8. Area and percent of forest land subject to levels of specific air pollutants that may cause negative impacts on forest ecosystems

8.1 Air Pollution

Air pollutants can alter physical processes such as water flow and elemental cycling, which can influence the relationship between insects, diseases, and their hosts. Forests have significant and dynamic interactions with the atmosphere. Air pollutants can reduce forest productivity and diversity, especially in sensitive species and genotypes. This section is focused on forest interactions with three categories of atmospheric compounds—greenhouse gases, criteria air pollutants, and acidic deposition—that are substantially affected by human activity. (For more information on air pollutants referenced in this section, see the list of sources listed at the end of section 8.1. This list contains both general references and specific publications used to write this report.)

The largest and most essential of these interactions is the uptake and respiration of carbon dioxide. Our forests and other ecosystems process tens of millions of tons of carbon dioxide annually. Carbon dioxide is captured during photosynthesis and most of it is returned to the atmosphere through respiration. A very small fraction (in the single digit percentiles) is captured in plant biomass and soils annually. Determining the amount of carbon stored in plants and soils can be difficult. Current estimates suggest as much as eight million tons of carbon dioxide is stored every year in our forest vegetation and soils. This capture or sequestration of carbon is, and will become even more, important as we seek to reduce Wisconsin’s net greenhouse gas emissions.

The remaining greenhouse gases (including methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride) have little to no direct effect on forests. However, potential changes in climate patterns caused by these gases, such as droughts, storms, and length of the growing season, could significantly affect forest communities.

Criteria pollutants and acidic deposition include ground level ozone, nitrogen and sulfur oxides, fine particulate matter, lead, and mercury. These compounds are released or formed naturally during volcanic activity, forest fires, lightning strikes, and other processes. These pollutants are typically present in the atmosphere at extremely low concentrations, but human activity has resulted in forests being exposed to elevated concentrations. Forests immediately downwind of industrial and urban sources are especially affected.

Oxygen (O2 at 21%) and nitrogen (N2 at 78%) are the dominant constituents of the atmosphere. Other compounds and pollutants are present in trace quantities relative to oxygen and nitrogen. Carbon dioxide (CO2) is the most abundant of these constituents, with a current concentration of about 386 parts per million (ppm). However, CO2 is increasing at a rate of about two ppm every year. Prior to the fossil fuel combustion and extensive land clearing of the last 200 years, CO2 concentrations averaged around 280 ppm.

Other greenhouse gases and all of the criteria pollutants are measured in the tens to hundreds of parts per billion. These compounds are substantially affected by seasonal climatic factors as well

as industrial and agricultural activities. Exposure to criteria pollutants and acidic deposition has been slowly decreasing due to regulatory actions and technological improvements.
Criteria pollutants, and especially greenhouse gases, have been shown to influence forests communities when assessed over decades and longer time frames. Acute foliar injury symptoms related to criteria pollutant exposure (i.e., ground level ozone) have been documented in ozone sensitive species. Current ozone exposures may be having impacts on some aspects of forest productivity (e.g., growth of ozone sensitive species in the higher exposure areas along Lake Michigan). However, quantifying impacts on productivity would be difficult to measure relative to the more important effects of drought, flooding, insects, diseases, and land management practices.

Concentrations of the major greenhouse gases (carbon dioxide, methane, and nitrous dioxide) in the atmosphere have varied over the millennia, but their concentrations have increased substantially with the fossil fuel combustion associated with industrial development and the land clearing associated with population growth and economic activity.

Carbon dioxide is an essential plant nutrient, but elevated atmospheric concentrations may lead to internal imbalances in tree nutrition, affect insect-disease relationships, and influence climate patterns. Nitrogen and sulfur compounds are essential plant nutrients as well, but their emissions are a direct cause of acidic deposition. Uptake and/or deposition of excess quantities of these compounds affect forest sustainability and ecosystem processes.

In contrast, ground level ozone can have toxic effects at even low concentrations (70-90 parts per billion). This compound is the most widespread regional air pollutant in the United States. The impacts of excess ozone range from acute foliar injury to chronic loss in tree productivity, and/or genetic diversity in forests.

All of these compounds may act synergistically with unanticipated consequences on forest ecosystem health and diversity. Generally, these changes to forest systems are considered to have undesirable impacts with potentially adverse effects on the economic and ecological benefits we derive from our current forests.

Major issues associated with atmospheric interactions include the following:

1. Changes in forest communities, economic relationships, and recreational uses.
2. Changes to insect-disease relationships as well as fire and management regimes.
3. Reductions in forest productivity and diversity including changes in forest species composition, acute foliar injury, and effects on sensitive species and genotypes
4. Changes to physical processes such as water flow, elemental cycling, wildlife habitat, and associated forest values

<u>Forest indicators and trends</u>
Trees, whether in urban or rural settings, will take up or filter pollutants and greenhouse gases from the atmosphere (see Table 8.a). This improves air quality, but a range of impacts, some

anticipated and some not, may also occur. The following trends in atmospheric pollutant concentrations are anticipated over the next ten to twenty years.

