducted ambient monitoring of the fine particles of air pollution that contribute to visibility impairment near two of the three Class I areas. The visibility data collected has allowed the state air agencies to establish the baseline (2000-2004) visibility conditions and continued monitoring will allow visibility conditions to be tracked overtime to see if reasonable progress is being made to achieve natural background visibility by 2064. Recent monitoring results indicate visibility is improving at a faster rate then the uniform rate of progress to achieve natural background visibility by 2064 (figure below).

Simulations for the worst visibility days for the baseline (2000 – 2004) visibility (upper left and lower right), the desired natural background visibility (upper right) to be achieved by 2064, and the current (2006 – 2010) visibility (lower left) at Shining Rock Wilderness. A person can see approximately 14 miles in the upper left and lower right image, approximately 73 miles in the upper right image, and approximately 18 miles in the lower left image.



Visibility monitoring results for the three federally mandated Class I areas on the Nantahala and Pisgah National Forests. The Regional Haze program is being implemented to achieve natural background visibility (green dashed line) by 2064 with visibility steadily improving at a uniform rate of progress (blue dashed line). Recent monitoring results (red solid line) indicate visibility is improving at a faster rate then the uniform rate of progress to achieve natural background visibility by 2064.

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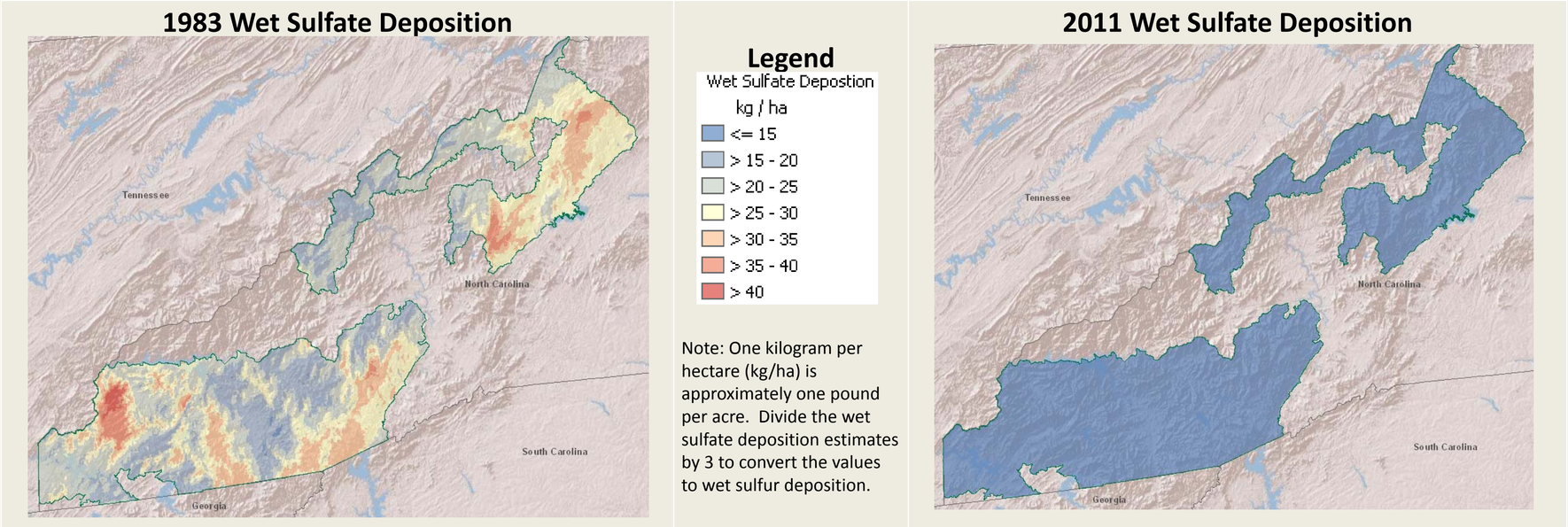
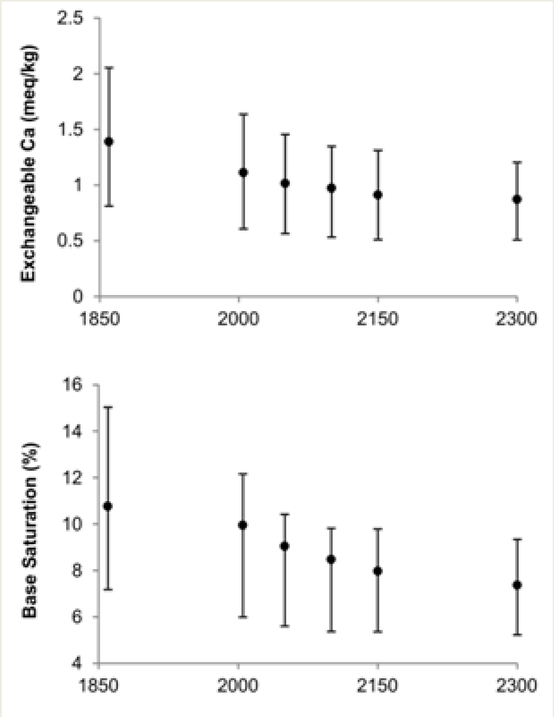
Air Resource Management