Table 8.a: Annual pollution removed by Wisconsin's urban forest

Pollutant	Amount removed by Wisconsin's urban forest (metric tons/year)
Ozone	3,310
Particulate matter	1,750
Nitrogen dioxide	760
Sulfur dioxide	520
Carbon monoxide	63

Source: Cumming et al., 2007

Greenhouse Gases – Greenhouse gas concentrations will continue to rise unless significant regulatory and voluntary efforts are made to reduce emissions at personal, state, national, and global levels. Increasing concentrations will contribute to climate change and will impact forest health and productivity. Effects are likely to be observed statewide and may be assessed as having positive or negative impacts depending on the specific parameter being measured. For example, certain species may become more prevalent or have greater productivity, while other species are diminished. Regardless, changes in the climate and our forests will alter traditional land uses, management activities, and recreational uses.

Criteria Pollutants – Ozone concentrations in the atmosphere and nitrogen, sulfur, and mercury emissions from regulated sources are anticipated to decrease as regulations on air pollution become increasingly restrictive at state and federal levels.

Peak concentrations and seasonal ozone exposures have been declining across the state, and particularly along the Lake Michigan shore (Figure 8.c, see Newport). The amount and severity of ozone induced foliar injury on bioindicator species has also been decreasing. We anticipate foliar injury symptoms will continue to be observed on sensitive species, though the amount and severity of injury is anticipated to continue declining, particularly in southeast Wisconsin if ozone exposures continue to decline (Table 8.b). Any impacts of ground level ozone on forest productivity are also expected to decline.

Acidic Deposition – Sulfates (SO4), the most acidifying element in acidic deposition, have been declining (formerly 4-6 lbs/acre now ranging from 2-3 lbs/acre). Unlike sulfates, nitrogen deposition has essentially remained the same at 4-6 lbs/acre. Current air pollution regulations will result in continued reductions in the rate of sulfur deposition. Some decrease in nitrogen deposition is anticipated, but the change is anticipated to be relatively small.

The following images display trees with ozone induced foliar damage (Figure 8.a, 8.b). Both images were taken between 1983-2007 at peak exposure. Ozone induced foliar injury creates a distinct, sharp edged inter-vein black to dark purple discoloration on the upper surface of FIA bio-indicator plants. The injury is contained in the palisade cells and is therefore internal to the leaf and cannot be rubbed or washed off. Injury is most obvious in August.

Figure 8.a: Ash with ozone induced foliar injury.
Figure 8.b: Black cherry with ozone induced foliar injury

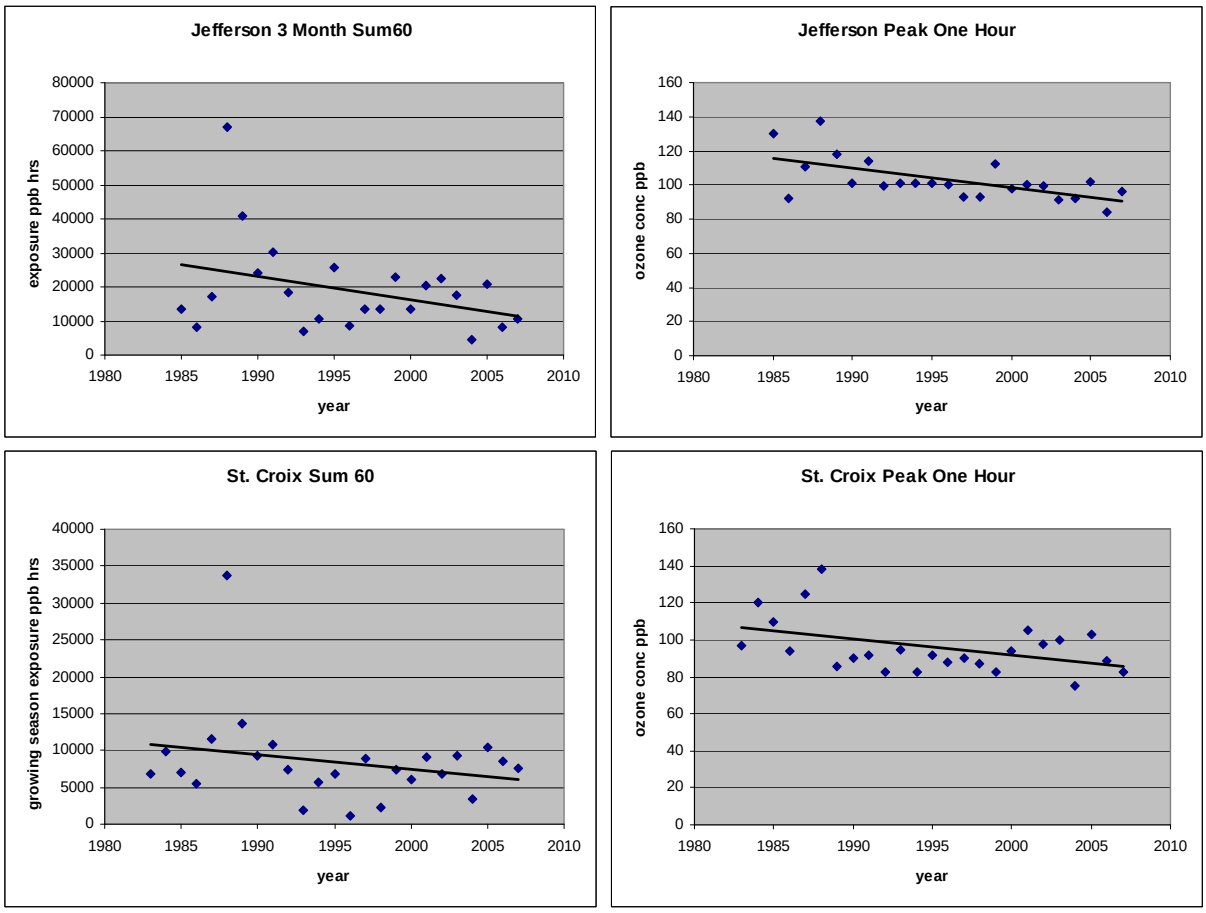
Table 8.b: FIA P3 bio-indicator trend ~2002-2007 (table showing annual trends in ozone injury)

	Data	Big leaf aster	Milkweed	Dogbane	Ash (white/ green)	Black cherry	Blackberry	Grand Total	% Injured plants
2002	# Plants surveyed	349	1396	723	969	935	571	4,943	2.2
	# Plants with injury	0	53	8	12	31	3	107	
2003	# Plants surveyed	417	1455	960	974	1059	517	5,382	0.8
	# Plants with injury	4	20	7	0	14	0	45	
2004	# Plants surveyed	422	1473	953	1023	964	618	5,453	1.4
	# Plants with injury	1	31	16	1	26	0	75	
2005	# Plants surveyed	260	900	570	495	455	253	2,933	

	# Plants with injury	0	17	3	1	3	0	24	0.8
2006	# Plants surveyed	207	831	573	470	473	255	2,809	
	# Plants with injury	0	10	11	3	14	0	38	1.4
2007	# Plants surveyed	220	785	523	350	412	170	2,460	
	# Plants with injury	0	3	0	0	2	0	5	0.2
Total number of plants surveyed		1,875	6,840	4,302	4,281	4,298	2,384	23,980	
Total number of plants with injury		5	134	45	17	90	3	294	
% Injured plants		0.3	2.0	1.1	0.5	2.1	0.1	1.2	

Source: FIA, 2007

DNR staff surveyed between 55 and 57 plots from 2002-2004 as part of an expanded biosite network. The network was reduced to the FIA ozone base grid in 2005 and 29 and 33 plots were surveyed in 2005-2007.