Acidic Deposition and Timber Harvesting Will Continue to Reduce Essential Nutrients

Decreased Sulfur Deposition Increases Soil Base Cations



Adequate supplies of base cations in the soil are essential for both healthy forests and aquatic ecosystems. The base cations include calcium (Ca), magnesium and potassium. Soils on the National Forest do vary in the potential amount of base cations that can be stored on the cation exchange sites. The base saturation (BS) is a metric used to describe how much of the soil cation exchange sites are occupied by base cations. Modeling results (figure right) indicates that both the base saturation and the amount of exchangeable calcium have decreased since 1860 on lands currently classified as suitable for timber harvesting. The removal of wood products (for uses such as lumber, paper, and firewood) has contributed to the base cation losses in the soil. Also, starting with the industrial revolution, the amount of sulfur deposition (primarily from the combustion of coal to produce energy) increased to the late 1970's and then significant reductions began with the Clean Air Act Amendments of 1990 (figures above). Further reductions in sulfur and nitrogen deposition are anticipated until at least 2064. Sulfates are the primary acid anion of concern for two reasons. First, they accelerate the loss of base cation by attaching to base cations as they move into the soil water solution. Second, the soils have been retaining a portion of the historical sulfur deposition and there will be a delayed response in base cation recovery even if sulfate deposition is decreased significantly.



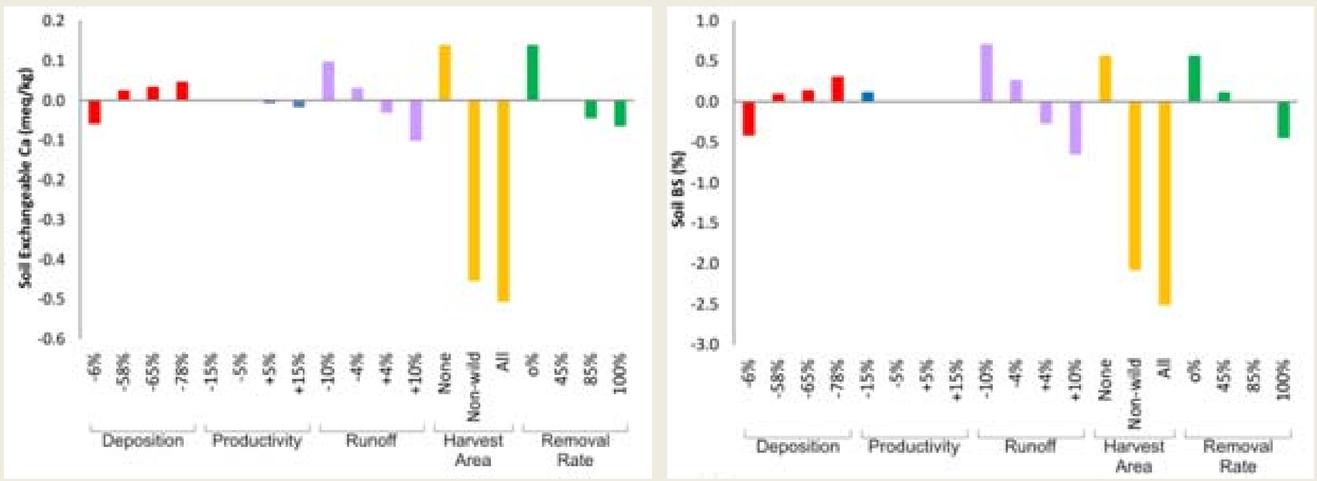
Both base saturation and the amount of exchangeable calcium are predicted to continue declining for the next two centuries, with the rate lower after 2100. The base case modeling results (figure right) assumed that 65% of the bole and bark would be removed when harvesting was conducted on land currently classified as suitable for timber harvesting, that the site productivity and water runoff would remain the same as current conditions, and sulfate deposition will continue to decrease 42% (in comparison to 2005 estimates) between 2010 and 2020. Additional reductions in sulfate deposition beyond 42% are possible if the current trend of converting coal-fired power plants to using natural gas continues. Both soil base saturation and exchangeable calcium are predicted to increase (see red bars in the figure below) if sulfur deposition is reduced at a greater percentage between 2010 and 2020.

Timber Harvesting Will Reduce Soil Base Cations

Calcium is an important component of cell walls and is removed from the nutrient cycling in a watershed if the boles and bark are removed from the site. Removal rates (green bars in the figure left) greater than 65% will decrease base cation availability; while no harvesting (0%) is predicted to increase the amount of base cations available for plant uptake more than the largest sulfur deposition reduction scenario.

Lands on the National Forests are also classified as unsuitable for timber harvesting. Most of these lands are located at high elevations that are sensitive to acidic deposition. The largest reductions in base cations are predicted to occur if 65% of the boles and bark were removed from land currently classified as unsuitable. The predictions for the unsuitable lands are shown with the "Non-wild" gold bar in the figure to the right.

Change From Base Scenario in the Year 2100



Climate Change -- Small Effect On Soil Base Cations

The annual temperature is likely to increase in the future. If nutrients (including nitrogen), soil moisture, and other environmental variables are adequate then forest productivity may increase. An increase in forest productivity (blue bars in the figure above) is predicted to result in a small decrease in the base saturation and exchangeable calcium in the soils. The amount of annual precipitation is predicted to change significantly in the United States; however, precipitation is currently predicted to remain the same or increase slightly on the Nantahala and Pisgah National Forests. An increase in precipitation was modeled as an increase in the runoff input parameter, and is likely to result in a decrease (purple bars in figure above) in base saturation and exchangeable calcium in the soils

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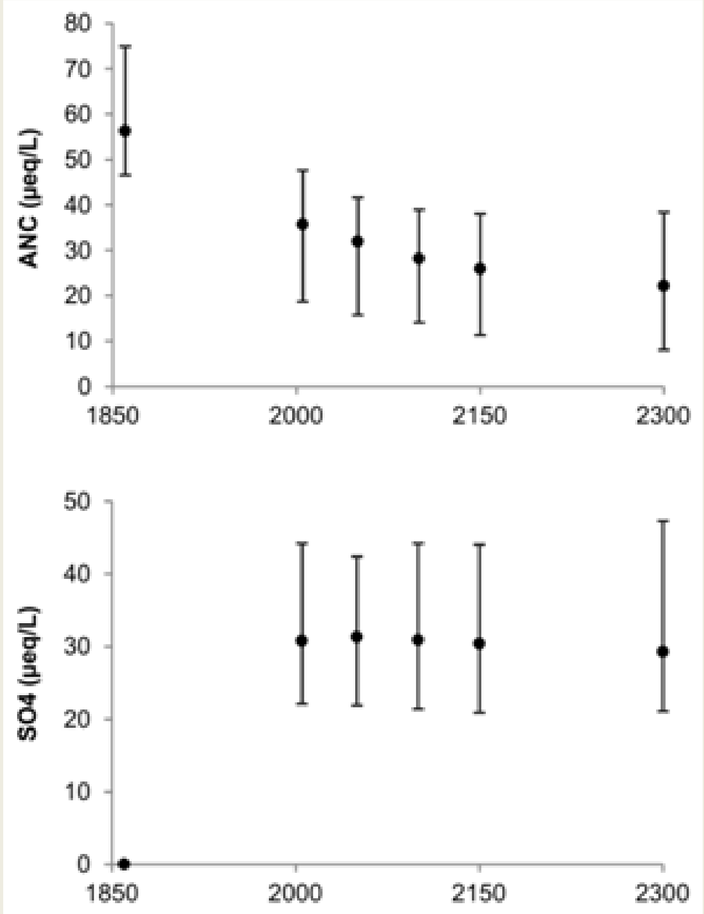
Air Resource Management