Criterion 3: Maintenance of forest health and vitality

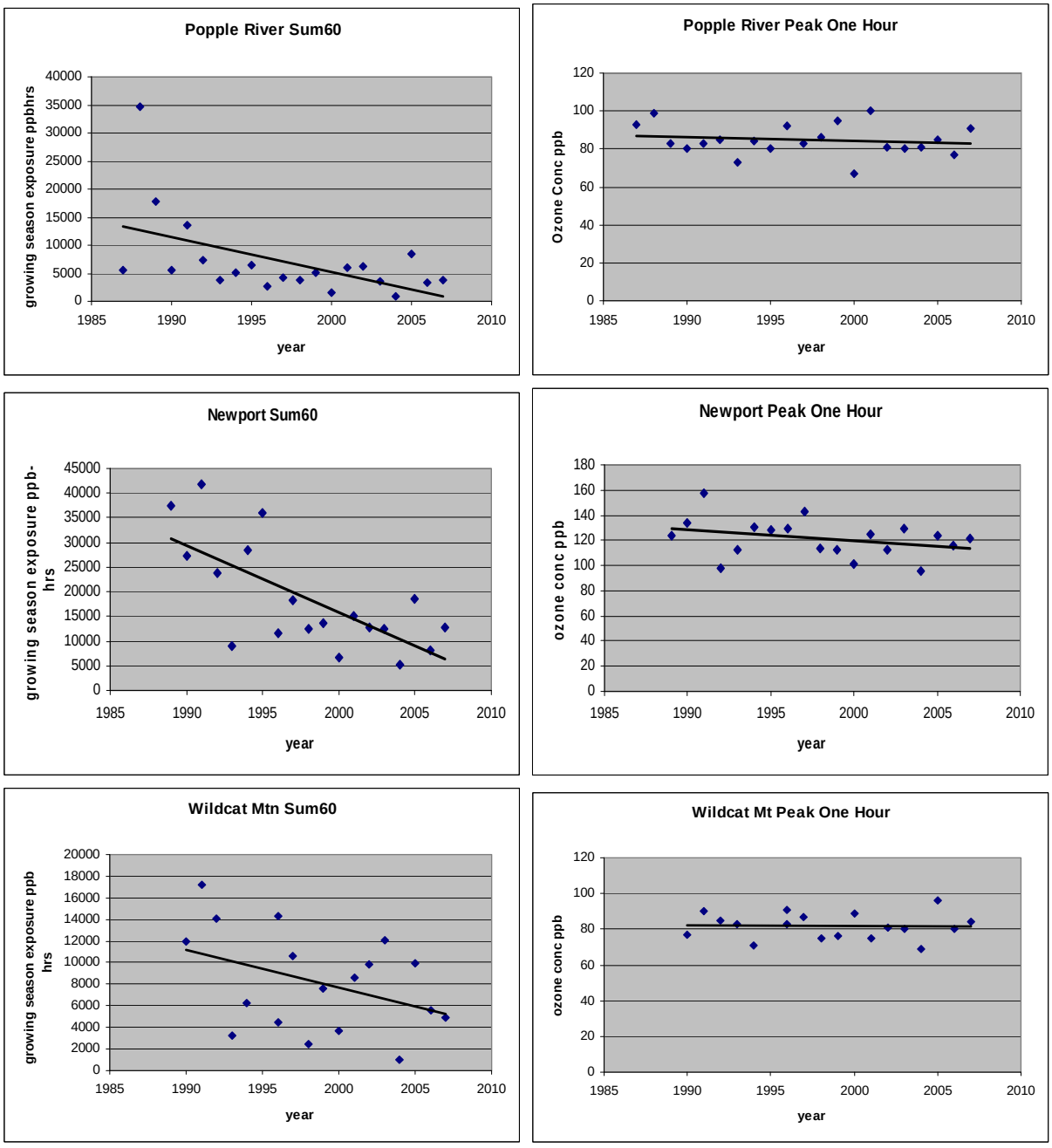


Figure 8.c: O3 trends at 5 sites in Wisconsin ~1983-2007
Summary and peak one hour seasonal exposure.
Source: WDNR, 2007

8.1 List of Sources

Descriptions of different categories of air pollutants

EPA criteria pollutants: http://www.epa.gov/air/urbanair/

EPA acid deposition: http://www.epa.gov/acidrain/

Criterion 3: Maintenance of forest health and vitality

EPA greenhouse gases: http://www.epa.gov/climatechange/emissions/index.html

Net uptake of carbon is very low and measured in single digits.

US Climate Change Science Program: http://www.climatescience.gov/Library/sap/sap2-2/final-report/sap2-2-final-all.pdf page 23

University of California Santa Barbara: http://www.esm.ucsb.edu/academics/courses/202/Lectures/ESM202Lecture7_2008_pdf.pdf

EPA: http://www.epa.gov/sequestration/index.html

Chemical composition of the atmosphere

NASA: http://nssdc.gsfc.nasa.gov/planetary/factsheet/earthfact.html

Air quality trends

EPA: http://www.epa.gov/airtrends/sixpoll.html

Quantifying impacts on forest ecosystems

NPS: http://www.nature.nps.gov/air/Pubs/pdf/gpra/GPRA_AQ_ConditionsTrendReport2006.pdf

NPS: http://www.nature.nps.gov/air/AQBasics/ecologic.cfm

Sources of greenhouse gases and increase in atmosphere

EPA: http://www.epa.gov/climatechange/science/index.html

EPA: http://www.epa.gov/climatechange/science/recentac.html

Ozone effects on forests

EPA: http://oaspub.epa.gov/eims/eimscomm.getfile?p_download_id=446635

Increasing rates of greenhouse gas accumulation in the atmosphere

EPA: http://www.epa.gov/climatechange/science/recentac.html

Criteria pollutant air quality trends

EPA: http://www.epa.gov/airtrends/sixpoll.html

Ozone trends and ecosystem impacts

FIA: http://fia.fs.fed.us/library/fact-sheets/p3-factsheets/Ozone.pdf

USDA Forest Service: http://nrs.fs.fed.us/fia/topics/ozone/default.asp

USDA Forest Service: http://www.nrs.fs.fed.us/fia/topics/ozone/pubs/pdfs/ozone%20estimation%20document.pdf