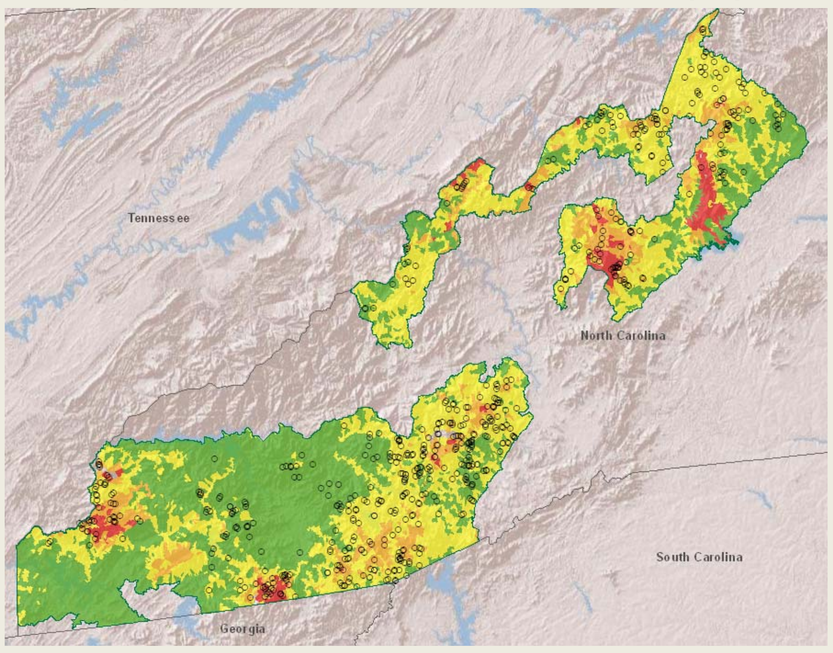
Acidic Deposition Is Still Too High For The Aquatic Ecosystem To Recover

The health of the aquatic ecosystem is directly tied to the health of the soils in a watershed. Soils on the Nantahala and Pisgah National Forests, especially at the high elevations, will continue to have decreases in the amount of available base cations. Therefore, the amount of base cations within the streams is predicted to decrease. The stream base cations (calcium, magnesium, potassium, and sodium) neutralize the harmful effects of acid anions (sulfates, nitrates, and choloride). The acid neutralizing capacity (ANC) is the metric used to measure stream health and streams with a large quantity of base cations will have a greater ANC and better aquatic biota health in comparison to a low ANC stream. In the future, the amount of sulfates (SO_4) in the streams will remain constant or perhaps decrease slightly. Stream ANC has decreased since 1860 and is predicted to continue decreasing in the future (graphic right).



Typically, impacts to aquatic biota, such as diatoms and insects, can begin to occur when the ANC is below 50 micro-equivalents per liter (µeq/L), while fish can be impacted directly when the ANC is 20 µeq/L or less, and brook trout (an acid tolerant species) is predicted to be extirpated from streams with an ANC less than 0 µeq/L. The steady state critical load is a calculation where the results predict if the current acidic deposition could impact the health of the aquatic ecosystem, either currently or some unknown time in the future. The graphics below shows sulfur deposition does exceed the critical load to maintain a stream ANC of 30 or 50 µeq/L for a large portion of the lands within the proclamation boundary. The graphics below also shows the known distribution of brook trout (open circles) and most of these populations are located where the critical loads are exceeded.

Steady State Critical Load for Stream ANC = 30 µeq/L



Legend

National Forests

Brook Trout Present

Yes

Sulfur Deposition Exceedence

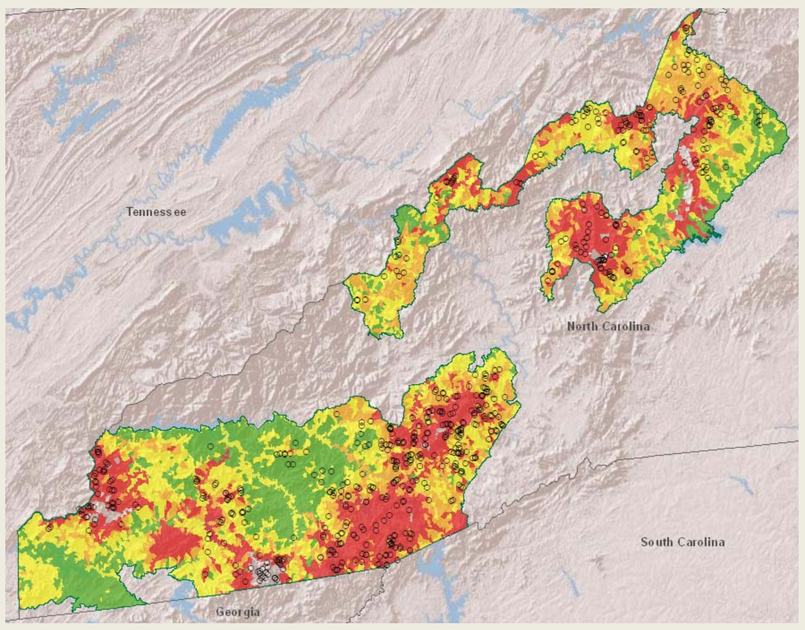
<= 1.0 times

>1.0 to 1.5 times

>1.5 to 2.0 times

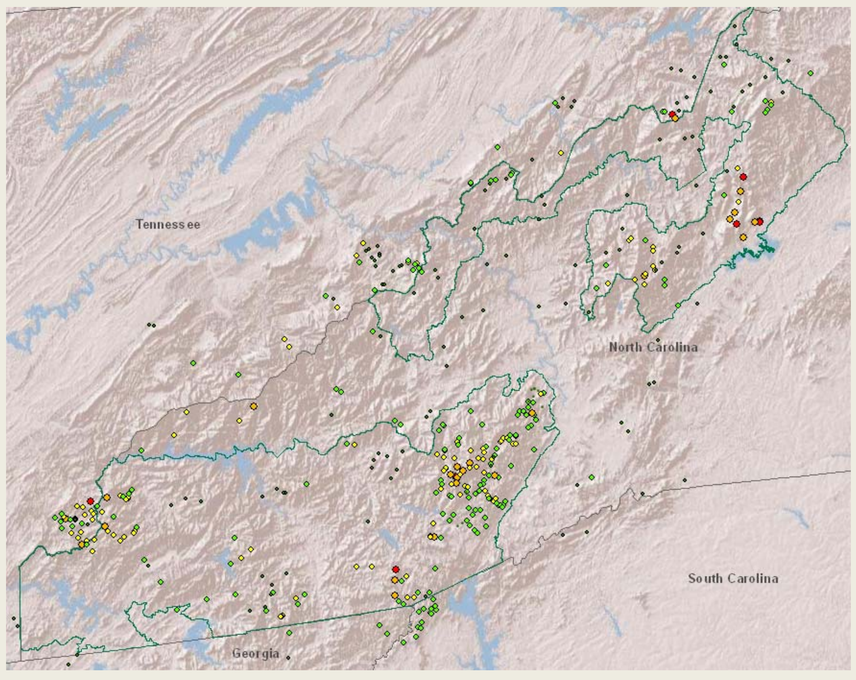
> 2.0 times

Steady State Critical Load for Stream ANC = 50 µeq/L



Numerous water samples have been collected near or within the National Forests and many of these samples have an ANC below 50 µeq/L, which suggests there may be negative impacts to sensitive aquatic biota (bottom left figure). The figure below on the right shows which streams can attain or maintain an ANC of 50 µeq/L if the total sulfur deposition remains at the same level as the 2009 – 2011 estimated average. There are streams, mostly at the lower elevation where the stream ANC of 50 µeq/L can be achieved or maintained by the year 2100 (shown as green squares). For many locations, the current atmospheric deposition of sulfur to the watershed exceeds the ability for the streams to attain or maintain an ANC of 50 µeq/L (yellow, orange and red squares) by 2100. There are even some areas at the highest elevations that can never attain an ANC of 50 µeq/L even if the total sulfur deposition is reduced to zero.

Calculated Acid Neutralizing Capacity (ANC) for Stream Samples



Legend

Stream Water Chemistry Results

Calculated ANC (ueq/L)

<0

0-20

20-50

50-100

>100

National Forests

Achieve or Maintain Desired ANC by 2100

Current Sulfur Depositon Exceeds By:

Cannot achieve desired ANC

<= 1.0 times

> 1.0 - 1.5 times

>1.5 to 2.0 times

> 2.0 times

Mean 2009 - 2011 Total Sulfur Deposition kg/ha

3.104449987 - 4.175666072

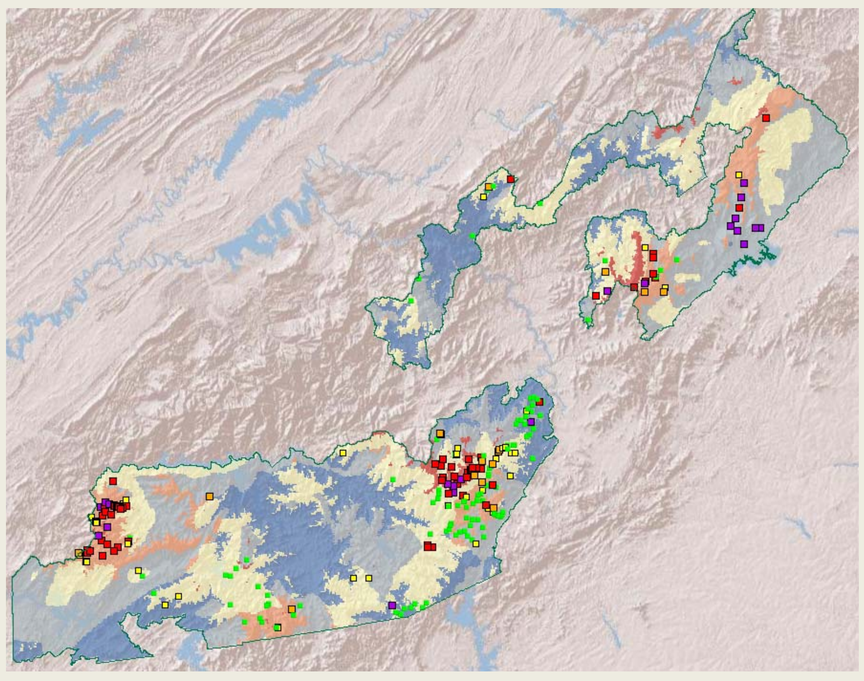
4.175666073 - 4.901328581

4.901328582 - 5.765212521

5.765212522 - 7.251092897

7.251092898 - 11.91606617

Current Total Sulfur Deposition In Relationship to Achieving or Maintaining an ANC of 50 µeq/L by 2100



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Air Resource Management